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FOREWORD

The International Scientific Conference 'Research for Rural Development' is organized annually by Latvia University of Life Sciences and Technologies, this year, for the 29th time. Scientists from several countries of the world gather during the conference.

During the conference 57 studies were presented. The authors of the studies are from 10 countries - Latvia, Lithuania, Estonia, Ukraine, Turkey, Poland, Sweden, Norway, Kyrgyzstan, Kazakhstan. In these Proceedings 43 scientific articles have been selected after careful review. The interdisciplinary papers contribute the latest scientific knowledge in agricultural sciences, forestry and wood processing, food science, economics, veterinary medicine, environmental engineering and landscape architecture, water management, agricultural engineering, information and communication technologies, education.

We believe that these Proceedings will be an excellent reference volume for researchers worldwide and it will stimulate further research in all the areas mentioned above.

We would like to thank all authors and reviewers for their contribution in international scientific level.

Many thanks to the chairpersons of all conference sections Z. Vitolina, J. Grinberga, L. Plocina, A. Spage, J. Galins, D. Bite, I. Leibus, G. Mazure, R.Čakšs for organization and management of effective work of the sections.

We hope to see you at the Latvia University of Life Sciences and Technologies next year during the 30th International Scientific Conference 'Research for Rural Development 2024'.

Natalija Sergejeva
Chairperson
Annual 29th International Scientific Conference
'Research for Rural Development 2023'

CONTENTS

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HYPERSPECTRAL IMAGING FOR EARLY DETECTION OF FOLIAR FUNGAL DISEASES ON SMALL GRAIN CEREALS: A MINIREVIEW

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Abstract
Globally crop pathogens and pests cause significant yield and quality losses in agriculture production systems. Foliar fungal diseases of small grain cereals are economically among the most important diseases worldwide and in the Baltics. Finding an effective, reliable, and easily accessible method for plant disease diagnosis still presents a challenge. Currently used methods include visual examination of the affected plant, morphological characterization of isolated pathogens and different molecular, and serological methods. All of these methods have important limitations, especially for large-area applications. Hyperspectral imaging is a promising technique to assess fungal diseases of plants, as it is a non-invasive, indirect detection method, where the plant's responses to the biotic stress are identified as an indicator of the disease. Hyperspectral measurements can reveal a relationship between the spectral reflectance properties of plants and their structural characteristics, pigment concentrations, water level, etc., which are considerably influenced by biotic plant stress. Despite the high accuracy of the information obtained from hyperspectral detectors, the interpretation is still problematic, as it is influenced by various circumstances: noise level, lighting conditions, abiotic stress level, a complex interaction of the genotype and the environment, etc. The application of hyperspectral imaging in everyday farming practice will potentially allow farmers to obtain timely and precise information about the development of diseases and affected areas. This review provides an introduction into issues of hyperspectral imaging and data analysis and explores the published reports of worldwide research on the use of hyperspectral analysis in the detection of foliar fungal diseases of small-grain cereals.
Key words: hyperspectral image cube, data analysis, spectral vegetation indices, computer vision, machine learning, deep learning.

Introduction

Human population relies heavily upon consistent and stable production of crops. One of the most important groups of crops in the Baltics is small grain cereals – wheat (*Triticum aestivum L.*), rye (*Secale cereale L.*), oat (*Avena sativa L.*) and barley (*Hordeum vulgare L.*), (Official statistics portal of Latvia (2023); Official statistics portal of Lithuania (2023) Statistics Estonia; (2023)).

Conventional and integrated cultivation of small grain cereals involves intensive fungicide application because these crops are susceptible to many fungal diseases. Most common fungal leaf diseases of small grain cereals in the Baltics are caused by the following pathogens: *Blumeria graminis, Parastagonospora nodorum, Puccinia recondita, Puccinia striiformis, Zymoseptoria tritici, Fusarium spp., Rhynchosporium secalis, Pyrenophora teres, Pyrenophora avenae* and *Pyrenophora tritici-repentis* (Sooväli & Koppel, 2003; Semaškiene & Ronis, 2004; Skuodienė & Nekrošienė, 2009; Bankina *et al*., 2011; Gaurilčikiene *et al*., 2011; Bankina *et al.*, 2013).

Plant health monitoring and early pathogen detection are critical to reduce the spread of disease and promote effective management practices. For pathogenic fungi detection and severity evaluation, three methods are currently used: (i) visual examination of diseased plants; (ii) pathogen identification on morphological features; (iii) molecular and serological methods (Martinelli *et al*., 2015). Visual disease examination by the agronomist or plant pathologist is mostly used in everyday farming, especially in small farms, but along with some advantages, like low costs, speed, the possibility to evaluate the status of infection, and no need for expensive infrastructure, there are some crucial limitations including high variability of conclusions due to different levels of individual knowledge and experience, human error and difficulty/impossibility to precisely monitor a large area of the crop (Bock *et al*., 2010; Martinelli *et al*., 2015). Additionally, visual examination of some fungal diseases is ineffective in the early stages, when there are no visual symptoms, such as lesions on the surface of the leaves, and only physiological/biochemical response mechanisms of plants, such as the reduction of the photosynthesis, are involved (West *et al.*, 2003). Identification of pathogens based on morphological features involves the isolation of fungal pathogens on suitable standard agar medium and analysis of culture characteristics, e. g. colony morphology, color, and asexual structures like sporangia, conidia, chlamydospores, sclerotia, etc. Light microscopes are used to study fungal structures (sporangia, conidia, and others), and the conclusions about the taxonomy and classification of a pathogen are based on the characteristics of

the listed structures (Narayanasamy, 2011). This approach is more accurate than visual assessment. However, it also involves expensive infrastructure, and it is restricted to large-scale applications, and *in vitro* cultivation is time-consuming (Narayanasamy, 2011). Molecular and serological methods mostly involve PCR (Polymerase Chain Reaction), hybridization, or biochemical assays. Molecular and serological methods are accurate and very sensitive, but they are restricted to large-scale applications, because of complicity and costs. They are unsuitable for disease status monitoring as they involve collecting samples mostly from plants with already clearly visible symptoms of disease; in some cases, it may misrepresent the real status of infections. Besides, molecular and serological methods require detailed sampling procedures, as well as expensive infrastructure (Martinelli *et al.*, 2015; Kashyap & Kumar, 2021).

Combining recent discoveries in microelectronics, optics, and data analysis an innovative and technology-based optical method, hyperspectral imaging has been developed, which can be also applied to a plant disease detection. Hyperspectral imaging is easy to use, non-destructive, and can be implemented in automated systems (e.g. unmanned aerial vehicles), considerably lowering workload (Mahlein, 2016). The main idea of using hyperspectral imaging is to measure the relationship between the spectral reflectance properties of plants and their structural features, pigment concentrations, water levels, etc., which are affected by plant biotic stress (Mahlein, 2016).

Materials and Methods

In the present study, the monographic method was used. The results of worldwide research on the use of hyperspectral analysis in the detection of foliar fungal diseases of small grain cereals (wheat, rye, oat, and barley) were studied as well as overall issues of hyperspectral imaging and data analysis were analysed and summarized.

Results and Discussion

Basic principles of hyperspectral imaging

Contrary to widely used consumer digital cameras which capture only three bands of the electromagnetic spectrum (red, green, and blue light), a hyperspectral sensor measures up to several hundred bands of the electromagnetic spectrum in the wavelength range of visible (400–700 nm), near-infrared (700–1000 nm) and short-wave infrared (1000–2500 nm) part of the electromagnetic spectrum (Lowe, Harrison, & French, 2017; Thomas *et al.*, 2018). Each pixel in a hyperspectral image acquires a different set of information about the reflectance (or transmittance) in each spectral band, and the sum of this information is called the spectral signature or spectral profile (Delalieux *et al*., 2007; Mahlein *et al*., 2013; Rumpf *et al.*, 2010).

Interactions between plant biophysical (e.g. leaf surface, tissue structure) and biochemical properties (e.g. pigment and water content) determine the patterns of leaf reflectance spectra (Blackburn & Ferwerda, 2008). Generally for green leaves, the visible light (VIS) region of electromagnetic radiation (400–700 nm) is responsible for light absorption by photosynthetic and other pigments; the near-infrared (NIR) region (700–1100 nm) is dominated by dry matter absorption; and in the shortwave infrared (SWIR) region (1100–2500 nm) water absorption occurs (Mishra *et al*., 2017). Significant changes in leaf reflectance induced at specific wavelengths in the visible (380–750 nm) and far-red (690–720 nm) ranges are more important than changes in reflectance in other regions of the electromagnetic spectrum to diagnose biotic stress (Carter, 1994 cited by Marín-Ortiz *et al*., 2020; Carter & Knapp, 2001).

Non-imaging hyperspectral sensors measure the average spectral reflectance in the field of view without spatial information. The area with a full spectral profile is obtained, the size of the area covered depends on the focal length, the angle of view, and the distance from the target. Because symptoms of early plant diseases often appear at sizes smaller than 1 mm, the use of non-imaging sensors for disease detection in some situations is limited (Thomas *et al.,* 2018). This is why hyperspectral imaging offers much higher capabilities in disease detection.

Imaging hyperspectral sensors or hyperspectral cameras obtain image data with spatial and high spectral resolution (Terentev *et al*., 2022). Mostly the cameras are divided by spectral range: (i) visible and near-infrared (VNIR) cameras have a spectral range of 400–1000 nm and (ii) short-wave infrared (SWIR) cameras provide a spectral range of 900–2500 nm (Moghadam *et al*., 2017; Bohnenkamp *et al.*, 2021) and by the spectral scanning type: push-broom, point scan, and snapshot (Kim & Cho, 2019; Mishra *et al.*, 2020). In recent years, a wide range of mini and medium-sized hyperspectral cameras for reasonable prices have been developed, and they can be used to capture small-size features of vegetation (at leaf and canopy level) including investigation of crop growth status, detection of early signs of crop stress caused by disease, weeds,

nutrition deficiency, etc. (Lu *et al.*, 2020).

A hyperspectral imaging system consists of four main elements: (i) a camera, (ii) a light source, (iii) a sample stage (no obligate), and (iv) corresponding control software (Morais *et al.*, 2019). The main elements of the imaging unit are the lenses, an imaging spectrograph, and an area detector. The light from the object passes through the objective lenses and enters a spectrograph. A spectrograph is a device used to disperse light into specific wavelengths. The scattered light is projected onto a detector that converts the photons into electrical signals that can be measured as the strength of different wavelengths into intensity values. Mostly there are two types of detectors – charge-coupled-device (CCD) camera or complementary metal-oxide-semiconductor (CMOS) camera (Mishra *et al*., 2017; Morais *et al*., 2019).

Different environmental conditions affect the results of hyperspectral imaging, of which lighting is the most important. The lighting system should provide adequate light intensity and composition without critical prevalence in a specific wavelength range, including sunlight other light sources such as tungsten halogen lamps (with different modifications), mercury or metal halide lamps, and light-emitted diodes (LED), can be used, each of the light sources has its advantages and limitations (Mahlein *et al.*, 2015). For the lighting calibration the measurement of reference material, with known reflection is another obligatory element to normalize the images (Lowe, Harrison, & French, 2017).

Data analysis

Hyperspectral imaging involves the integration of two acquisition modes: spectroscopy and imaging (Amigo, Babamoradi, & Elcoroaristizabal, 2015). A camera detects spectral signatures and spatial information from the surface of an object within the sensor field of view. A hyperspectral image consists of a series of narrow-band sub-images arranged across the reflectance spectrum, forming a 3-D cube or spectral hypercube (Amigo, Babamoradi, & Elcoroaristizabal, 2015; Mishra *et al.*, 2017). The hyperspectral curve obtained by measuring plant leaves contains noise and variations of structural features, so there is a need to do some curve transformations that should be performed before spectral analysis to describe the spectral curve more accurately and according to the most important structural features (Song *et al*., 2011). Generally, information gathering from hyperspectral images requires the following steps (methods): (i) preprocessing treatment, (ii) feature extraction, (iii) analysis, and (iv) acquisition of desired information (Bravo *et al*., 2003; Morais *et al.*, 2019).

From a plant disease detection perspective, different data analysis methods are used to answer three main questions: (i) Is the disease present? (ii) What specific disease is affecting the plant? and (iii) How severe is the disease (quantifying the degree of severity)? There are two main approaches to answering those questions: (i) the use of spectral vegetation indices or (ii) the use of computer vision, machine learning, and deep learning methods.

Besides detecting the presence of disease, an important task for image analysis is to distinguish between different diseases and identify a specific pathogen. A possible solution is spectral information divergence classification, which compares the deviation between the observer spectra and reference spectra (spectral library or averaged spectra of interest from the data), where similarity is based on the smaller deviation value. If the divergence value between the observed spectrum and a reference spectrum is larger than a set threshold, the observed spectrum is not classified as matching the reference spectrum (Du *et al*., 2004).

Spectral Vegetation Indices (SVI) is a widely used approach for analyzing and detecting changes in plant physiology and chemical composition (Mahlein *et al.*, 2013). The indices are based on the reflectance (or absorption) of certain wavelengths and are designed to evaluate various plant parameters, such as pigment content (Blackburn, 1998), leaf area (Rouse *et al.*, 1974 cited by Bravo *et al.*, 2003) or water content (Peñuelas *et al*., 1993 cited by Mahlein *et al.*, 2013). Usually, a particular spectral vegetation index has a quantitative relationship to a specific trait of interest, i.e. the pigment or water content of the products (Mahlein *et al.*, 2013). Spectral vegetation indices are evaluated using a specified formula, which usually combines the reflectance of a few bands into a single index. One of the most commonly used spectral vegetation indices is the Normalized Difference Vegetation Index (NDVI) (Rouse *et al.*, 1974 cited by Bravo *et al.*, 2003) it is used to estimate biomass, plant vitality, and 'greenness'. The popularity of NDVI is linked to its potential for application at the field scale, its ability to separate vegetation and soil, or evaluate the vitality of the crop (Bravo *et al.*, 2003). There are also other common SVIs: Red edge normalized ratio ($NR_{red\ edge}$); Photochemical reflectance index (PRI); Green chlorophyll index (Cl_{green}); Carotenoid reflectance index (CRI); Simple ratio index (SRI); Water index (WI); Moisture stress index (MSI), etc. (Lowe, Harrison, & French, 2017; Zhang & Zhou, 2019).

Several successful efforts have been also made

to apply spectral vegetation indices for the detection of plant diseases (Hatfield *et al.*, 2008), but wide-scale usage for specific disease detection has not been attempted, because these indices lack disease specificity and do not assess other factors, such as abiotic stress, coupled biotic stress factors, etc. (Mahlein *et al.*, 2013). A possible solution could be the combination of different wavelengths with spectral disease indices which allows the detection of the disease with spectral sensors, considering that each disease has a specific spectral signature (Mahlein *et al.*, 2013).

As an example, the health index is based on the normalized reflectance difference at 534 to 698 nm and the absolute reflectance at 704 nm. The health index can be combined with the powdery mildew index, which is calculated on the normalized reflectance difference of 520 and 584 nm and the absolute reflectance at 724 nm (Mahlein *et al.,* 2013). Generally, disease detection based on spectral vegetation indices or spectral disease indices is characterized as a simpler method, which doesn't include complicated data analysis, data library collection, and machine learning, but the main disadvantage is low specificity and a narrow possibility to use it for early disease detection.

A direction with higher practical application potential is data analysis using machine learning, deep learning, and computer vision methods. The deep learning approach is based on different neural networks (convolutional, artificial, radial basis function neural networks, etc.), and the difference is related to the used vision system (Arens *et al.*, 2016; Lowe, Harrison, & French, 2017; Ramya *et al.*, 2020). Artificial neural networks are interconnected collections of nodes called 'neurons' where every 'neuron' analyses one element of input data or one pixel of the image (Ramya *et al.*, 2020).

The machine learning approach is based on an algorithm to model knowledge of data, in other words, it is a data analysis technique that teaches computers (artificial intelligence) to do what humans and animals naturally learn from experience. There are four types of machine learning: unsupervised learning, semi-supervised learning, supervised learning, and reinforcement learning (Ramya *et al.,* 2020).

Generally, deep learning is more complex than disease detection based on vegetation indices, but with the added efforts very impressive rates of classification and recognition are achievable.

Hyperspectral imaging application for foliar fungal disease detection on small grain cereals

In the last couple of decades, a lot of research has been done involving the use of hyperspectral imaging for the detection of disease or severity evaluation of fungal disease of small grain cereals, but most often in wheat. Some examples are analysed below.

Zhao *et al*. (2014) studied the severity of yellow rust (caused by *Puccinia striiformis*) on individual plant leaves of wheat using a field portable hyperspectral spectrometer. The results indicated that changes in the content of foliar water and chlorophyll were induced by yellow rust, but the reflectance values varied depending on the adaxial or abaxial surfaces of the leaf. Authors conclude that hyperspectral measurements of wheat leaves to evaluate severity are more appropriate at later stages of disease development (Zhao *et al*., 2014). Guo *et al.* (2020) examined the possibility of yellow rust identification on wheat leaves based on spectral and textural features of hyperspectral images. A support vector machine and different features (optimum wavebands, vegetation indices, and textural features) were used with the best results reached when the models included a combination of both spectral and textural features (Guo *et al.,* 2020).

Infection of plants by wheat powdery mildew (caused by *Blumeria graminis* f. sp. *tritici*) was studied by Zhang *et al.* (2016) using hyperspectral imaging analysis to detect the effect of differentiating background (shadows) on the effectiveness of identification of infected and healthy plant leaves. Five different vegetation indices and classification and regression trees were used to analyze the data. Healthy leaves were identified with the highest accuracy of 99.2%, while infected leaves were determined with an accuracy of 88.2% and 87.8%, respectively (Zhang *et al.*, 2016). In another study of powdery mildew, a hyperspectral imaging dataset and machine learning algorithms were used (Zhao *et al.,* 2020). Three methods were compared – random forest, principal component analysis, and the successive projections algorithm. The highest accuracy of 93.33% by a cross-validation method was reached by applying a support vector machine model based on principal component analysis (Zhao *et al.,* 2020).

For Septoria tritici spot disease detection and severity assessment, a hyperspectral data library of the canopy from 335 wheat cultivars was collected using a spectroradiometer by Yu *et al.* (2018). The authors obtained the following results: (i) canopy reflectance and selected indices could be used to quantify Septoria tritici patches, and (ii) the best efficiency was achieved, using normalized difference

water index with an accuracy of 93% (Yu *et al.*, 2018). On 18 different wheat genotypes and disease-free plots, Anderegg *et al*. (2019) collected time-resolved hyperspectral reflectance data from the canopy. The lack of specificity and disease assessments were confirmed by gained results although used data analysis methods based on reflectance spectra at individual time points were indicative of the presence and severity of Septoria tritici blotch infections.

A microscope with a hyperspectral camera was used to study the interaction between powdery mildew and barley genotypes with high susceptibility by Kuska *et al.* (2017). Qualitative and quantitative assessments of pathogens were used to explain changes in hyperspectral signatures. Analysis of hyperspectral images which reflects the development of the disease revealed spectral characteristics of hyperspectral response against the pathogen. Hypersensitive response spot localization was based on an advanced data mining approach before the spots became visible on the RGB images. Gained results show that sensor-based phenotyping is suitable to facilitate expensive and time-consuming visual assessment of plant disease resistance (Kuska *et al.*, 2017). In another research barley plants inoculated with powdery mildew, brown rust (caused by *Puccinia hordei*), and net blotch (caused by *Pyrenophora teres*) were studied using data mining techniques of hyperspectral time-series image datasets (Wahabzada *et al.*, 2015). The authors were able to identify differences between the symptoms of three pathogens and illustrate the crucial trends of spectra during disease development on barley plants (Wahabzada *et al.,* 2015).

Most of the studies were conducted in controlled conditions and inoculation was done by known pathogens; however, in field conditions plants are exposed to abiotic stresses, such as salinity, extreme temperature, nutrient stress, or drought, resulting in decreased plant defence capacity and increased susceptibility to biotic stresses that cause additional changes into disease detection models (Mittler & Blumwald, 2010; Szittya *et al*., 2003; Zhu *et al.,* 2010). Additionally, some studies have revealed that plants prioritize their responses to attain one of the individual stresses which involved in combination of biotic and abiotic stress combinations (Atkinson *et al.,* 2012; Schenke, Bottcher, & Scheel, 2011). Therefore, analysing hyperspectral data gained in field conditions abiotic stress factors should be considered (Suzuki *et al.*, 2014).

Conclusions

1. There has been a significant increase in the scientific literature over the recent couple of decades, focusing on detecting biotic and abiotic stress in plants using hyperspectral image analysis.
2. Early detection of crop diseases would allow controlling the spread of the disease more effectively, thus reducing yield and quality losses and minimizing the negative impact of agriculture on the environment.
3. One of the main reasons for the increase in usage of hyperspectral imaging is the reduction of the costs of a camera and the improvement of technical parameters.
4. The number of vegetation and disease indices is increasing, the combination of different indices and significant wavelengths can improve the effectiveness of disease status indication; however, the accuracy is affected by other abiotic/biotic factors.
5. Computer vision, machine learning, and deep learning methods have a great potential for practical application in the future although currently there are not many successful examples of usage for the detection of fungal diseases of small grain cereals.

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CHANGES IN SEMI-NATURAL GRASSLAND DISTRIBUTION IN RELATION TO COMMON AGRICULTURAL POLICY 2014–2020 AREA-BASED PAYMENTS IN LATVIA

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Abstract
Semi-natural grasslands (SNG) are essential in the context of farmland biodiversity. The Common Agricultural Policy (CAP), on the other hand, is an important tool for the continuation of the management of semi-natural grasslands. Explicit knowledge on the pattern of grassland area changes is important to foster a more effective use of CAP for grassland biodiversity conservation. Our aim was to determine the habitat-specific changes in the distribution of Latvian SNG across different management regimes. Based on state-owned geospatial data of SNG distribution in 2014 and 2022, we assessed changes in semi-natural grassland areas over nearly ten years by analyzing grassland management and spatial distribution including areas inside and outside the Natura 2000 network. The spatial distribution of SNG remained similar in both periods. Eastern Latvia retained the highest share of SNG while the central part showed the most pronounced increase in new localities of SNG due to extensive habitat mapping carried out in recent years. Abandonment appeared as a more important threat to SNG in the Natura 2000 network and more profoundly to unproductive habitat types while transformation into arable land and grassland intensification was a considerable threat to SNG outside the network and to more productive habitat types. We suggest that agri-environment schemes should address the different needs of SNG in the Natura 2000 network and outside it.
Key words: grassland management, agri-environment, Natura 2000, abandonment farmland.

Introduction

Among the high nature value farmland (HNV), natural and semi-natural permanent grasslands (SNG) are the most valuable for biodiversity conservation in agricultural landscapes, and most of them are habitats listed in the Annex I of Habitats Directive 92/43/EEC (European Commission, 1992). Among the other permanent grasslands, SNG have considerably higher species richness and dependence on low-intensity farming that includes grazing and mowing with no ploughing, fertilization, drainage, herbicide use or reseeding (Herzon *et al*., 2021).

A significant decrease has taken place in the cover of SNG across Europe and the Baltic States show the highest reduction in HNV in the last decades (Anderson & Mammides, 2020). The importance of semi-natural grasslands has declined due to the intensification of management in parts of agricultural land (including conversion of semi-natural land to arable crops) and abandoning in other areas (Rounsevell *et al*., 2003; Vinogradovs *et al*., 2018).

To support HNV farmers by making a more effective use of the Common Agricultural Policy (CAP) and prioritizing the protection of HNV farmlands, explicit knowledge of the pattern of grassland area changes is important. In addition, there is surprisingly little scientific information on the habitat-specific effects of agri-environment schemes (AES) on distribution patterns. Although all semi-natural grassland habitats of the Habitats Directive fully depend on low-intensity agriculture (Halada *et al*., 2011), threats and pressures differ considerably among habitat types. For instance, more productive mesic and some wet grassland types in central Europe are more threatened by intensification (fertilization, improvement of sward by reseeding or even plowing), while most unproductive wet and dry grasslands are prone to abandonment (Ridding, Redhead, & Pywell, 2011; Dengler & Tischew, 2018; Janssen *et al*., 2021).

Whether this finding is true for Eastern-Baltic countries like Latvia and how it manifests at the landscape scale remains unclear. Our study addressed this knowledge gap by focusing on the changes in the distribution of productive and unproductive SNG in Latvia. The aim of this article was to determine the habitat-specific changes in the distribution of Latvian SNG across different management regimes.

Materials and Methods

Our data represented the implementation period of the Rural Development Programme 2007–2013 and 2014–2020. During the first period, SNG conservation management was addressed by the action-oriented agri-environment scheme 'Maintenance of Biodiversity in Grasslands' (MGB) aimed at fostering biodiversity-friendly management of permanent grasslands across the country. Eligible areas included all SNG habitats and cultivated permanent grasslands that are important habitats for bird species. The management requirements were common for all eligible habitat types and included mowing with or without hay removal once per season from 1 August

until 15 September or grazing (0.4–0.9 animal units), and any improvement of grassland was forbidden. There was a flat payment rate of 123 EUR ha^{-1}. During the Rural Development Programme period from 2014 to 2020, the same AES continued with the same management prescriptions. Yet, the approach to the payment calculation changed. Starting from 2015, differentiation of the payment into four classes based on grassland productivity was introduced ranging from 55 EUR ha^{-1} to 206 EUR ha^{-1} (less productive grasslands received higher payment); thus, the drivers of the uptake of SNG habitats changed.

To analyze the spatial pattern of SNG distribution, the country was divided into 2,778 grid cells of 25 km^2 each quadrant. All data were collected for each grid cell. We analyzed seven out of the ten grassland habitat types occurring in Latvia. Habitat type 6110* (asterix stands for priority habitats) *Rupicolous calcareous grasslands of the Alysso-Sedion albi,* and 6430 *Hydrophilous tall herb fringe communities* were omitted because they do not depend on agricultural activity, and 1630* *Coastal meadows* were not included because this is a landscape-level habitat type that can overlap spatially with other grassland habitat types. SNG were split into two groups of productivity according to the habitat-specific national data on productivity (Table 1).

Data on SNG area and distribution in 2014 and in 2022 were obtained from national-level georeferenced EU grassland habitat maps owned by the Nature Conservation Agency for both study periods. We used all SNG polygons irrespective of their management or abandonment at the time of mapping. Distribution data for 2014 contained all SNG mapped from 2001 until 2014. The dataset for 2022 included only those SNG that were mapped as such in the period from 2014 to 2022. Importantly, some portion of SNG that were part of the 2014 database but were documented as afforested or converted to arable land during the repeated inventories in later years have been discarded from the database in the frame of the database maintenance by Nature Conservation Agency. Productive habitat polygons accounted for 82% of the total area, and unproductive habitats accounted for 13% of the total area. The remaining 5% were polygons that included several habitat types with a mosaic structure and therefore could not be explicitly related to one of the habitat groups; consequently, they were omitted from further analysis.

To analyze the state of SNG management, we defined the following management statuses: (1) abandoned – SNG polygons that were mapped as such but not included in the agricultural parcel register of the Rural Support Centre and did not receive any payments from CAP instruments; (2) managed in AES – grasslands that received subsidies under the action-oriented AES 'Maintenance of Biodiversity in Grasslands' (the only grassland-related AES in Latvia); (3) converted to arable land – SNG polygons that were mapped as such but that were registered in the agricultural parcel register of the Rural Support Centre as arable land; and (4) managed as permanent grassland with no restrictions to biodiversity conservation (registered in the agricultural parcel register and receiving one or several of the following subsidies – direct payment, payment for organic

Table 1

HD grassland habitats analysed in the present study grouped into two productivity groups

Habitat group	HD habitat code and name (European Commission, 2013)	Phytosociological alliances (Auniņš, 2013; Mucina *et al.,* 2016)	Productivity, dry hay t ha^{-1} yr^{-1} (Rūsiņa, 2017a)
Productive habitats (dry hay more than 1 t ha^{-1} yr^{-1})	6270* (asterix stands for priority habitats) *Fennoscandian lowland species-rich dry to mesic grasslands*	*Cynosurion cristati, Calthion palustris*	1.0–2.0
	6450 *Northern boreal alluvial meadows*	*Deschampsion cespitosae, Magnocaricion gracilis, Magnocaricion elatae*	1.5–4.0
	6510 *Lowland hay meadows*	*Arrhenatherion elatioris*	1.5–4.0
Unproductive habitats (dry hay less than 1 t ha^{-1} yr^{-1})	6120* *Xeric sand calcareous grasslands*	*Armerion elongatae, Koelerion glaucae*	<0.5
	6210* *Seminatural dry grasslands on calcareous substrates*	*Filipendulo vulgaris-Helictotrichion pratensis*	0.5
	6230* *Species-rich Nardus grasslands*	*Violion caninae*	<0.5
	6410 Molinia meadows	*Molinion caeruleae*	0.5–1.5

farming, and payment for less favorable areas).

The comparative method was used, which determined the change of SNG areas in Latvia from 2014 to 2022. The results were presented in hectares and percentages. The method of analytical and logical analysis was used to determine the reasons for the changes in the area over the studied period.

Results and Discussion

Changes in SNG area

The total area of SNG increased from 44 662 ha in 2014 to 61 232 ha in 2022. The increase is mostly explained by the improved level of knowledge due to the continuous SNG habitat mapping in the frame of conservation planning in Natura 2000 network, as well as the country-wide habitat mapping project 'Nature Census' that was launched in 2017 by the Nature Conservation Agency. Some portion of the increase could be attributable to ecological restoration of SNG habitats that started in early 21c. For instance, ca. 7200 ha were restored in the period from 2000 to 2017 (Rūsiņa, 2017b). However, there is no updated statistics available about the total area restored or recreated until now.

Although it is a very positive tendency that SNG area has increased considerably, the observed increment is still very far from the minimum favorable conservation area needed to secure favorable conservation status as defined in the Habitats Directive. In Latvia, it is estimated that the favorable protection area should be between 130 000 and 390 000 ha (Rūsiņa, 2017a).

A large proportion of all SNG was abandoned in both study periods, and it was more pronounced in grasslands located in Natura 2000 network than outside it (Figure 1).

In 2014, 38.5% of the SNG area was abandoned (did not receive any CAP payments) outside Natura 2000. In 2022, this proportion decreased to 29.9%. At the same time, 47.3% of the SNG area located in the Natura 2000 network was abandoned in 2014 while this proportion decreased to 36.6% in 2022. On contrary to abandonment, SNG outside the Natura 2000 network were more exposed to ploughing. 3.9% of the total area of SNG mapped until 2014 was ploughed up in 2014 outside Natura 2000 while only 0.3% was ploughed inside the network. A similar ratio remained in 2022 but to a lesser extent. Importantly, for management in 2022, only data on actual SNG areas in 2022 were available for analysis and they did not include areas destroyed either by ploughing for tree planting or for other reasons in the period from 2014 to 2021. Thus, comparison is valid only for ploughed area ratio between outside and inside the Natura 2000 network, but not for the absolute amount of ploughed area of SNG in the given time period.

Our results are in line with the recent European wide evaluations of HNV transformation inside and

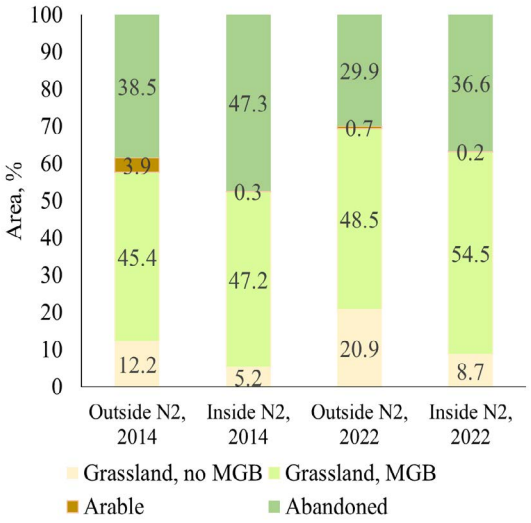

Figure 1. Management of semi-natural grasslands inside and outside Natura 2000 network in 2014 and in 2022. N2 – Natura 2000 network, MGB – agri-environment measure 'Maintenance of Biodiversity in Grasslands'.

outside the Natura 2000 network. There is evidence for an increase in arable land at the expense of grasslands in HNV farmlands in countries that joined the EU in 2004 or later (Reif & Vermouzek, 2019), and this finding has also been true for the Natura 2000 sites. However, Natura 2000 network experienced slightly lower ratio of transformation in comparison to the HNV outside the network. According to Anderson & Mammides (2020), arable land increased by 64% and transitional woodland by 9% within high nature value farmlands during the years 2012–2018 in Latvia. A similar tendency was observed in Lithuania, but Estonia experienced very little change – only a 6% increase in arable land and a 1% decrease in transitional woodlands. Our results show that abandonment is a more important threat to SNG in the Natura 2000 network while transformation into arable land is a considerable threat to SNG outside the network, and this pattern is consistent across time.

Management of SNG and CAP area-based payments

A comparatively small proportion of managed SNG was not supported by the agri-environment measure MGB. However, this area was two times larger outside the Natura 2000 network than inside it (12.2% versus 5.2% in 2014, and 20.9% versus 8.7% in 2022). Although this area is maintained as permanent grassland, there is no guarantee that biodiversity is intact because all other CAP payments for permanent grasslands do not prohibit intensive mowing or grazing combined with substantial fertilizing.

Two productivity groups of habitats – productive and unproductive (Table 1), showed a differing pattern of distribution and changes in

area in relation to management type (Figure 2). Unproductive habitats experienced a much higher abandonment rate than productive habitats in both periods. However, the proportion of abandoned areas decreased considerably in the second period. Productive habitats had a higher share of areas managed as permanent grasslands outside the agri-environment commitment of the MGB measure, and this tendency increased in the second period. At the same time, the ploughing pattern differed among periods. A considerably higher proportion of productive habitats was ploughed in 2014 than in 2022 (Figure 2).

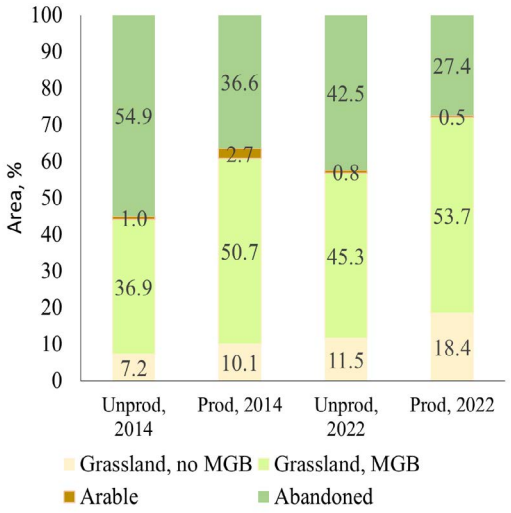

Figure 2. Management of productive and unproductive semi-natural grassland habitats in 2014 and in 2022. MGB – agri-environment measure 'Maintenance of Biodiversity in Grasslands'; Unprod – unproductive habitats, Prod – productive habitats.

Our results confirm findings of other studies that threats to SNG are habitat-specific (Ridding, Redhead, & Pywell, 2015; Dengler & Tischew, 2018). Productive habitat types are more threatened by intensification. In our case, it was either ploughing or avoiding to apply for grassland biodiversity related agri-environmental support that requires less intensive management regime. On contrary, unproductive habitats were threatened by abandonment. Similarly, unproductive dry semi-grasslands are highly threatened by abandonment also in neighboring countries. In Lithuania, over 72% of these grasslands are unmanaged (Uogintas & Rašomavičius, 2020). Abandonment of these habitats leads to considerable loss in the provision of ecosystem services and multifunctionality of landscapes (Prangel *et al.,* 2023).

The spatial pattern of grassland distribution changed slightly between the two periods. More grasslands were located in Eastern Latvia, less – in the central part of the country (Figure 3). The coverage of SNG across the whole country was higher in 2022 than in 2014. The largest difference was observed in the central part of Latvia, where in 2014 there was a much higher number of empty grid cells than in 2022.

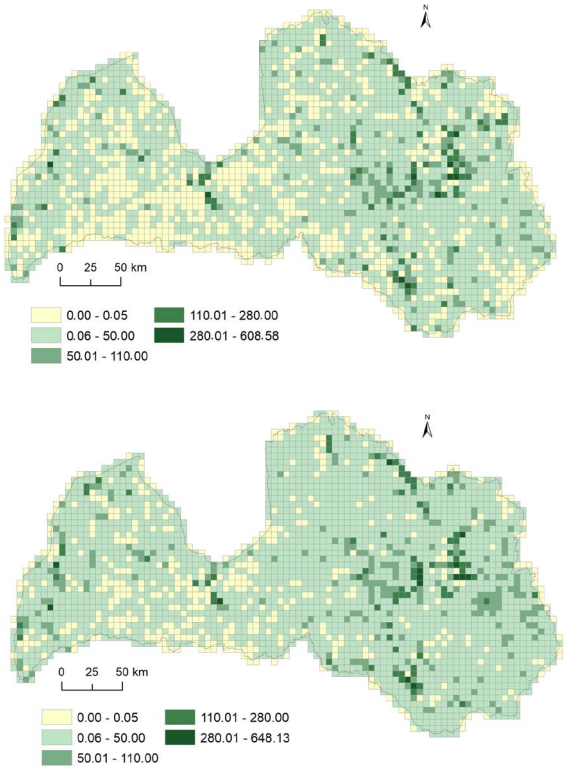

Figure 3. Distribution of SNG in Latvia. The legend shows grassland cover in hectares per 5×5 km cell. Upper figure 2014, lower – 2022.

The spatial structure of the intensity of the agri-environment support measure 'Maintenance of Biodiversity in Grasslands' showed overall high intensity in both periods (Figure 4).

The positive trend observed is that as the overall area under SNG increased, the supported area also increased, indicating that grassland owners were interested in applying for support and meeting the necessary conditions.

Despite the changes in CAP, Latvia still has a high proportion of unmanaged SNG (Figure 5). From 2014 to 2022, the abandoned areas have decreased from 20 336 ha to 17 761 ha. Some of this decrease can be attributed to the restoration of abandoned SNG (reversion of abandoned areas to managed SNG). However, some of it is due to the deletion of such areas from the database – those abandoned SNG areas that were still considered as SNG in 2014 but completely overgrown by 2022 have been omitted from the SNG spatial geodatabase of Nature Conservation Agency (permanent loss of area of

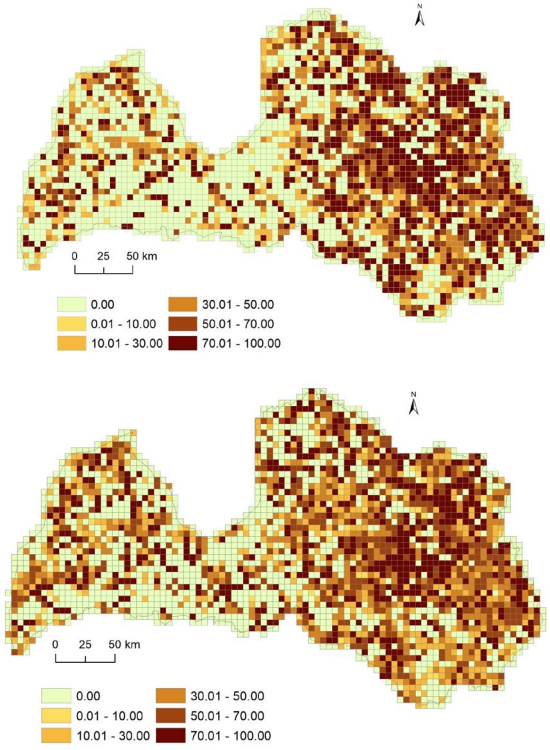

Figure 4. Spatial pattern of the intensity of agri-environmental support measure 'Maintenance of Biodiversity in Grasslands' shown as the percentage of supported area out of the total area per 5*5 km cell in both study periods. Upper figure 2014, lower – 2022.

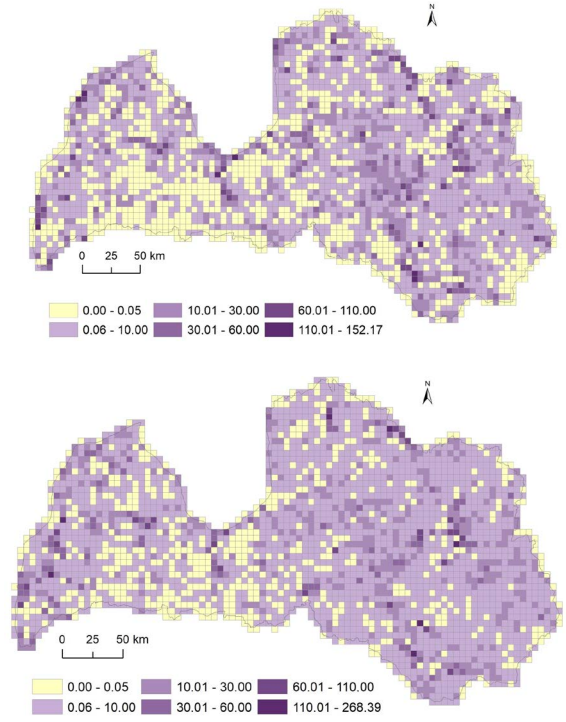

Figure 5. Distribution of abandoned SNG in 2014 (upper figure) and 2022 (lower figure) in hectares.

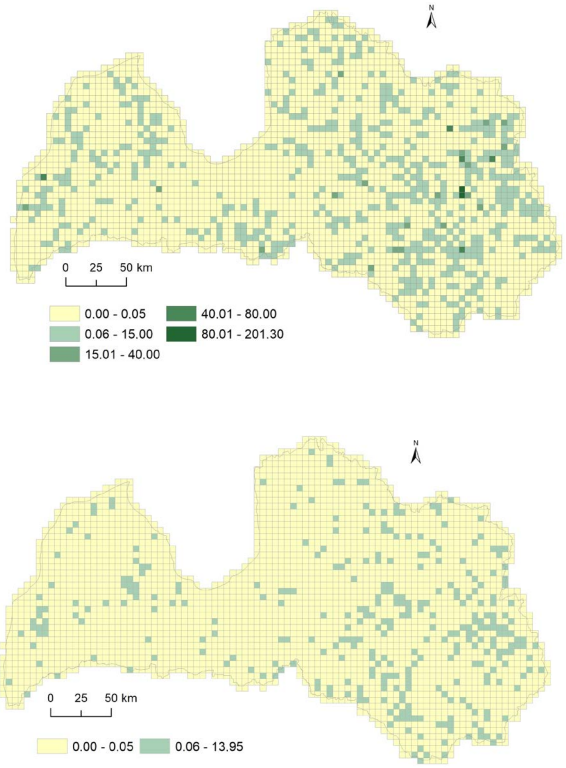

Figure 6. Distribution of ploughed SNG in 2014 (upper figure) and 2022 (lower figure) in hectares.

SNG). The loss of SNG area due to abandonment is a common problem across Europe, especially, in Eastern Europe (Török *et al*., 2018) and CAP support plays a crucial role as an effective tool for protecting grasslands from abandonment (Halada *et al*., 2017).

Still, the way how the abandoned land is reintegrated in management should be carefully considered to achieve not only production goals but also biodiversity goals (Valujeva *et al*., 2022). As our findings indicate, the conversion of SNG into arable land or other intensified agricultural land use remains a significant risk in Latvia (Figure 6). The total area of ploughed SNG reached 2 475 ha in 2014 (area of SNG mapped as such in the period from 2004 to 2014 and reported as under arable land in 2014) and 342 ha in 2022. However, the lower area in 2022 was due to a lack of data on the area ploughed between 2014 and 2022. More detailed conclusions would require accurate monitoring data on the abandonment and ploughing of SNG.

Conclusions

1. The total area of SNG experienced a significant increase from 2014 to 2022. This increase can primarily be attributed to the improved knowledge obtained through habitat mapping efforts. Ecological restoration efforts also played a role but to a lesser extent over the past decade.
2. Our findings indicate that abandonment posed a

greater threat to SNG within the Natura 2000 network, whereas transformation into arable land and intensification of grasslands were significant threats to SNG outside the network. This pattern remained consistent during both study periods.

3. The abundance of SNG habitats and their uptake in grassland biodiversity related agri-environment schemes differed between the productive and unproductive habitat groups. Productive habitats experienced higher impact of ploughing and intensification, while unproductive habitats were more prone to abandonment.
4. The spatial distribution of SNG remained relatively similar between the two periods. Eastern Latvia retained the highest share of SNG while the central part showed the most pronounced increase in new localities of SNG.
5. Considering our findings, we suggest that agri-environment schemes should address the different needs of SNG in Natura 2000 network and outside it. From one side, the support should promote introduction of extensive management of SNG in Natura 2000 sites to tackle abandonment problem, and from the other side – to prevent ploughing or intensification of SNG outside the network.

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THE VITALITY OF *TAXUS BACCATA* L. IN FOREST STANDS IN SLITERE NATIONAL PARK, LATVIA

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Abstract
Taxus baccata L., a relic of the Atlantic flora, is fourth of Latvia's coniferous tree species, and it is endangered with a limited utilization because of its rare distribution. Evaluation of species condition, tree vitality and unfavourable factors influencing tree growth is crucial to improve species status. Measurements of forest stands with *T. baccata* autochthon and anthropogenic populations were collected, crown condition was rated, damages of trees were assessed, and projective cover of vegetation (canopy closure, shrub and herbaceous layer) was evaluated to determine the effect on *T. baccata* populations in Slitere National Park, Latvia. Main results show that factors strongly influencing the vitality of *T. baccata* are soil reaction and light conditions. Mostly the light conditions were determined by the canopy closure. Major conditions of shade negatively influenced the vitality and distribution of *T. baccata*.
Key words: *T. baccata*, vitality, light conditions, crown parameters, soil pH.

Introduction

Nowadays it is difficult to imagine forest stands with up to 28 m high trees of *T. baccata* (Thomas & Polwart, 2003). Nevertheless, not long ago, *T. baccata* was a common component of forest stands across Europe – from Fennoscandia to Mediterranean region and Caucasia (Dovčiak, 2002). Valuable properties of wood were the cause of intensive cutting of large arrays of millennial forest stands of *T. baccata* (Riekstiņš, 1986; Thomas & Garcia-Martí, 2015). Further several reasons poorly impacted the distribution of *T. baccata*: utilization by humans, destruction of forests as a result of wars, fragmentation of the populations, climate change (Riekstiņš, 1986; Thomas & Polwart, 2003).

The north-east borderland of natural distribution of the species is in Latvia (Riekstiņš, 1986). It grows mainly on coastal lowland: distribution is limited by mild oceanic climate and specific edaphic conditions (Riekstiņš & Laiviņš, 1984; Thomas & Garcia-Martí, 2015; Thomas & Polwart, 2003). The largest autochthon population of *T. baccata* in the country is in Slitere National Park, where it has been under different protection regimes since 1921 (Riekstiņš, 1981). Population is located on approximately 7 km long and 0.5-1 km wide region along hillside of Zilie kalni, including three geologically diverse structures: moraine, a bluff of the Baltic Ice Lake and abrasion-accumulation low land (Blūms, 1987).

Among other coniferous tree species *T. baccata* is highly distinguished because of its eminent vitality and ecological plasticity which allows it to reach extremely old age – up to 2000 years (Thomas & Garcia-Martí, 2015). Although it can adapt to changes, it has become endangered in a number of European countries, including Latvia. Despite its shade-tolerance, insufficient light conditions and prolonged shading can decrease the vitality of the tree (Devaney *et al*., 2015; Riekstiņš, 1981). Light conditions are influenced by dominant trees within the forest stand, shrub layer and the density of forest stand (Dovčiak, 2002). Some countries have developed special forestry methods of stand thinning to increase the light conditions. It results as an increase of crown dimensions of *T. baccata*, which also increases the vitality of the tree (Vacik *et al*., 2001). Another negative impact on *T. baccata* well-being is density of herbivore population: often they tend to feed on tree leaves, shoots and bark and they also strongly impact the natural regeneration of species by fully exterminating the seedlings (Blūms, 1982; Thomas & Polwart, 2003).

One of the essential factors influencing the vitality of *T. baccata* is soil reaction (pH) (Riekstiņš & Laiviņš, 1984). It requires alkaline soils, most favourable are sandy loam and clay with fine drainage and suitable moisture levels. Another limiting factor is climate (Thomas & Garcia-Martí, 2015; Thomas & Polwart, 2003). As a species loving warmth, high relative air humidity and mild oceanic climatic conditions, *T. baccata* is an indicator species for climate change (Thomas & Garcia-Martí, 2015).

The aim of the study was to determine which factors – stand density, soil pH, damages, light conditions and projective cover of vegetation – influenced the vitality and distribution of *T. baccata* in Slitere National Park.

Materials and Methods

Data was collected in Slitere National Park. To determine what conditions are favourable for distribution of *T. baccata*, three forest stands with anthropogenic plantations (Zviedri – ZV (*Myrtilloso-polytrichosa*), Juši – JU (*Oxalidosa*, *Aegopodiosa*, *Myrtilloso-polytrichosa, Dryopterioso-caricosa, Filipendulosa, Myrtillosa turf.mel., Oxalidosa turf.mel.*), Dadzīši – DA (*Oxalidosa*)) and three autochthon provenances (Vilku līnija – VL

(*Dryopterioso-caricosa*), 'Jaunlīdumu' grava – JG (*Aegopodiosa*), Daiķu īvju liegums – DIL (*Aegopodiosa*)) of *T. baccata* were selected for data collection. 22 sample plots (500 m^2) were made to collect dendrometric measurements (height, diameter at breast hight (DBH)) of forest stand to determine stand variables, such as forest stand basal area, growing stock and density and if or how it affects development and growth of *T. baccata*. In addition, for each *T. baccata* individual diameter at ground level, crown length and diameter were measured, foliage transparency (FT), crown density, crown dieback (CD) was evaluated to establish favourable light conditions for species. Crown dieback helps to evaluate if there are significant damages caused by insects, wind, unfavourable growing conditions or herbivores. Dying of fine twigs in the outer or upper part of the tree were counted, if it could be determined that dying began at the terminal part of the branch (Schomaker *et al*., 2007). Indices are related to tree growth, survival and vitality. To determine *T. baccata* potential to obtain and exploit solar energy (Devaney *et al*., 2015), composite crown volume (CCV) was calculated *(Schomaker et al*., 2007).

In order to determine the overall status of the species, tree vitality was assessed. Vitality of trees was estimated visually in grades:
vigorous (3) – healthy tree with symmetrical crown, dense foliage, without observed damages or negative impact of damage on tree growth;
supressed (2) – healthy but damaged tree or with signs of possible competition or other unfavourable impact of growing conditions, medium foliage density;
low-vigour (1) – unhealthy tree with distinct damages, high foliage transparency, underdevelopment in growth, dissymmetrical crown, adventive buds;
withered (0) – dry, dead tree with no indication of growth.

Occurrence of damages (biotic – caused by ungulates, entomological, phytopathological and abiotic) was established to determine if they impact the vitality of *T. baccata*.

Soil samples (200) were collected from upper layer of soil (0–20 cm) and below (20–40 cm) to establish favourable soil reaction (pH) levels for *T. baccata*. Soil reaction was determined potentiometrically in laboratory. For each sample two tests were made with distilled water and two with potassium chloride (KCl). The average variables were calculated to determine the amplitude of soil reaction in which T. *baccata* occurs.

Growing conditions in and between the objects were compared using Ellenberg indicator values. The projective cover of vegetation was measured in summer. It was measured in forest stand layer (canopy closure, E3), shrub layer (E2), herbaceous layer (E1). Percentage of all layers was calculated, to determine, if it influences the vitality of *T. baccata*. Linear Regression Analysis was used to indicate if and how the factors (light, moisture, soil reaction, nitrogen) interacts with analysed groups (study areas) (Lund & Lund, 2018a). Analysis of variance (ANOVA) was selected as statistical technique to compare the means of factors that are defined by single categorical variable (Lund & Lund, 2018b) and to estimate if the factors had a significant impact on study areas. Post-hoc test was used to estimate if there are essential differences between study areas. An indicator of similarity between study areas was attached.

Spearman's rank correlation coefficient r_s was used to determine if there is a correlation between the composite crown volume and factors determining growing conditions, between the average forest stand density and the number of *T. baccata* individuals per hectare and between the average forest stand density and the average DBH and diameter at root collar.

Results and Discussion

The study was conducted in old, broadleaved and mixed forest stands, typical in nature reserve area which is located in the south part of Slitere National park. Forest stands on mesotrophic, meso-eutrophic and eutrophic soils were surveyed. In general, all forest stands in study areas were high density, rich in species diversity, fertile in terms of soil conditions with medium or high moisture levels. The most common tree species in the study areas were *Alnus glutinosa* (L.) Gaertn. and *Picea abies* (L.) H.Karst. Overall, the state of *T. baccata* populations, both autochthonic and anthropogenic were satisfactory with some exceptions. Species distribution range widely in different geological structures; however, the edaphic conditions were similar in terms of pH levels.

The average forest stand parameters are summarized in Table 1. All analysed forest stands were full density stands, except for forest stand in study area 'Jaunlīdumu' grava (JG), respectively 0.7. The drying out of large dimension trees (*Fraxinus excelsior* L. and *Ulmus glabra* Huds.) had resulted in widespread of openings. The second lowest forest stand density was found in study area Vilku līnija (VL), respectively 0.97: the reason was a forest site type – *Dryopterioso-caricosa*. Forest stand grows on 2.25 m deep peat (*Eutric Rheic Histosol* (*Hyperorganic Lignic*)) layer with alkaline underground outflows, which causes openings in the forest stand where moisture level is too high for tree survival. The high indexes of density could be a result of old, natural, undisturbed forest stands.

Table 1

Dendrometric parameters of forest stands with *Taxus baccata*

Object ID	*Basal area*, m^2 ha^{-1}	*Growing stock*, m^3 ha^{-1}	*Density*
ZV	30.8	288.7	1.09
JU	30.8	305.8	1.03
DA	30.5	285.2	1.05
VL	27.1	243.7	0.97
JG	20.7	217.5	0.70
DIL	33.1	337.7	1.31

The percentage of healthy *T. baccata* individuals in study areas (Table 2) indicates general state of vitality. Study areas with autochthon provenance of *T. baccata* in forest stands had the highest proportion of healthy trees, because of preferable growing conditions. The highest proportion of healthy individuals were in study area Daiķu īvju liegums (DIL) (80%), but it should be taken in account that there were only 33 individuals of *T. baccata* per hectare. DBH and diameter at root collar range widely (respectively 0.4 (DA) – 26.2 cm (VL) and 0.6 (VL) – 34.8 cm (VL)) due to low vigour or high level of natural regeneration of species. If second, it shows strong vitality of the population. It should be taken in account that diameter at root collar is essentially influenced by the form of the tree: *T. baccata* tends to form as a shrub or it can have more than one dominant stem (Thomas & Polwart, 2003). The height of *T. baccata* varied between 0.37 m (JU) and 11 m (JG) which could be interpreted as a result of different growing conditions. It also could characterise the state of natural regeneration.

Higher density of forest stand decreased the distribution of *T. baccata*: a significant negative correlation (r_s = -0.8678; $p < 0.001$) was found between the average forest stand density and the number of *T. baccata* individuals per hectare (Alavi *et al*., 2020; Dovčiak, 2002). We also found a positive correlation (r_s = 0.6942; p = 0.01)) between the average density of forest stand and average DBH and diameter at root collar. Density of forest stand influenced the microclimatic conditions: forest stand acts as a shield for severe frosts.

The average CCV characterizes crown dimensions, density and biomass. Increase of the volume intensifies receiving the sunlight and vice versa, which is vital for tree to provide itself with chemical energy (Devaney *et al*., 2015). Largest average CCV was found in study area Daiķu īvju liegums (CCV = 4.9 ± 12.27 m^3), but it should be taken in consideration that the occurrence of *T. baccata* in this study area was only 33 trees per hectare. Second largest CCV was found in Vilku līnija (CCV = 3.5 ± 9.7 m^3): it could indicate a vigorous population with favourable light conditions (Devaney *et al*., 2015). The influence of surrounding trees and the level of competition could be a cause for smallest CCV found in Dadzīši (CCV = 1.9 ± 2.4 m^3) (Thomas & Garcia-Martí, 2015). A significant negative correlation r_s = -0.627 (p = 0.02) was found between the average forest stand basal area and CCV, indicating that the dimensions of *T. baccata* crown were undersized in forest stands with high density index: being slow growing but tenacious species, *T. baccata* can withstand unfavourable conditions (Thomas & Polwart, 2003).

The average index of foliage transparency (FT) is

Table 2

Vitality of *Taxus baccata* and average dendrometric and crown variables

Object ID	ZV	JU	DA	VL	JG	DIL
Healthy individuals, %	69	43	34	78	78	80
T. baccata trees per hectare	100	180	293	255	266	33
$D_{1,3}$, cm	5.76 ± 2.81	3.52 ± 3.32	3.95 ± 2.4	6.18 ± 4.07	5.72 ± 3.99	7.58 ± 3.06
D_{sk}, cm	9.61 ± 3.69	6.46 ± 4.69	8.84 ± 3.3	10.70 ± 5.89	11.13 ± 6.37	11.62 ± 4.59
H, m	3.88 ± 1.39	2.96 ± 1.6	3.47 ± 1.2	5.27 ± 2.02	4.03 ± 2.53	6.00 ± 3.37
Composite crown volume, m^3	2.0 ± 4.2	1.7 ± 7.73	1.9 ± 2.4	3.5 ± 9.7	2.6 ± 9.72	4.9 ± 12.27
Foliage transparency, %	74.5 ± 24.24	71.0 ± 28.07	55.0 ± 25.13	68.3 ± 20.66	65.3 ± 15.76	37.5 ± 10.95
Crown dieback, %	54.3 ± 38.4	64.8 ± 40.91	14.7 ± 30.15	48.0 ± 23.8	49.3 ± 15.4	5.0 ± 2.74

known to negatively correlate with tree vitality and health (Schomaker *et al*., 2007). Almost all of the study sites where FT index indicated dense crown (Daiķu īvju liegums (37.5 ± 10.95%), Dadzīši (55 ± 28.07%), 'Jaunlīdumu' grava (65.3 ± 15.76%) and Vilku līnija (68.3 ± 20.66%)) were autochthon provenances. Therefore it implies favourable light conditions. A significant negative correlation $r_s = -0.6719$; ($p = 0.01$) has been found between the CCV and FT *(Schomaker et al*., 2007).

Crown dieback (CD) shows the amount of crown parts that has recently died. The largest index (CD = 64.8 ± 40.91) was found in *T. baccata* plantation Juši (JU), that could indicate early signs of stress (Schomaker *et al*., 2007). In comparison to that, remaining populations with lower CD indexes could imply more favourable conditions.

The largest proportion of vigorous trees were situated in forest stands with autochthon populations of *T. baccata* (Vilku līnija (78%), 'Jaunlīdumu' grava (78%), Daiķu īvju liegums (80%)). A considerable number of vigorous individuals were in study area Zviedri (ZV) (69%) – an anthropogenic plantation. It indicates that there were favourable growing conditions for *T. baccata*. The smallest proportion of withered trees are in Vilku līnija (2%) and 'Jaunlīdumu' grava (2%), but in Daiķu īvju liegums and Dadzīši (DA) withered trees were not observed. In Dadzīši individuals of *T. baccata* showed a strong vitality although trees were severely damaged by herbivores and abiotic factors, such as wind. In Daiķu īvju liegums no withered or low-vigour class individuals were observed. But it should be taken in consideration that only 6 individuals of *T. baccata* were found within the sample plots. In study areas Zviedri, Juši, Vilku līnija, 'Jaunlīdumu' grava most of low-vigour trees were small in dimensions and there were phytophatalogical damages observed, such as withering of shoots, yellowing of leaves and defoliation. Figure 2 shows further details of occurrence of damages.

The average values of soil reaction (pH) are summarised in Table 3. Almost all pH levels in forest stands with autochthon populations of *T. baccata* were higher – more alkaline than acidic. It represents the favourable pH levels for *T. baccata*: $pH_{KCl} = 5.41 \pm 0.3$ – $pH_{KCl} = 5.79 \pm 0.5$ (0–20 cm) and $pH_{KCl} = 5.52 \pm 0.11$ – $pH_{KCl} = 5.8 \pm 0.22$ (20–40 cm). Similar results were found in study area Zviedri (ZV): $pH_{KCl} = 5.24 \pm 0.58$ (0–20 cm) and $pH_{KCl} = 5.73 \pm 0.45$ (20–40 cm). In Slitere National Park *T. baccata* range widely, displaying the ability to adapt (respectively pH_{KCl}: 3.36–7.02 in the upper layer of soil and 3.73–6.7 in deeper layer of soil). In general, it is observed that soil reaction in upper layer of the soil is more acidic than in deeper layer. Figure 1 represents the vitality and occurrence of *T. baccata* in relation of soil pH levels. The litter of dominant stand and the advanced growth creates layer of possibly acidic conditions (Amacher *et al*., 2007), whereas in deeper layers of soil the hydrogen ions (H+) are leaching through. The fine roots of *T. baccata* responsible for absorbing nutrients and water are situated in the upper layer of soil; therefore, the pH levels in the surface of soil are most crucial. High pH levels in the upper layer of soil had positive effect on *T. baccata* vitality. Figure 1 represents the link between pH levels and CCV. A significant positive correlation $r_s = 0.7241$ ($p < 0.001$) between the CCV and the levels of pH in the upper layer of soil (0–20 cm) was found.

The occurrence of damages observed in forest stands with *T. baccata* in Slitere National Park is summarised in Figure 2. It shows that increase of damages caused by ungulates reduces the composite crown volume. Most observed damages were caused by ungulates: herbivores, such as *Cervus elaphus* L., *Capreolus capreolus* L. and *Alces alces* L. The

Table 3

Soil reaction in study areas in Slitere National Park

Soil reaction (pH)	Object ID					
	ZV	JU	DA	VL	JG	DIL
pH_{H2O} (0–20 cm)	6.20 ± 0.35	5.94 ± 0.82	5.35 ± 0.41	6.71 ± 0.26	6.56 ± 0.34	6.26 ± 0.32
pH_{KCl} (0–20 cm)	5.24 ± 0.58	4.94 ± 0.92	4.28 ± 0.38	5.67 ± 0.28	5.79 ± 0.5	5.41 ± 0.3
pH_{H2O} (20–40 cm)	6.44 ± 0.4	5.99 ± 0.65	5.60 ± 0.41	6.80 ± 0.27	6.55 ± 0.25	6.45 ± 0.23
pH_{KCl} (20–40 cm)	5.73 ± 0.45	5.06 ± 0.9	4.52 ± 0.48	5.8 ± 0.22	5.53 ± 0.3	5.52 ± 0.11

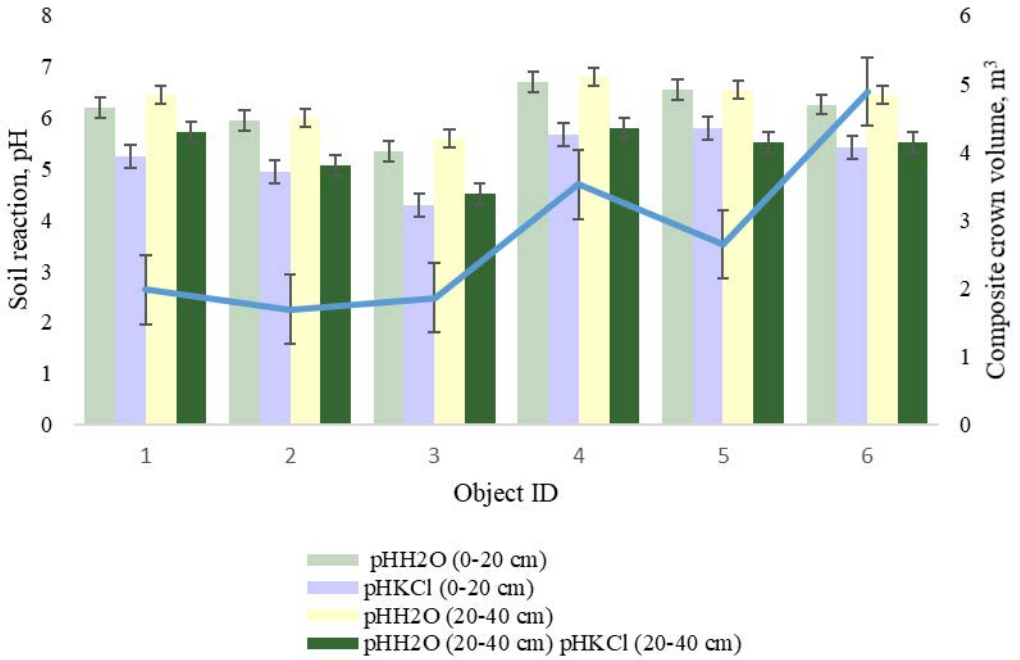

Figure 1. The vitality of *Taxus baccata* in relation of soil reaction in Slitere National Park.

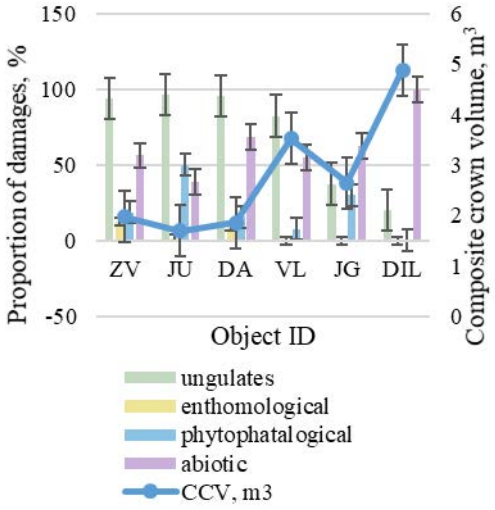

Figure 2. The occurrence of biotic and abiotic damages of *Taxus baccata* in relation with composite crown volume in Slitere National Park.

damages they caused were bit shoots and branches, teared bark, chipped branches or even the top of the tree. On some occasions there were signs of damaged root system, caused by hoofs. The least observed were enthomological damages, such as damages, where insects had been feeding on the bark or leaves of *T. baccata*, which indicates low impact on the vitality of tree. In some of the studied areas a considerable amount of phytophatalogical damages were found, such as die-back of young shoots and yellowing of the leaves. It was observed, that phytopathological damages were widely distributed in anthropogenic plantations, which indicates, that the growing conditions were not suitable for *T. baccata*; therefore, the resistance to pathogens was low. Commonly observed were abiotic damages mostly caused by wind: often fallen deadwood supressed *T. baccata*. Still, most of the trees were able to continue their growth: a new dominant shoot was observed, or the tree became more shrub-like. Verifying the relationship between damages and CCV, significant negative correlation r_s = -0.787 (p = 0.002) was found only between the CCV and the damages caused by ungulates. The frequent occurrence of damages caused by herbivores could affect the distribution and vitality of *T. baccata* even more in the future (Thomas & Garcia-Martí, 2015).

The projective cover of vegetation (Table 4) was analysed using Ellenberg indicator values. Indices indirectly imply the growing conditions, based on the environmental necessities of the species. The conditions of light, moisture, soil reaction and nitrogen in all study areas were determined. Similarity between the study areas Zviedri, Juši, Dadzīši and 'Jaunlīdumu' grava was explained by a similar – medium amount of herbaceous plants. Significant distinction was found in Vilku līnija where the cover of vegetation was 100% due to distinctive charesteristics of forest site type *Dryopterioso-caricosa* where extremely wet areas were covered by hydrophilic species and the light conditions were sufficient. In Daiķu īvju liegums, the cover of vegetation was only 41% (Table 4), indicating low light conditions, probably caused by dense shrub layer. Similar moisture conditions were found in herbaceous layer in all study areas except Dadzīši and Vilku līnija. In the first area, the moisture

Table 4

Ellenberg indicator values in study areas in Slitere National Park

Object ID	Light	Moisture	Soil reaction	Nitrogen
ZV	3.87[a]	5.29[ab]	4.34[a]	5.18[ab]
JU	4.40[a]	5.95[ab]	4.62[a]	6.46[b]
DA	2.83[a]	4.29[a]	5.09[a]	5.50[ab]
VL	5.94[b]	6.80[b]	5.74[a]	5.18[ab]
JG	3.60[a]	5.79[ab]	5.53[a]	6.48[ab]
DIL	4.30[ab]	4.90[ab]	3.95[a]	4.76[a]

conditions were extremely low, but in second – extremely high. Similarity was found between study areas Zviedri, 'Jaunlīdumu' grava and Daiķu īvju liegums: in these areas moisture level was medium. Essential similarity between study areas in terms of soil reaction conditions were found; therefore, it indicates soil reaction as a limiting factor of *T. baccata* distribution. Similarity between study areas was found in conditions of nitrogen levels except for Daiķu īvju liegums and Juši.

Vital similarities between study areas were found in terms of soil reaction and light conditions. Therefor it shows that these factors influence the vitality and distribution of *T. baccata* above all.

To indicate if there is a vital impact of projective cover of vegetation on the vitality of *T. baccata*, the average percentage of vegetation cover was calculated (Table 5).

Table 5

Proportion of vegetation cover in study areas in Slitere National Park

Object ID	Canopy closure, %	Shrub layer, %	Herbaceous layer, %
ZV	92 ± 10	32 ± 7	79 ± 22
JU	84 ± 20	52 ± 22	79 ± 26
DA	96 ± 6	62 ± 47	90 ± 17
VL	86 ± 12	57 ± 9	100 ± 0
JG	81 ± 13	64 ± 32	79 ± 18
DIL	99 ± 3	75 ± 2	41 ± 10

The immense percentage of vegetation cover in all study areas, is common in broad-leaved and mixed forests. The projective cover of dominant stand was within 81–99%: it indicates that trees were exploiting the growing area to the maximum, but it also created shady conditions below the canopy. The percentage of shrub layer was lesser than in the stand layer, usually composed of *Corylus avellana* L. and *Picea abies* (L.) H.Karst. A significant negative correlation r_s = - 0.6299 ($p < 0.001$) between CCV and the projective cover of stand layer was found, indicating that intensive shading caused by closed canopy negatively influences the vitality of *T. baccata* (Dobson *et al*., 2021; Dovčiak, 2002). A negative correlation r_s = -0.6538 $p < 0.001$) between CCV and herbaceous layer was also found, but in this case the herbaceous layer was negatively impacted by the dimensions of crown density of *T. baccata*.

Conclusions

1. The dimensions of *T. baccata* were positively influenced by dense forest stands, decreasing several risk factors. However, the distribution of *T. baccata* tends to increase in more open forest stands.
2. The crown dimensions of *T. baccata* decreased within an increase of forest stand basal area, which has resulted as a weaker ability to produce energy in the process of photosynthesis; therefore it reduced the vitality of *T. baccata*.
3. *T. baccata* negatively responded to poor light conditions, which were mainly determined by the canopy closure.
4. Soil reaction influenced the distribution and vitality of *T. baccata*. However, the wide range of pH levels within the areas where *T. baccata* were distributed, shows its ability to adapt.

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CARBON STOCK OF DECIDUOUS FORESTS ON ORGANIC SOILS IN LATVIA

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Abstract
Forests play a significant role in the mitigation of climate change through carbon storage and sequestration. However, a forest's capacity to absorb carbon is influenced by a number of factors, such as soil characteristics, the selection of tree species, and the application of silvicultural practices. A study in Latvia was conducted to evaluate the carbon stock and sequestration potential of birch, common aspen, black alder and grey alder growing on periodically waterlogged and drained organic soils. Empirical data of forest resources were obtained from the National Forest Inventory (NFI) from 2016 to 2020. The findings indicate that black alder may thrive in both soil types, as it showed the best increase in carbon stock in periodically waterlogged soils, reaching a maximum of 129 t C ha^{-1} at the age of 61–70 years. Greater carbon sequestration in tree biomass occurs on drained soils compared to periodically waterlogged. Birch, aspen, and black alder stands may store between 106 and 119 t C ha^{-1} at age of 61 and 70 years, which is similar to grey alder stands at ages of 31–40 (114 ± 0.73 t C ha^{-1}). Therefore, a short rotation for grey alder growing on drained organic soils could maximize carbon accumulation and add substitution value. These results suggest that different types of deciduous trees have varying capacities for carbon storage and sequestration, and that it's important to consider site-specific factors, rotation age and silvicultural practices when aiming to maximize carbon sequestration in tree biomass.
Key words hemiboreal forests, peat soils, carbon storage, climate-smart-forestry.

Introduction

The mitigation of climate change has become a vital commitment for many nations, particularly for those with large forested areas that are capable of storing and sequestering carbon in tree biomass, vegetation, and soil (especially organic soil). The efficient use of land resources to optimize carbon storage is becoming increasingly important in the pursuit of climate neutrality objectives (Chen, 2021).

The ability of a forest to absorb carbon is significantly affected by several factors, including soil characteristics, tree species selection, and silvicultural practices. Silvicultural methods, such as drainage, thinning, and fertilization can be used to enhance the carbon sequestration potential of forest stands (Dixon, 2009).

In Latvia, approximately 11% the total forest area is situated on periodically waterlogged organic soils with an organic (peat) layer exceeding 30 cm. These forests typically have low productivity, with an average stock ranging from 110–180 m^3 ha^{-1}, depending on the soil fertility and water regime as well as selected tree species (Zālītis & Jansons, 2013). The productivity of these stands is generally limited due to excessive soil moisture with some exceptions such as black alder and grey alder stands. Drainage with open-type ditches has been identified as the most effective measure to enhance the productivity and above-ground carbon storage of these forests (Zālītis *et al*., 2013). Currently, approximately 12% of the total forest area in Latvia consists of drained forests with organic soils (peat layer >20 cm), with a growth potential ranging from 220–400 m^3 ha^{-1} (Zālītis & Jansons, 2013).

The most common deciduous tree species found in Latvia are birch (*Betula spp.*), common aspen (*Populus tremula*), black alder (*Alnus incana*), and grey alder (*Alnus glutinosa*). Furthermore, they exhibit different growth rates and biological ages at which they begin to degrade. As a result, forest policy has established to define felling ages for different tree species. Fast-growing tree species, such as grey alder, does not have a felling age, whereas aspen can be harvested at the age of 40 years. Black alder (71 years) and birch (71 or 51 years at poor site types) have longer rotation cycles (Meža likums, 2000).

Fast growing deciduous trees with shorter rotation cycle can be advantageous for carbon sequestration purposes as well to provide substitution effect for fossil energy sources (Binkley *et al*., 1997; Rytter & Rytter, 2016; Tullus *et al*., 2013). While energetic wood has a lower substitution factor than other wood assortments, there has been a growing demand for energetic biomass, thus increasing its value (*Material Economics*, 2021). Birch and black alder have more valuable timber assortments with a longer life span and higher substitution potential (Claessens *et al*., 2010; Dubois *et al*., 2020).

The economic efficiency of forest land use is primarily influenced by the selection of tree species suitable for soil conditions. However, in order to comply with aspects of climate change mitigation targets, it is necessary to promote the replacement of low-productive stands with the most suitable tree species to develop more productive stands in terms of carbon sequestration. Climate-Smart Forestry

is a focused strategy that aims to maximize the potential advantages of forest ecosystems and the forest industry to capture CO_2 in tree biomass as well as through material and energy substitution (Weatherall *et al*., 2022). Information in the scientific literature about carbon stock of deciduous trees growing on organic soils is scarce; however, it is necessary for management purposes. Therefore, it is crucial to conduct research on tree species growth and carbon storage potential on a national scale. The aim of this study is to evaluate the carbon stock and sequestration potential in tree biomass of deciduous forests growing on periodically waterlogged and drained organic soils.

Materials and Methods

Information about forest resources in Latvia has been gathered through the National Forest Inventory (NFI) since 2003. The NFI uses four permanent sample plots (500 m^2) in each 4x4 m grid network across the territory of Latvia, totaling 16157 sample plots. Each sample plot is remeasured every five years. In the current study, data from the NFI (from 2016 to 2020) were used to obtain stand-level growing stock. This study focused on deciduous forests in Latvia, specifically the four most common native tree species: birch, common aspen, black alder and grey alder, growing on organic soils. The research analyzed empirical data of deciduous forest stands growing on drained and periodically waterlogged (undrained) organic soils (Table 1). The forest stands were grouped based on the soil type: drained – forest stands are improved with an established ditch system that regulates the groundwater level and others lacking drainage systems and thus are periodically waterlogged. Forest stand growing stock was estimated using locally developed models for each tree species by Liepa (Liepa, 1996). Study stands were divided by 10-year age classes up to 90 years. Biomass-weighted means were calculated based on the proportional distribution of the whole tree biomass of different species in forest stands, taking into account the proportional distribution of admixed tree species (Liepiņš *et al*., 2018, 2021). Data on weighted average C content in wood (g kg^{-1}) were used to calculate average carbon stock and mean annual rate of carbon accumulation in tree biomass for each tree species and 10-year age class (Bārdule *et al*., 2021). Annual carbon sequestration (accumulation) was calculated by dividing carbon stock with stand age. Normal distribution of data was checked with the Shapiro-Wilk normality test. A t-test was used to evaluate the statistical significance of average carbon sequestration differences observed between two distinct soil type groups for each species. A linear model was used to test the effect of tree species, soil type, and stand age on the dependent variable – carbon stock. Significant effects ($p \leq 0.05$) were examined with ANOVA type III test (sum of squares). All data analyses were performed at level α=0.05 with R Studio (R Core Team, 2021).

Table 1

Number of observations (plots) for each species and soil type

Age	Drained soils				Periodically waterlogged soils			
	Birch	Black alder	Aspen	Grey alder	Birch	Black alder	Aspen	Grey alder
1-10	50	13	6	7	14	15	-	2
11-20	33	11	2	3	14	15	-	3
21-30	16	4	1	2	16	7	2	4
31-40	34	4	-	2	16	13	2	3
41-50	35	9	1	5	43	16	-	4
51-60	60	14	3	-	45	21	-	2
61-70	46	11	2	-	30	18	-	-
71-80	28	8	2	-	18	13	-	-
81-90	13	2	1	-	6	4	-	-

Results and Discussion

Carbon stock

The evaluated tree species exhibit differences in their carbon sequestration capacity (Table 2), as well as the required length of their rotation cycle. Carbon stock of all analyzed deciduous tree species have similar trend: carbon stock increases with increasing stand age (Figure 1). In some cases, high data variation of carbon stock for some tree species can be observed. This could be explained with small sample size in certain decade and differences in specific growing conditions, site index and management history.

Table 2

Average carbon stock (t C ha^{-1}) by decades

Age	Drained soils				Periodically waterlogged soils			
	Birch	Black alder	Aspen	Grey alder	Birch	Black alder	Aspen	Grey alder
1-10	1.09	2.69	1.72	0.28	0.53	2.83	-	2.02
11-20	18.45	16.66	6.72	21.36	13.18	16.68	-	3.22
21-30	36.10	24.90	-	57.19	31.56	42.23	46.06	31.55
31-40	69.63*	68.86	34.13	114.30	45.91*	48.11	50.11	53.50
41-50	80.72	86.26	102.46	56.21	69.63	73.48	-	59.14
51-60	87.49	105.77	127.58	-	69.58	98.12	-	20.33
61-70	106.47*	114.24	119.05	-	84.99*	129.41	-	-
71-80	106.57*	133.21	168.82	-	67.89*	116.49	-	-
81-90	94.10	139.80	199.95	-	68.19	126.70	-	-

* significant differences ($p<0.05$).

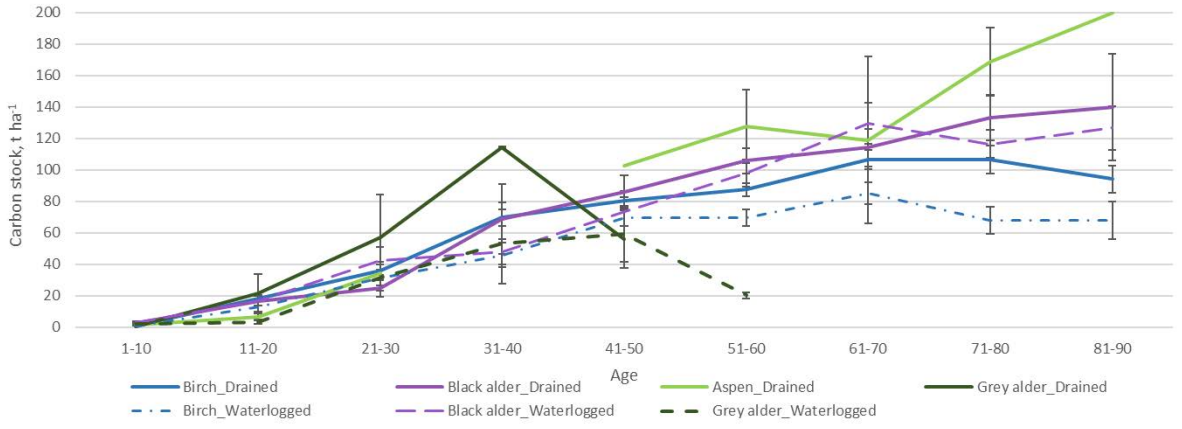

Figure 1. Average carbon stock of deciduous forest stands per decade in both soil types (whiskers denote ± standard error).

Drained soils

On drained organic soils, the carbon stock of grey alder forest stands reached its maximum by the age of 31–40 years, thus grey alder can potentially reach 114 ± 0.73 t C ha^{-1} (average ± standard error) in a 40-year rotation. However, after the fourth

decade, carbon accumulation in grey alder stands significantly decreases as the trees begin to decay due to biological factors (Arhipova *et al*., 2011), leading to emissions from dead wood (Köster *et al*., 2015). Indeed, to maximize carbon sequestration, it is advisable to cultivate grey alder stands for a period of up to four decades, subsequently harvesting them and initiating re-growth. This approach allows for efficient utilization of the grey alder resources while ensuring continuous and sustainable carbon sequestration over multiple growth cycles. (Rytter & Rytter, 2016). Hence, the carbon accumulation over two successive rotations is projected to reach 228 t C ha^{-1} by the eighth decade (Figure 2), aligning with the felling age of the other species, namely birch and black alder. At an age class of 61–70 years, the carbon storage capacity in stands of birch, aspen and black alder exhibit comparable levels, with birch accumulating 106 ± 6.18 t C ha^{-1}, followed by black alder at 114 ± 12.02 t C ha^{-1}, and then aspen at 119 ± 53.22 t C ha^{-1}. Notably, the carbon sequestration achieved by these tree species within the age of 61–70 years is comparable to that attained by grey alder within the age range of 31–40 years. Aspen and black alder continues to increase carbon stock even until the age of 81–90 years, achieving carbon stocks of 200 t C ha^{-1} and 140 ± 33.40 t C ha^{-1}, respectively. However, it is crucial to interpret aspen carbon stock estimates with caution due to potential overestimation caused by unregistered or unaccounted internal stem decay. This concern is particularly relevant for older stands, as internal decay becomes more common and its proportion often increases over time (Ķēniņa *et al*., 2022). Hence, an effective management strategy for aspen stands involves implementing shorter 40–50-year rotation cycles to optimize carbon sequestration and promote the substitution of fossil materials (Figure 2). Additionally, younger aspen trees are less prone to decay-related damage, reducing the risk of timber loss. Birch, however, displays a distinct pattern, with its maximum carbon stock (107 t C ha^{-1}) attained within the age range of 71–80 years, which goes along with the legislated age of final felling for birch. Furthermore, it is noteworthy that only birch stands exhibited a significant difference between the two soil types. Specifically, within the 4th, 7th, and 8th decades, significant variations were observed in the average carbon stock. This indicates that the soil type plays a significant role in influencing the carbon storage potential of birch stands during this specific time period.

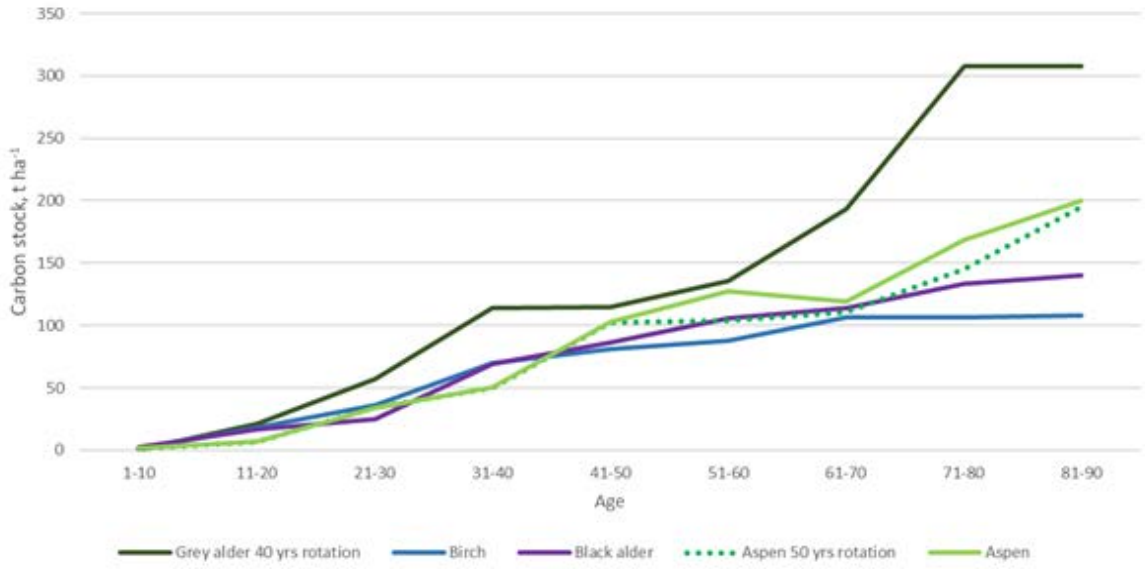

Figure 2. Total carbon stock of deciduous forest stands on drained organic soils within 90 years period. Comparison of two rotation cycles for grey alder and aspen with one rotation for birch and black alder.

Periodically waterlogged soils

The carbon stock of deciduous forest stands in periodically waterlogged organic soils exhibits a trend similar to that in drained organic soils. Black alder shows better growth and carbon accumulation potential in periodically waterlogged organic soils than in drained, and this could be explained with tree species biological traits to favour growth in wet conditions (Claessens *et al*., 2010). Among the tree species studied, black alder displays the best increase in carbon stock, reaching a maximum of 129 ± 13.10 t C ha^{-1} at the age of 61–70 years, followed by birch with a maximum carbon stock of 85 ± 6.95 t C ha^{-1} at the same age. Grey alder reaches a maximum carbon

stock value of 59 ± 17.71 t C ha^{-1} at the age of 41–50 years. However, all tree species exhibit a decline in carbon stock after reaching their respective maximum values. Periodically waterlogged organic soils are known to have a reduced carbon stock potential compared to drained organic soils, hence forest drainage is often regarded as a useful management practice for trees growing in forest types with organic soils. Similar findings have been reported by previous studies (Laurén *et al*., 2021; Lupikis & Lazdins, 2017; Maki, 2015; Zālītis, 2006; Zālītis *et al*., 2013), which have demonstrated the positive effect of drainage on tree growth. However, black alder is an exception to this trend by exhibiting comparable carbon accumulation potential in both periodically waterlogged and drained organic soils. Moreover, black alder demonstrates a faster growth rate during the early growth stage in periodically waterlogged organic soils, which makes it better suited for growing in wet conditions when compared to other deciduous tree species found in the region. Furthermore, it is worth noting that available data from the National Forest Inventory (NFI) regarding aspen stands growing on periodically waterlogged organic soils provides estimates specifically for the third and fourth decades. This pattern may be partially attributed to the fact that during the initial two decades, aspen often coexist with other species. However, as time progresses, aspen gradually outcompetes slower-growing trees, leading to its dominance in the subsequent decade.

Annual carbon sequestration

Average annual carbon sequestration was evaluated for the whole analyzed time period for both soil type groups (Figure 3). On average, the largest average annual carbon sequestration potential (1.43 ± 0.09 t C ha^{-1} yr^{-1}) can be observed for black alder in both soil types, followed by aspen in drained soils (1.34 ± 0.25 t C ha^{-1} yr^{-1}). Birch shows better carbon sequestration potential in drained soils compared to periodically waterlogged, 1.34 ± 0.05 t C ha^{-1} yr^{-1} and 1.16 ± 0.05 t C ha^{-1} yr^{-1}, respectively, and the difference is statistically significant ($p<0.05$). Grey alder shows the lowest carbon sequestration potential in drained soils and periodically waterlogged soils, 1.20 ± 0.31 t C ha^{-1} yr^{-1} and 0.94 ± 0.18 t C ha^{-1} yr^{-1}, respectively; however, the difference is insignificant. Lower average annual carbon sequestration for grey alder compared to other species could be explained with rapid decrease of carbon stock after the reached maximum due to wood decaying (Arhipova *et al*., 2011; Ryan *et al*., 1997).

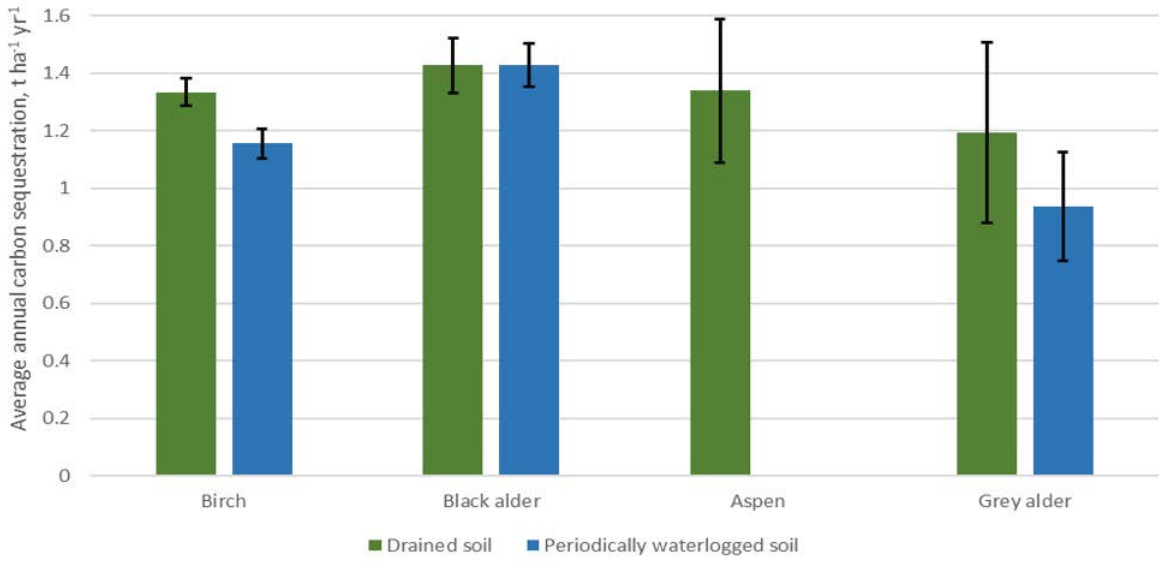

Figure 3. Average annual carbon sequestration for deciduous stands growing in drained and periodically waterlogged organic soils (whiskers denote ± standard error).

Linear model

A linear model was constructed to investigate the variables that influence carbon stock. The analysis of variance of the model revealed that several factors significantly affect carbon stock in the stands under investigation (Table 3). Specifically, soil type, dominant tree species, and stand age were identified as major determinants of carbon stock. The findings suggest that these factors play a crucial role in the ability of forest stands to store carbon, and thus, should be taken into consideration when developing forest management strategies aimed at maximizing carbon storage.

Conclusions

1. Carbon accumulation capacity in tree biomass

Table 3

Results of analysis of variance

Variable	Sum of squares	F-value	p-value
(Intercept)	1230	1.002	0.3124
Soil type	30611	25.427	<0.001
Tree species	29346	12.188	<0.001
Stand age	496497	412.410	<0.001

during one rotation cycle in deciduous stands is strongly influenced by soil conditions, selected tree species and rotation age.

2. Forest drainage is a useful silvicultural technique for boosting carbon sequestration in deciduous stands growing on organic soils, as evidenced by the higher average annual carbon sequestration in drained soils.
3. Regardless of the soil moisture regime, black alder is a viable tree species for growing on organic soils since it has an equivalent average yearly sequestration potential in both drained and periodically waterlogged soils.
4. Grey alder and aspen are fast growing tree species that can be managed in short rotation cycles on drained organic soils to maximize carbon sequestration and possibly substitution effect for fossil fuels.

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FLUE GAS ANALYSIS OF APPLE AND GREY ALDER WOOD PELLETS IN A MEAT SMOKEHOUSE CHAMBER

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Abstract
The use of the smoke released during the wood burning process to prepare food products is a centuries-long tradition, practically all over the world. However, during the combustion process, a group of compounds called polyaromatic hydrocarbons (PAHs) are formed in the flue gases, which are carcinogenic and condense during the smoking process and diffuse into the smoked food product. Therefore, permissible PAH norms have been set for food producers, which significantly complicate the use of wood. In the study, using a gas analyzer, we measured the flue gases released during the burning of specially made, apple and gray alder wood pellets, with and without enrichment of the supplied air with ozone. The use of ozone does not ensure a higher burning temperature of pellets, but it stabilizes it – temperature fluctuations are significantly wider using non-ozonated air (697 to 817 and 611 to 817 °C, respectively). The content of CO_2, CO, as well as CH_4 and N_2O increases significantly in apple wood flue gases using ozonated air, while CH_4 increases and N_2O decreases in gray alder smoke. Which generally indicates specific reactions with ozone during combustion. Comparing the flue gases released during the burning of apple and grey alder wood pellets, grey alder smoke contains significantly more N_2O and CO_2 than apple wood pellet flue gases. On the other hand, using ozonated air in the combustion process increases N_2O significantly in the flue gas of apple tree pellets compared to white alder.
Key words: ozone, smoking meat, polyaromatic hydrocarbons (PAHs).

Introduction

Apple and grey alder wood are used to produce smoked foods using traditional technologies (Stumpe & Viksna, 2009). However, during the smoking process on the surface products condensate and absorb polyaromatic hydrocarbons (PAHs) that are present in smoke, followed by the diffusion of PAHs within the product. PAH compounds are cancerogenic and in order to protect consumers, norms have been introduced that food manufacturers must fulfill. As a result, technologies were introduced into production that use different smoking liquids (liquid smoke) with different tastes and smells, or use short, intense periods of smoking. However, the problem is relevant both for manufacturers who stick to traditional technologies and for all home manufacturers. The PAH content of smoked foods depends on the humidity, burning temperature, oxygen concentration and air exchange fan rate of wood used in the smoking (Hitzel *et al*., 2013, Shkaljac *et al*., 2014).

Wood burning process is the oxidation of the organic part of the solid – conversion to combustion products of flue gas. The combustion theory states that the final products for the total combustion of wood are carbon dioxide (CO_2), water vapor H_2O, nitrous monoxide (NO), nitrous oxide (NO_2), which is also, of course, ash and mixed minerals of different origin, as well as metals: KCl, SO_2, HCl, Cu, Pb, etc., while wood is not completely burned in addition to Carbon monoxide (CO), CxHy, tar, soot, H_2, N_2O, polyaromatic hydrocarbons, etc. (Williams *et al*., 2012; Van Loo *et al*., 2008; Obernberger *et al*., 2006; Nussbaumer *et al*., 2003). This points to the importance of ensuring the complete burning of wood for smoked products, since the least of the compounds produced by PAHs are released. Only nitrogen compounds formed by the conversion of wood nitrogen to N_2 and nitrogen oxides (NO, NO_2) remain in practice (Williams *et al*., 2012; Van Loo *et al*., 2008).

In order to ensure the complete burning of wood, it is necessary to ensure burning temperature is above 850 °C and air supply (higher than the calculated consumption factor) and good gas mixing (Van Loo *et al*., 2008). The inflow of air into the combustion chamber shall be provided artificially by means of fans, providing continuous oxygen supply directly in the combustion area. However, wood burning at a high and uniform temperature is difficult to achieve, due to the heterogeneous properties of wood (wood density, moisture, etc.), which today is successfully solved by wood pelletizing. Studies have found that adding ozone is a promising method for improving and controlling burning processes. In recent decades, the impact of the addition of ozone on combustion processes has been widely studied, ranging from simple heating burners to internal combustion engines (Wenting *et al*., 2019). Ozone has demonstrated the ability to accelerate ignition and control the timing of the ignition, to improve the spread and stabilization of the flame, affecting emissions of flue gases and reducing the formation of certain pollutants (Docquier & Candel, 2002; Wenting *et al*., 2019). This

improvement is closely linked to ozone chemistry, particularly ozone decomposition, to obtain atomic oxygen and rapid exothermic ozonizes reactions with unsaturated hydrocarbons (Greene & Atkinson, 1992; Atkinson & Carter, 1984). Ozone decomposition at relatively low temperatures is responsible for most improvements in combustion achieved through O_3. Such reactions release reactive atom oxygen and accelerate the chain's branching process.

The aim of the study was to find out the composition of the flue gases released during the combustion process of grey alder and apple wood pellets in the chamber of the smokehouse, enriching the air supplied during the combustion process with and without ozone.

Materials and Methods

The wood pellets are made of apple and grey alder wood without bark, from each tree species of 6 ± 1 and 8 ± 1 mm in diameter, moisture content respectively apple 6.5 ± 0.3 and 6.9 ± 0.2, grey alder 6.2 ± 0.4 and 7.0 ± 0.2, length from 5 to 35 mm, mechanical strength ≥ 97.5%. The produced pellets corresponded to the quality indicators of class EN2 (ENplus Handbook).

Each wood pellet type depending on trees species and size were burned in an experimental furnace (Figure 1) in three repetitions, total 12 experiments. Each experiment started from 'cold' burning furnace. Pellets from the tank (volume 3 liters) were transferred to a combustion chamber with a thread-type rotating shill of 40 mm diameter, a rotation rate of 6 rotations per minute. The air supply in the combustion chamber was constant – provided with a fan (airflow 10 m^3 h^{-1}). In addition, the possibility of aerial enrichment with ozone is provided. We used 6 high-voltage discharge elements with a nominal capacity of 60 g h^{-1} to generate ozone. The ozone generators were queued in a stainless metal housing and paired. Respectively, each pair of ozone generators, worked in 15 second intervals to prevent them from overheating.

The flue gases released during the pellets burning were passed through the flue-canal into the experimental smoker. Flue gases have been measured in a meat smoking chamber (Figure 1) by pumping a flue gas through a special type of tube that is built into a door and ensures the absorption of flue gases from the middle of the chamber. Flue gas measurements were started when the temperature of the chamber reached a working temperature of ~ 90 ± 5 °C.

For the flue gas analysis, we used Gasmet DX4040. The calibration is made before starting the measurements and is valid for a maximum of 24 hours or until a sudden change in the temperature of the environment where gas analyzer is located. The gas used to perform the calibration is nitrogen 5.0. The analyzer is cleaned out of this gas until stable values are achieved, which is close to zero to be obtained for the gases to be analyzed. A measurement of the ambient air is carried out first in order to identify the starting level. For example, CO_2 should be around 400 ppm. If this is not the case, the smoking chamber must be ventilated. Probe installation. The probe is introduced into the chamber through the door close to the center of the chamber. The pipe connecting the probe to the analyzer passes through a cooling circuit in order to force the condensation of water vapor before entering the analyzer. The gas analyzer sample cell is sensitive to water and could be damaged.

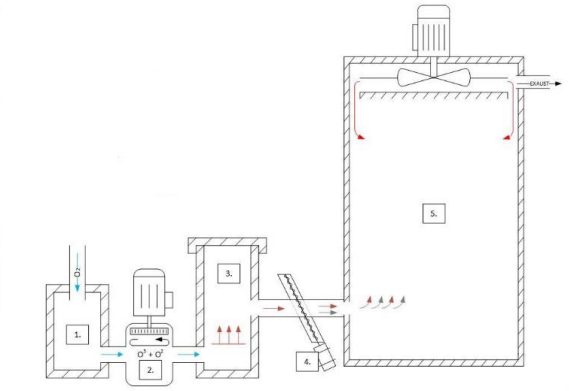

Figure 1. An experimental combustion chamber with a smokehouse. (1 ozone generator; 2 air flow fan; 3 burning camera; 4 additional smoke generator; 5 smokehouse chamber).

The analyzer pump is started in a continuous cycle to perform periodic measurements. The measurements were done every 120 seconds at least 30 minutes. The spectrum is recorded and interpreted in real time and checked in post processing.

Additional temperature measurements have been performed in the combustion chamber using temperature sensors of type pt100 in the smoking chamber. The estimated marginal means for the levels of significant effects were compared using the Tukey's HSD multiple comparison test. The data analysis was performed in R v. 4.1.2. (R Core Team, 2018).

Results and Discussion

The burning temperature of the apple and grey alder wood pellets did not differ significantly if in burning chamber supplies atmospheric air or enriching it with ozone (Table 1). However, the range of combustion temperature with O_3 enriched air is significantly shorter (697 to 817 and 611 to 817 °C, respectively) compared by using atmospheric air. On the other hand, the flue gases analyzed differed significantly. As a result of the introduction of ozonated air, significantly less CO_2, CH_4 and CO

were detected in the combustion gases, while N_2O differ depends on the tree species used to make the wood pellets (Table 1). Ozone reactions with fuel release of atomic oxygen resulting in an increase in chain reaction response rates at relatively low temperatures (Wenting *et al*., 2019), resulting in a rapid oxidation of released pyrolysis gases at higher initial temperatures, and consequently in differences in flue gas concentrations (Wenting *et al*., 2019).

As predicted, the different pellets diameter of the tree species did not significantly affect the composition of the smoke gases analyzed, so they were analyzed together. However, we observed significant differences in the composition of flue gases, depending on the tree species wood used in the manufacture of granules, which are directly related to differences in the chemical composition of apple and grey alder wood (Anderson *et al*., 2009; Cichy *et al*., 2018). A different pyrolysis gas composition is released during the combustion process for each tree species, which also affects reactions with O_3 and further differences in flue gas composition (Zandersons *et al*., 2009). By burning apple wood pellets, it releases significantly higher CO_2, CO, CH_4, N_2O, as well as water vapors are released by the use of ozonated air. On the other hand, when burning grey alder wood pellets with ozonated air, only CH_4 is released significantly more, but N_2O is reduced, while other gases did not differ significantly (Table 1). Long-term storage of grey alder wood is characterized by natural processes that reduce the amount of organic acids, found in wood during studies of pyrolysis processes (Zandersons *et al*., 2009). During the production of pellets, the most likely amount of organic acids in grey alder wood has decreased, which also explains only the increase in CH_4 in the flue gases.

On the other hand, when analyzing the differences in the composition of the flue gases between tree species, using shaded air during the combustion process, apple wood granules emit more N_2O and H_2O in the flue gases than grey alder pellets. Without the use of ozonated air in the combustion process, the opposite effect is that grey alder pellets emit more N_2O and CO_2 than apple-wood pellets. Which, in general, refers to differences in the wood chemical properties which have a significant impact on the composition of flue gases.

Table 1

Mean values of the analysed flue gases when burning apple and grey alder wood pellets, with and without enrichment of the air entering in the combustion chamber with ozone

Species	Air supply	Burning temperature, °C	Water vapour H_2O, ppm	Carbon dioxide CO_2, ppm	Carbon monoxide CO, ppm	Nitrous oxide N_2O, ppm	Methane CH_4, ppm
Apple	O_3	767±3.7	$1.14±0.02^{a}$	$11962±525^{a}$	$1376±61^{a}$	$0.47±0.11^{a}$	$49.6±3.2^{a}$
Grey alder	O_3	768±2.8	$1.09±0.04^{b}$	$11974±1351^{ab}$	$1396±256^{ab}$	$0.13±0.05^{b}$	$43.6±3.2^{ab}$
Apple	Air	766±3.9	$1.07±0.04^{bc}$	$6895±1325^{b}$	$1069±121^{b}$	$0.18±0.02^{b}$	$38.6±1.7^{bc}$
Grey alder	Air	771±4.1	$0.95±0.09^{c}$	$9891±1580^{c}$	$1121±219^{bd}$	$0.22±0.01^{c}$	$36.8±3.4^{c}$

a,b – different letters in superscript represent significant differences ($p<0.05$) between light treatments for a concrete morphological variable of a concrete clone according to Tukey's HSD test results. Numbers after plus-minus signs represent 95% confidence intervals.

Conclusions

1. Enrichment of the air supplied to the combustion chamber with O_3 did not affect the average burning temperature of apple and grey alder wood pellets. However, the use of O_3 ensures a smoother combustion process – smaller temperature fluctuations in the combustion chamber.
2. Using ozone-enriched air when burning apple wood pellets increases flue gases CO_2, CO, CH_4, N_2O, as well as water vapor than when burning them without ozone supply. On the other hand, when burning grey alder wood pellets with ozonated air, only CH_4 is emitted significantly more, while N_2O decreases.
3. When comparing between tree species, burning grey alder wood pellets released more CO_2 and N_2O in the flue gas than burning apple wood pellets, while the use of ozonated air in the

combustion process increased N_2O in the flue gas burning apple wood pellets.

4. By introducing ozonated air into the combustion chamber, it is possible to influence the combustion process, as a result of which the composition of flue gases changes significantly, but further practical research must be carried out in order to start the practical use of ozone.

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LONG TERM EFFECTS OF TOTAL BIOMASS HARVESTING ON UNDERSTORY VEGETATION AND TREE STAND IN NORWAY SPRUCE STANDS

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Abstract
Northern Europe will be one of the locations where the renewable energy from forests could displace fossil fuels as a result of climate change: therefore, it will become more crucial to maintain renewable materials that also collect CO_2. By taking tree biomass out of forest stands, we could create more renewable resources to use in practice, but this has certain negative effects on the forest ecology, including nitrogen leaching and vegetation degradation. The goal of the study is to investigate the effects of full biomass removal (FBR) in Norway spruce (*Picea abies* (L.) H. Karst.) forest stands and how this forest management affects vegetation regeneration, tree stock and carbon storage overall. The aforementioned structures were assessed at various forest ages. The central region of Latvia contains Norway spruce stands with all of the sample sites under study situated on drained peaty mineral soils and weakly aerated gleyic soils. As a result of the long-term evaluation, it was determined that the forest vegetation in FBR was similar to that in the same-age control stand (SAC) and that vegetation can successfully regenerate. The average tree height and DBH is lower in areas where stump removal and understory biomass was not carried out. Statistically significant ($p<0.05$) long-term influence of stump removal on the average height and diameter of Norway spruce can be identified in all parameters, except, tree height in *Myrtillosa mel*. forest type. Total biomass removal in long term has almost no significant effect on tree stand and vegetation regeneration.
Key words: picea abies, full biomass removal, long run, vegetation.

Introduction

Since forest ecosystem covers 65 million ha of the region, forestry is economically significant in Northern Europe. The two main tree species are Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) H. Karst.) (Thuresson, 2002). Climate change will enhance the need for this region to guarantee a sustainable supply of renewable materials in Europe (Hanewinkel *et al*., 2013). Northern Europe's forestry and forest industry are developed (Thuresson, 2002) and capable of meeting the rising demand brought on by the growth of the human population (Bologna & Aquino, 2020), increasing the share of forest area allotted for different purposes (Weiss *et al*., 2019), and aiming to sequester carbon in the products to slow down climate change (Pukkala, 2017). Climate change mitigation goals are constantly rising (Adams *et al*., 2015) and cannot be achieved alone by reducing emissions; sequestration, which is ensured by forests and wood products, is a crucial component to achieve these goals (Yousefpour *et al*., 2018). Increasing the use of logging residue (branches, tops, and stumps) to replace fossil fuels is one aspect of the approach (Ranius *et al*., 2018). This strategy has recently come under fire, in part because of its unknown long-term effects on the forest ecosystem (Walmsley & Godbold, 2010).

In comparison to the stem, which accounts for 69% of the overall tree biomass, the spruce's stump-root system accounts for about 17% of the biomass of the entire tree (Kaarakka *et al*., 2018). Nowadays, Finland is one of the few nations where whole-tree harvesting is used on a greater scale, along with Sweden and Norway to a lesser extent (Uri *et al*., 2015).

According to recent research, when compared to conventional forest management, the chemical composition and pH of the soil were not significantly altered by removing all tree biomass from the forest (Saarsalmi *et al*., 2010). Yet, even little changes in chemical composition can have an impact on the growth of ground cover since plants are typically sensitive to even small alterations, such as nutrient deficiencies (Haferkamp, 1988). The principal limiting factor of vegetation in boreal forests is nitrogen (N) (Haferkamp, 1988) which largely occurred in the soil and litter, notably in spruce and pine forests (Merilä *et al*., 2013). However, the main sources of nitrogen in the forest stand are theoretically gone when all the biomass has been taken out, which may have a negative impact on ground vegetation regrowth in more rich forest stands (Ring *et al*., 2017).

The majority of recent studies (Aosaar *et al*., 2020; Saarsalmi *et al*., 2010; Uri *et al*., 2015) have concentrated on the effects of increased biomass, mineral element composition, stump generation, and whole-tree harvesting on the spread of root rot (*Heterobasidion* sp.). It is unclear how this form of management would influence ground cover vegetation in the long-term, especially in drained spruce forests, because current research does not account for the long-term effect. One of the main obstacles in developing forestry and doing anything new is being aware of influence of this activity on biodiversity (Messier *et*

al., 2013). Moreover, the addition of biomass from the use of tree stumps in forest management may help to slow the rate of deforestation.

The study's aim is to evaluate the long-term effects of full biomass removal and stump harvesting on vegetation growth as well as the quantity of carbon and nitrogen stored in drained spruce forests and forest stocks.

We assume that ground cover vegetation can return to previous state based on earlier findings in Scots pine (Jansons *et al*., 2016), but there have been no investigations of the same nature for Norway spruce in various forest types.

Materials and Methods

The study site was in Norway spruce stands in the central region of Latvia, Kalsnava (56°42'6N, 24°50'22E, 113 m above sea level). According to National forest inventory data, 3.33% of Latvia's forests are *Myrtillosa mel*. forest type with drained mineral soils, and 0.95% are *Myrtilloso-sphagnosa* poorly aerated gleyic soil. Moderately rich soils can be found in *Myrtillosa mel*. and *Myrtilloso-sphagnosa*. (Liepa *et al*., 2014).

The national meteorological agency reported that the mean monthly temperature between January and July, respectively, ranged from -5 to +17.4 °C. The average annual rainfall was about 700 mm. The average number of days with snow cover is 112 days, with a depth of 26–42 cm, the primary wind directions are south and west, and the predominant vegetation period is between 190 and 192 days. Permanent frost occurs on November 15th (Nikodemus *et al*., 2018).

The study site's sampling plots were chosen based on information about specific management that was documented: in 1974, following a clear-cut, all above-ground biomass, stumps, and roots with upper soil layer (approximately 10 cm thick) were removed by a bulldozer, resulting in full biomass removal (FBR). Six FBR stands with the least amount of remaining woody biomass (roots) were created as a consequence. Young stand (five stands), control stand (SAC, nine stands), mature stand (six stands), and old stand (six stands) with ages of (11 years, 50 years, 100 years, and 130 years, respectively) were chosen as the comparative regions in the same forest types (Table 3).

All data were gathered 43 years after FBR in July 2017. A total of 38 transects, each measuring 50 meters, were used to evaluate the vegetation. They were all laid out in a North-South orientation and put within stands that were at least 15 m from the boundaries. We established 17 sampling plots (for a total of 646) with a two-meter spacing and a size of 1 m x 1 m on each transect to visually analyze the ground vegetation. The relative percentage of each plot's ground cover species was calculated, and the vegetation was divided into layers of moss and lichen, vascular plants and dwarf shrubs. Moreover, bare soil and tree seedlings were addressed.

The sample plots were divided into nine sample plots in FBR and SAC stands with a radius of 12.62 m, and their area is 500 m^2. Tree data (height and DBH) were taken on transects where vegetation data had already been collected. The following variables were calculated for each tree whose diameter at 1.3 m exceeded 6 cm: the distance from the plot's center, the species, the diameter at 1.3 m, and the height of the tree.

Moreover, soil samples (100 cm^3) were taken at depths of 0–10 cm, 10–20 cm, 20–40 cm, and 40–80 cm, as well as one litter sample (10*10 cm), roughly in the midpoint of each FBR and SAC transect. These samples were taken in order to better understand the differences in soil composition between FBR and SAC stands. The samples were delivered to the laboratory at LSFRI 'Silava', where they underwent analysis. We utilized the elemental analysis method proposed by (LVS ISO 10694:2006, n.d.) to calculate the total amount of carbon in the soil.

Each stand's mean relative cover of each species was computed. The Shannon-Wiener (H′) index (Shannon, 1948) was used to describe species diversity. (Spellerberg & Fedor, 2003). With the software R 3.4.2, the Shannon-Wiener indices among a set of stands were statistically compared using the analysis of variance at the significance level of α=0.05 (R Core Team, 2020). The Analysis of Similarities (ANOSIM) was used to statistically compare the composition of vegetation between all stands in one forest type. The R package 'vegan' (Oksanen *et al*., 2013) was used for both studies. The ANOSIM analysis produced two values: the p-value and the R-value, which ranged from 0 to 1 (Clarke, 1993). Calculations were made for the tree stand's average diameter, average height, basal area. A t-test was used to check whether stand parameters were statistically different. Characterize Elemental analysis is used to calculate the overall amount of carbon in a forest stand, with conifers and deciduous trees having average carbon values of 50.8% and 48.8%, respectively. The formula for Elemental analysis was from Thomas & Martin, 2012 publication.

Results and Discussion

When comparing the same forest type's FBR and SCA stands, there was no discernible difference in species diversity; nevertheless, species diversity was noticeably and significantly higher on drained soil (Shannon-Wiener indices of 3.2 and 2.2, respectively) than on wet soil (1.1 and 1, respectively). The young stand had the highest index (1.5) in *Myrtillosa-*

sphagnosa, which was significantly different from the FBR and SAC stands. The *Myrtillosa mel*. stand had the highest overall indices (Table 1). Forest stands undergo a rapid change in growth circumstances after clear-cutting. Clear-cutting reduces the number of species. However, as the forest regenerates over time, the former species reappear (Priedītis, 1999). The presence of bare soil in the forest also promotes seed sowing (Smythe, 1970), but as shade and moisture levels rise, many species become unable to thrive, lowering the Shannon-Wiener index (Ellenberg, 1988).

Table 1

Shannon-Wiener diversity indices in the study area of Myrtillosa mel. and Myrtilloso-sphagnosa Equal letters (abcd) in one forest type means that there is no significant difference

FBR[1]	SAC[2]	Young stand	Mature stand	Old stand	
3.4^{ac}	3.19^{cd}	3.16^{ab}	3.12^{b}	2.18^{d}	*Myrtillosa mel.*
1.11^{ac}	1.02^{a}	1.53^{b}	1.03^{a}	1.36^{bc}	*Myrtilloso-sphagnosa*

[1]. FBR – Full biomass removal stand, [2].SAC – Same age control stand.

Table 2

The ANOSIM results between FBR and control stands in both forest types

	SAC[2]	Young stand	Mature Stand	Old stand	Forest Type
FBR[1]	0.03	0.07	0.15	0.38	*Myrtillosa mel.*
FBR[1]	0.11	0.56	0.35	0.47	*Myrtilloso-sphagnosa*

[1]. FBR – Full biomass removal stand, [2].SAC – Same age control stand.

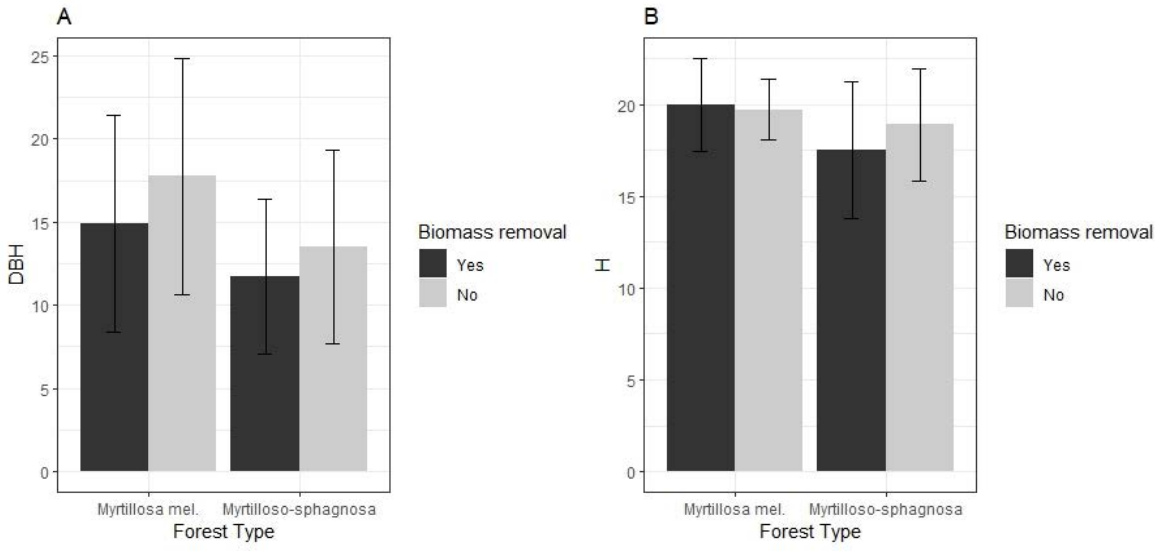

Figure 1. A mean DBH (cm) between biomass removal and conventional harvesting in both forest types. B mean tree height (m) between biomass removal and conventional harvesting in both forest types (in both pictures A and B error bars show standard deviation).

The ground vegetation of FBR stands in *Myrtillosa mel*. was most comparable to that of SAC and young stands (ANOSIM, R=0.07 and R=0.03, respectively). The same pattern was also seen in the *Myrtilloso-sphagnosa* forest type, where the FBR and SAC stand had the highest resemblance (R=0.11) (Table 2). Although FBR management and clear-cutting are different, the difference is not substantial (Berķis *et al*., 2013; Liepa *et al*., 2014; Olsson & Staaf, 1995). This resemblance between FBR and SAC stands is mostly due to the strong shade provided by spruce forests, which inhibits the growth of species that cannot tolerate shade (Huston, 1994). There were no significant differences on soil carbon (P>0.05) between FBR and SAC stands in *Myrtillosa mel.* (respectively, 90 g kg^{-1} and 111 g kg^{-1}) and *Myrtilloso-sphagnosa* (respectively, 95 g kg^{-1} and 86 g kg^{-1}) forest types when the total quantity of carbon (C) in the soil (80 cm) was examined. As there is also a significant difference amount of C between SAC stands in the two forest types, this type of management is likely to result in CO_2 emissions that do not have a positive effect on climate change in the current situation and should be followed by low-emission management practices (DeLuca & Boisvenue, 2012). Moreover, indications for soil density also indicated a detrimental effect; specifically, higher soil density causes lower C levels in the soil (Lazdiņš, 2012). The average diameter of the SAC stand in the *Myrtillosa mel*. forest type is 2.86 cm or 16%, greater than the FBR stand, which is statistically significant (P<0.05) from each other. The average diameter of the SAC stand in the *Myrtilloso-sphagnosa* forest type is 1.77 cm or 13%, greater than the FBR stand, which is statistically different (P<0.05) from each other (Figure 1). According to a Swedish study, which indicates a considerable difference in DBH between standard clearcutting and removal of all biomass, a stand might be significantly limited in growth by the removal of all biomass (Egnell, 2011).

Table 3

Stand type, composition, age and number of transects in both forest types of newest information

Forest Type	Type	Stand compostition	Age	Stand	Transects
Myrtillosa mel.	FBR[1]	10E	49	111-14	1
	FBR[1]	10E	49	111-15	4
	FBR[1]	10E	35	112-10	2
	SAC[2]	10E	41	108-13	1
	SAC[2]	10E	52	108-19	1
	SAC[2]	9E1B	49	112-12	1
	SAC[2]	10E	40	113-9	1
	SAC[2]	10E	34	121-9	2
	SAC[2]	10E	33	129-20	1
	Young stand	8E2P	24	156-9	1
	Young stand	7E3B	25	192-6	1
	Mature stand	7E2P1B	114	128-6	1
	Mature stand	8E1B1P	118	153-6	1
	Old stand	6E2P1A1B	144	28-35	1
	Old stand	7E3P	138	282-5	1
Myrtilloso-sphagnosa	FBR[1]	10E	50	66-3	1
	FBR[1]	10E	50	66-6	1
	SAC[2]	10E	49	61-15	1
	SAC[2]	10E	50	93-22	1
	Young stand	7E3A	26	72-2	1
	Young stand	9E1B	24	108-14	1
	Mature stand	9E1B	105	289-10	1
	Mature stand	10E	112	260-3	1
	Old stand	7E2A1B	154	247-8	1
	Old stand	10E	156	275-33	1

[1]. FBR – Full biomass removal stand, [2].SAC – Same age control stand.

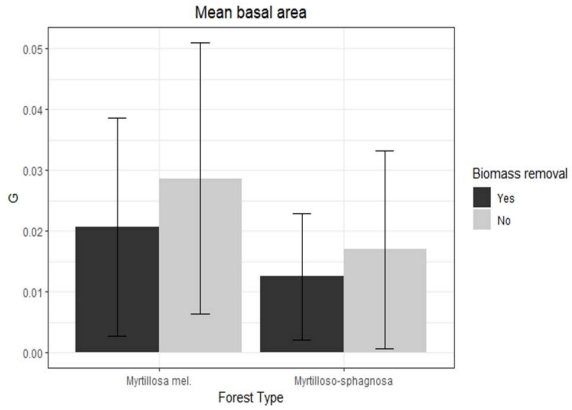

Figure 2. Mean basal area (G) between biomass removal and conventional harvesting in both forest types.

The SAC stand is 0.27 m or 2% lower than the FBR stand in the *Myrtillosa mel*. forest type, which is not statistically different (P>0.05) from each other. The SAC stand is 1.37 m or 6% higher than the FBR stand in the *Myrtilloso-sphagnosa* forest type, which is statistically different (P<0.05) from each other. According to a Finnish study, the removal of all biomass, which is what we observed in the *Myrtillosa mel*. stand in our study, may not have an impact on the growth of trees height (Kaarakka *et al*., 2014), while the removal of all biomass causes a greater deficit of nutrients in the *Myrtilloso-sphagnosa* stand (Egnell, 2011).

The basal area of the SAC stand is 0.0079 m^2 or 28% larger than the FBR stand in the *Myrtillosa mel.* forest type, which is statistically significant (P<0.05) from each other. The basal area of the SAC stand is 1.37 m, or 6%, larger than the FBR stand in the *Myrtilloso-sphagnosa* forest type, which is statistically different from each other (P<0.05) (Figure 2). Because there are no organic materials left in the forest stand from the previous stand after the removal of the whole biomass, the basal area of the trees might be reduced, which is impacted by the lack of minerals (Egnell, 2011; Sterba, 1988).

Conclusions

1. FBR stands were the most comparable to SAC stands among all the studied forest types in terms of the understory flora.
2. Between FBR and SAC stands, there was no statistically significant difference in soil carbon.
3. After all biomass is eliminated, tree stand DBH, height, and basal area have a considerable negative impact.
4. As a result of the long-term evaluation, it was determined that the forest vegetation in FBR was similar to that in the same-age control stand (SAC) and that vegetation can successfully regenerate.

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WEATHER SENSITIVITY OF RADIAL INCREMENT OF PINUS STROBUS IN AN EXPERIMENTAL PLANTATION IN THE WESTERN PART OF LATVIA

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Abstract
The phenomenon of global climate change holds utmost importance in its impact on forest ecosystems. To mitigate the effects of this phenomenon, several European countries have introduced non-native tree species into their forests. However, comprehensive ecological analysis is needed to assess the suitability of these non-native species. Pinus strobus is often considered a potential substitute for native species. Tree-ring analysis is a useful methodology for evaluating the relationship between tree growth and meteorological conditions, given the significant impact of these conditions on tree development. In this study, 25 core samples were collected from an experimental plantation of Pinus strobus located in the western part of Latvia for analysis. The plasticity of the tree-ring width of Pinus strobus was evaluated using a multiple additive regression model. The analysis revealed that the previous summer precipitation was a significant factor, indicating the drought sensitivity of the increment. Additionally, the temperature in the previous July and August was also found to be a significant meteorological parameter, suggesting some trade-offs between growth and the formation of nutrient reserves. The estimated growth responses suggest that the radial increment of Pinus strobus growing outside its native range is highly weather-sensitive, implying uncertainty in its growth with anticipated climatic changes. These findings emphasize the need for further ecological analysis to determine the suitability of non-native tree species and their ability to withstand the climatic changes.
Key words: climate-growth relationships, growth response, introduced trees, white pine.

Introduction

Global climate change is of paramount importance in the current environmental landscape, and its ramifications are already being experienced worldwide (Allen *et al*., 2015). Occurrences of severe weather events are occurring more frequently and with greater intensity (You & Wang, 2021). These effects can be exacerbated by increased damage caused by insect infestations and wildfires (Spathelf *et al*., 2014). The increased temperatures linked to global warming are predicted to cause a lengthened growing season, which is expected to benefit the growth of plants; therefore, it is likely to affect forests (Kirilenko *et al*., 2007). Although the rate of species migration due to climate change can be much more rapid than in the past (Clark, 1998), their rates of migration may still be too slow to adjust to the speed of climate change (Aitken *et al*., 2013).

Many European countries are introducing non-native tree species into their forests as a strategy for reducing the effects of climate change (Santopuoli *et al*., 2019). However, the presence of non-native species presents both opportunities and potential risks (Ricciardi *et al*., 2009). On the one hand, they enhance productivity and biodiversity, yet on the other hand, certain species might become invasive (Felton *et al*., 2013). While non-native species may not hold the same cultural and historical significance as native species, they can serve as viable replacements in situations where the benefits are clearly evident (Schlaepfer *et al*., 2011). To assess the suitability of non-native species in a particular habitat, a comprehensive ecological analysis is necessary (Keča *et al*., 2019). Retrospective analysis of tree increment is an important method for evaluating the sensitivity and adaptability of trees to various biotic and abiotic factors (Speer, 2011).

Pinus strobus is among the tree species that are frequently introduced in Central Europe (Pötzelsberger *et al*., 2020), which is widely distributed in its native range of North America (van Arsdel, 1961). *Pinus strobus* has been noted for its adaptation to hot and dry temperate climates (Davis, 1983) and rapid growth and long life expectancy (Hepp *et al*., 2015; Klisz *et al*., 2022). It typically occurs in multiple forest types, particularly in areas with sandy soils that are moderately to poorly fertile and well-drained (Abrams, 2001). The rate of growth for this species exceeds that of other pines and hardwoods, with increment culminating between 10–20 years of age (Burns *et al*., 1990), yet exhibits a relatively low shade tolerance when young (Abrams, 2001). Although in its secondary distribution range *Pinus strobus* shows low productivity as a result of its sensitivity to global warming and drought (Klisz *et al*., 2022; Podrázský *et al*., 2020). *Pinus strobus* is of significant economic value, providing lumber, paper, and various wood products and its conical form and aesthetic appeal make it a favoured choice for landscaping (Krumm *et al*., 2016).

Given the broad introduction of *Pinus strobus* in Europe because of its ecological adaptability (Krumm *et al*., 2016), the current study aimed to evaluate the species sensitivity and growth potential to meteorological conditions when grown outside its native range in a hemiboreal stand (plantation). The study hypothesized that summer precipitation may constrain the growth of *Pinus strobus*.

Materials and Methods

An experimental plantation (1.13 ha) of *Pinus strobus* situated in western Latvia within the hemiboreal forest zone of the Eastern Baltic region 57.24°N; 22.63°E) was studied. The plantation was established around 1900, yet seed origin is unknown, but likely to be from Northern Germany. The initial spacing of the plantation was 4x4m. To our knowledge, the plantation has not been fenced. Edaphic conditions can be considered mesotrophic, the soil was silty and free draining. Around the year 1950, the plantation was supplemented by planting containerized seedlings of local origin. Natural admixture of Norway spruce (*Pinus sylvestris*), silver birch (*Betula pendula),* silver fir (*Abies alba*), and pedunculate oak (*Quercus robur*) was observed. The diameter and height measurements for the sampled *Pinus strobus* trees had an average value of 41.5 ± 12.7 cm and 25.0 ± 3.1 m respectively.

The studied site's climate can be categorized as moist-continental with coastal features (Kottek *et al*., 2006) Across the months, the average temperature fluctuated between -2.2 ± 3.0 °C in February to +17.6 ± 1.6 °C in July. The mean annual temperature from 1992 to 2021 was +7.1 ± 0.7 °C, mean temperature for summer months (June–August) 16.5 ± 1.5 °C. The mean annual precipitation was 664 ± 78 mm, and the summer months had the greatest monthly precipitation, with an average of 72 ± 28 mm. The average number of days with rainfall during the summer months was 12.4 ± 2 and minimum eight days with precipitation. Meteorological data were obtained from CRU for grid points situated within a 35 km radius of the location being investigated (Harris *et al*., 2020).

The trial inventory and sample collection were conducted in March 2020. Pressler's increment corer was used to collect two cores from opposing directions from the stem of each tree; 25 dominant healthy trees were cored in total. After drying, the cores were placed onto wooden mounts and sanded. LINTAB6 was used to measure the width of the tree rings (0.01mm precision) (RinnTech, Heidelberg, Germany). Using the COFECHA tool, tree-ring width (TRW) time series were cross-dated using a combination of graphical and statistical methods (Grissino-Mayer, 2001). Variability in tree-ring width (TRW) series was characterized using the r-bar, expressed population signal (EPS), mean sensitivity (SENS), first-order autocorrelation (AC1), and signal-to-noise ratio (SNR), which were estimated from detrended data (Wigley *et al*., 1984). The data was detrended using both a negative exponential curve and a cubic spline (20 years rigidity, 0.5 cut-off frequency). First order autoregressive model ('AR1') was used in the detrended series to eliminate autocorrelation (von Arx *et al*., 2017), creating a prewhitened dataset. The common period 1970–2020 was analyzed.

A principal component analysis was carried out to assess the differences in radial growth patterns (Buras *et al*., 2018). The prewhitened dataset was used for the analysis. The residual chronology was derived by utilizing a preprocessed dataset that had been prewhitened, and then applying a statistical method known as a bi-weight robust mean (Bunn, 2008). The study aimed to determine the association between the residual chronology of tree-ring width and different meteorological factors. To achieve this objective, a non-parametric, stationary bootstrapped Pearson correlation analysis was performed (Zang & Biondi, 2013). The climatic variables that were examined were the mean monthly temperature, the total amount of precipitation, and the standardized evapotranspiration index (SPEI) (Vincente-Serrano *et al*., 2010).

The set of meteorological variables influencing the radial increment of trees was evaluated using multiple additive regression (mixed model) (Wood, 2011). Such a model was used as it allows the evaluation of non-linear responses of growth under a temporal climatic gradient (Wood, 2011). Pre-whitened tree-ring width data series of trees were used as the response. Arbitrary groups of the best meteorological predictors (fixed effects) were selected based on the Akaike Information Criterion. To evaluate the possibility of collinearity among the predictors, the variance inflation factor was used. As crossed random intercepts, tree and year were considered random effects. Diagnostic plots were used to examine the homogeneity and normality of the model residuals. The statistical analysis was performed using R version 4.1.3 (R Core Team, 2022).

Results and Discussion

From 25 selected trees, the cross-dating of 22 trees spanning the period 1970–2020 was successful. Evaluation of this dataset by the expressed population signal (EPS) yielded values of 0.90 or higher for both periods, surpassing 0.85 (Wigley et al. 1984) (Table 1), implying explicit environmental forcing of increment. This was supported by the signal-to-noise ratio (SNR), which was intermediate (17.67). Similar growth patterns between trees (Figure 2) were detected and

mean sensitivity (SENS) of interannual variation of tree-ring width was intermediate (Speer, 2011). The correlation between the current growth and previous growth, as indicated by the first order autocorrelation, was moderate, and lower in comparison to Scots pine (Matisons *et al*., 2021).

Table 1

Descriptive analysis of cross-dated tree-ring width time series for Pinus strobus

Time period	Radial growth (mm/100)				SENS	AC1	r-bar	EPS	SNR
	Max	Min	Mean	SD					
1907–2020	857	14	265.19	127.9	0.24	0.51	0.419	0.909	10.03
1970–2020	857	16	265.19	121.1	0.25	0.48	0.446	0.946	17.67

SENS – mean sensitivity; AC1 – first order autocorrelation; r-bar – mean interseries correlation; EPS – expressed population signal; SNR – signal to noise ratio; SD – standard deviation; Maximal, Minimal, Mean tree-ring width.

The mean tree-ring width time series exhibited similar tendencies with several signature years coinciding among trees. The studied trees showed a decrease in radial growth till 1948 when a growth peak occurred (Figure 1A). Negative signature years coincided with cold and fluctuating temperatures in the early part of the year, as well as warm and dry summers (1970, 1976, 1984, 2004, 2007, and 2014), indicating that trees under marginal conditions (e.g., outside native range) have not been adapted to climate fluctuations and do not take advantage of favorable conditions when available (Allen *et al*., 2015). The presence of positive signature years was noted in 1975, 1996, and 2012, and were concurrent with warm spring, indicating early commencement is beneficial for growth (Chhin *et al*., 2018).

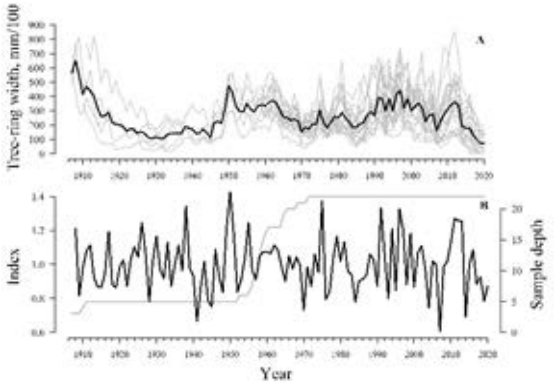

Figure 1. *Pinus strobus* tree-ring width time series: mean time series (A) and residual chronology (B) with sample depth (gray line).

The detrended time series of tree-ring widths revealed two principal components, which accounted for 51.42% of the variation (Figure 2). No distinct grouping was evident, suggesting a continuous gradient of responses with no obvious divergence despite the differences in the age of trees. Thus, a single chronology was built to portray the high-frequency patterns of variation.

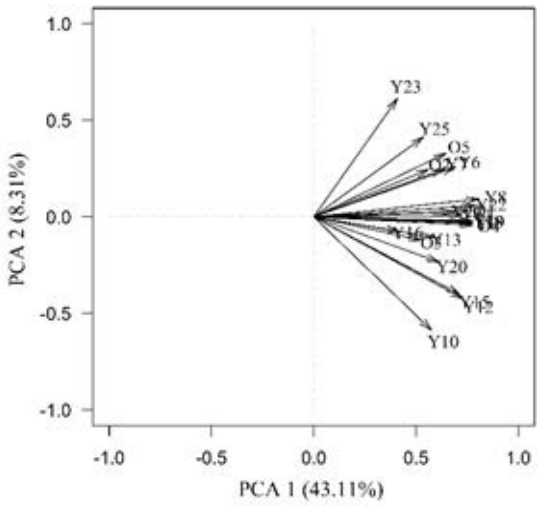

Figure 2. The loadings of the principal components of detrended *Pinus strobus* tree-ring width time series for the 1970–2020 period. The numbers in parentheses indicate the percentage of variance explained by each component.

The developed tree-ring width chronology demonstrated a correlation with 12 of the examined meteorological factors, with a particular emphasis on the temperature and precipitation levels of the preceding summer (Figure 3). The strongest positive correlations were observed with SPEI of the previous July and August, followed by the precipitation of the previous June and July, indicating drought sensitivity of increment (Chhin *et al*., 2018; Marchand *et al*., 2012). Similarly, summer precipitation significance in the current year was highlighted in Estonia and *Pinus strobus* native range (Chhin *et al*., 2018; Läänelaid

et al., 2019; Marchand *et al*., 2012). Conversely, statistically significant negative correlations were observed with the temperature of the previous July and August (Figure 3). As temperature increases in late summer, a shift in the allocation of nutrients towards the formation of generative buds occurs, resulting in decreased growth in the vegetative effort (Hacket-Pain *et al*., 2018).

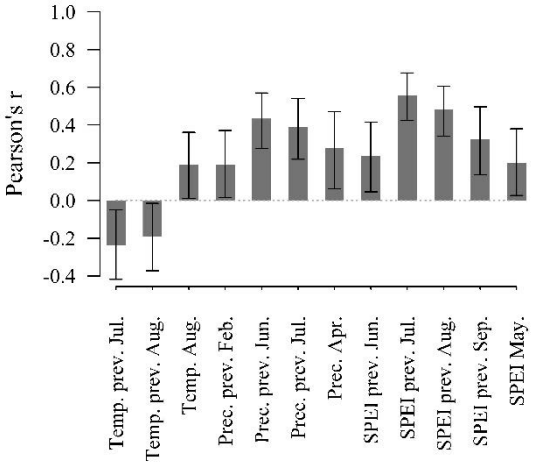

Figure 3. Statistically significant bootstrapped Pearson correlation coefficients (with confidence intervals) between residual chronology of tree-ring and meteorological variables for time period: 1970–2020.

A set of 10 meteorological factors were identified as the primary factors contributing to the high-frequency variations in tree-ring width, accounting for 32% of the overall variation (Table 2). SPEI in the previous July was estimated as the main limiting effect (the highest F-value), followed by precipitation previous February and SPEI in the previous June, indicating principle sensitivity to drought. All of the significant variables were estimated with quadratic or cubic effects on tree-ring width (Figure 4), implying that the studied temporal climatic gradient has been comparable to that genotypes have adapted (Wilmking *et al*., 2020). This suggests high climatic sensitivity of the species outside its native range. However, the findings also indicated the flexibility of the relationship between weather patterns and tree growth (Matisons *et al*., 2021). SPEI in the previous July (Figure 4G), which had the most significant effect was estimated to cause a response with an explicit threshold (SPEI=0.0), indicating drought sensitivity of growth (Harvey *et al*., 2020). Moisture balance in May (Figure 4H), when rapid cell expansion occurs increasing water demand (Muller *et al*., 2011), had a sigmoid response, indicating a positive effect of excessive moisture availability. Contrastingly, SPEI of the previous June (Figure 4F) was estimated with a sigmoid response with local maxima and minima around 0.7 and -0.7, respectively. This probably indicates relationships with the amount of solar radiation, as the water table most likely is still high (Strand *et al*., 2006). The influence of precipitation during the preceding February (Figure 4E) was generally positive (except in low snow conditions), possibly associated with the insulating characteristics of the snow layer (prevention of cold temperature caused root injury) as well as the replenishment of the water table in spring (Chhin *et al*., 2018; Tierney *et al*., 2001). The reactions to temperature during the preceding June and July (Figure 4A; 4B) indicated an optimum for radial growth of approximately 14–17 °C, as indicated by the response curves, suggesting a balance between adequate xylogenesis and drought conditions (Muller *et al*., 2011). Additionally, a positive effect was estimated for temperature in the previous July exceeding 18 °C (Figure 4B). This could potentially be associated with an elevated level of solar radiation (Strand et al., 2006). The temperature in August had both immediate and lasting impacts on

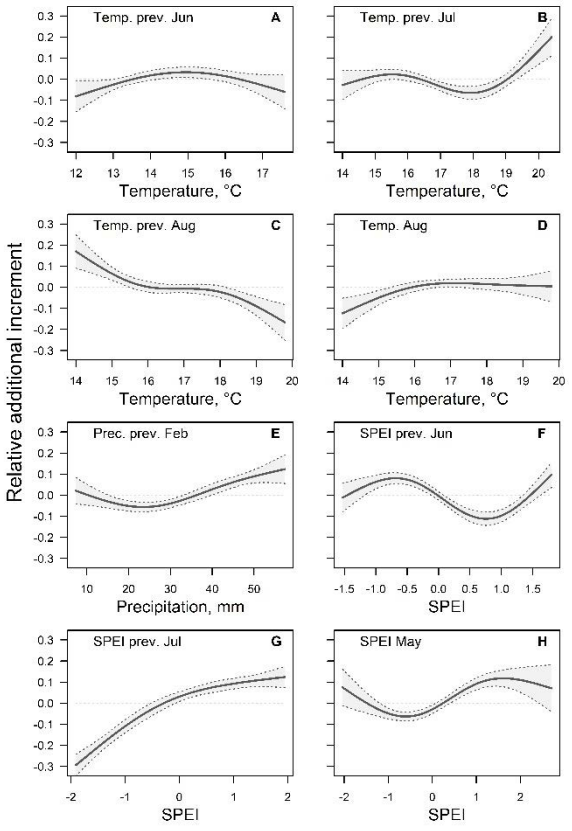

Figure 4. Smoothing spline estimates with 95% confidence intervals of tree-ring width response to meteorological variables (1970–2020) of Pinus strobus.

growth, yet the responses were contrasting (Figure 4D). The temperature in the preceding August had a mostly unfavourable impact (Figure 4C), with an interval of irresponsiveness of 16–18 °C, implying some trade-offs between growth and formation of nutrient reserves. In contrast, low temperatures in current August (<16 °C) had a positive effect, which might be related to the initiation of cold hardening (Beck *et al*., 2004).

Table 2

Smoothing Spline statistics from Generalized Additive Mixed Model for Pinus strobus tree-ring width and meteorological variables, 1970-2020

Fixed effects			
Smoothening term	Effective degree of freedom	F-value	p-value
Temperature in previous June	2.35	2.79	0.034
Temperature in previous July	2.88	8.62	<0.001
Temperature in previous August	2.66	9.55	<0.001
Temperature in August	2.42	5.63	0.006
Precipitation in previous February	2.66	20.70	<0.001
SPEI in previous June	2.94	17.37	<0.001
SPEI in previous July	2.53	62.66	<0.001
SPEI in May	2.89	14.95	<0.001
Random effects			
Groups	Standard deviation		
Year	<0.001		
Tree	<0.001		
Residual	0.22		

The estimated responses imply that the radial increment of *Pinus strobus* growing outside the native range is highly weather sensitive, suggesting that uncertainty of its growth would increase with anticipated climatic changes. This contradicts with extended ecological plasticity of the species, compared to native populations (Brier *et al*., 2020), likely as narrowly specialized genotypes (provenance) have been studied. Nevertheless, the plasticity and genetic adaptation of the responses indicate the adaptability of the species to a broader climatic gradient, particularly if enhanced by breeding (Burns *et al*., 1990).

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A REVIEW: ALTERNATIVES TO SUBSTITUTE FRUCTOSE IN FOOD PRODUCTS FOR PATIENTS WITH DIABETES

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Abstract
Diabetes is a metabolic disease whose prevalence in the world is increasing every year. To improve the life quality of diabetes patients and achieve better treatment results, adjusted food products with lower carbohydrate quantities are necessary. Primarily fructose is used in products for diabetes patients, but fructose increases obesity risk. The aim of the study is to evaluate available scientific articles on potential natural sweeteners for the substitution of fructose in food products for people with diabetes. Natural sweeteners could be a good alternative to fructose, they decrease product glycemic index and positively influence the health of diabetes patients. Stevia is a plant used in food production for obtaining sweet taste. Glycosides extracted from stevia are food additives, i.e. sweeteners. Stevia decreases sugar levels and improves insulin secretion, it has antibacterial and antioxidative features. The use of stevia in food production causes a bitter aftertaste of products. To disguise the bitter aftertaste, other natural sweeteners are added to stevia. Thaumatin is a sweet protein used in food production. To improve product taste, polyols and other natural sweeteners are added. Polyols are a good alternative for fructose substitution because they slightly influence sugar levels in the blood and they have high chemical thermal stability. Products containing different combinations of several natural sweeteners possess the best sensory features. The research results show that stevioside, rebaudioside, thaumatin, and polyols are good alternatives for fructose substitution in products. To clarify how sweeteners, influence food product features additional researches are necessary.
Key words: stevia, steviol glycosides, thaumatin, polyols, diabetes.

Introduction

Diabetes is a metabolic disease that, if not treated, is characterised by increased sugar levels in the blood. The disease is also characterised by insulin secretion or insulin activity distortion resulting in carbohydrate, fat, and protein metabolism dysfunction (Adler *et al*., 2021). Diabetes prevalence in the world is growing every year. In 2021 in the age group from 20 up to 79 years, 537 million people were suffering from diabetes which constitutes 10.5% of the total adult population in this age group (*IDF Diabetes Atlas 10th Edition*, n.d.). For diabetes patients having obesity, increased blood pressure, continuously increased sugar level in the blood, and increased cholesterol level, the risk of heart and blood vessel diseases is considerably higher (Elek & Bíró, 2021). The development of obesity is influenced by genetic factors, age, physical activities, and eating habits (Ling & Rönn, 2019).

In food production, glucose and sucrose are substituted by fructose to decrease the glycemic index. Fructose is a natural sugar found in many fruits. An equal quantity of fructose is sweeter than one of glucose and sucrose *(Taskinen et al*., 2019). Fructose metabolism takes a longer time and only part of fructose is turned to glucose. Fructose does not increase the sugar level in the blood as much as the same quantity of glucose does (Teff *et al*., 2004). Diet enriched with fructose facilitates fat acid synthesis in livers and fosters accumulation of triglycerides. (Muriel *et al*., 2021). In the Netherlands, in 2016 the systematic report stated that the substitution of carbohydrates needed for energy does not affect insulin concentration in the system measured on empty stomach. Keeping the same consumed fructose quantity, the tendency to increase insulin concentration measured on empty stomach has been observed for people with excessive weight or obesity (Ter Horst *et al*., 2016). Increased fructose consumption has negative side effects. The main fructose metabolism routes are the ones that provide turning to glucose and lipids. Therefore, exorbitant fructose intake increases fructose concentration in the port that stimulates endogenous glucose production and lipid synthesis in the liver which is connected with metabolic syndrome, alcohol-free fatty liver disease, obesity, and type 2 diabetes (Merino *et al*., 2020). In the major fructose metabolic processes, different cardio- and metabolic risk factors can be caused in the tissues, including the small intestine, liver, and kidneys. They are steatosis, hypertriglyceridemia, increased obesity, and increased blood pressure (Hannou *et al*., 2018). Fructose sweetening effect is two times higher than that of glucose. For people, it can be the reason for higher craving for fructose-containing alcohol-free drinks (Mai & Yan, 2019).

Taking into account the aforementioned, the aim of the study is to evaluate available scientific articles on potential natural sweeteners and their technological properties for substitution of fructose in food products for people with diabetes.

Materials and Methods

The research was performed using the monographic method to review the most suitable alternatives of sweeteners aimed at the substitution of fructose. The information was searched in *Science*

Direct, *Scopus,* and *Google Scholar* for original studies and reviews published in English for the period from 2004 to 2022. Full-text papers were included in this study. A wide range of keywords such as stevia, steviol glycosides thaumatin, polyols, diabetes, obesity, sweeteners, fructose, food production and glycemic index was used to find relevant literature. The articles in any way unrelated to sugar diabetes (slimming, glycemic index, glucose control, medical treatment, prophylaxis) were excluded. The pool review collected 44 full-text articles.

Results and Discussion

To improve life quality and treatment results for diabetes patients, sweeteners causing no or minimal influence on glucose levels in the blood are used in food production. Sweeteners can be distinguished into low-calorie sweeteners and no-calorie sweeteners. No-calorie sweeteners are further divided into artificial and natural ones. Summarising information on suitable natural sweeteners three sweeteners were selected: steviol glycosides, thaumatin, and polyols.

Stevia and Steviol glycosides

Development and risk factors of diet-dependent diseases can be decreased and eliminated by observing a healthy lifestyle introducing a balanced diet as well as changing eating habits. Stevia has several fatty acid and minerals constituents that are essentially meaningful in pharmacy and food production (Singh *et al*., 2019). Stevia contains glycosides which belong to the secondary metabolites of the plant diterpenoid group. Its chemical structure base has steviol (Libik-Konieczny *et al*., 2021). In the composition of stevia there are the following components: stevioside (5–10%), rebaudioside A (2–5%), rebaudioside C (1%), ducloside A (0.5%), rebaudioside D, E, F (0.2%) and steviolbioside (0.1%) (Wojewoda *et al*., 2018). Stevioside and rebaudioside A have the best sweetening effect (Wang *et al*., 2020). Besides having additional glycosides stevia is a good source of vitamins and minerals. In stevia composition, there are irreplaceable amino acids, fatty acids and other favourable bioactive combinations including flavonoids, phenolic compounds, phytosterols, chlorogenic acids, and hydrocarbons (Wölwer-Rieck, 2012). Stevia is 200–400 times sweeter than fructose (Hameed *et al*., 2020). Recommended daily intake for steviol glycosides that is allowed to consume is 4 mg kg^{-1} of body mass (Swiader *et al*., 2019). The use of steviol glycosides in drinks is wider than that in food products (Table 1). Steviol glycosides is used in dairies such as ice cream, yoghurts, and flavoured milk. It is also used in the production of breakfast cereals, cereal bars, certain confectionary, and sweet bread (Ahmed *et al*., 2011). Partial substitution of fructose with steviol glycosides gives a total carbohydrate quantity decrease in confectionary as well as product colour and consistency improvement (Yildiz & Gocmen, 2021). Stevioside and glycosides is widely researched from the point of view of both chemical characteristics and its influence on human and animal systems. Using stevioside and glycosides in the diet leads to a decrease of glucose levels in the blood (Ahmad & Ahmad, 2018). Steviosides improve pancreas beta cell function for diabetes patients (Philippaert *et al*., 2017). Rats studying research have proven that adding stevia extract to their diet and substituting fructose with it lead to the fact that the researched animals developed better metabolic, oxidative, and histopathological indicators (Ranjbar *et al*., 2020). Clinical researches prove that stevia and its separate combinations have therapeutic and pharmacological effects and do not harm human health. Stevia leaf extract and individual Stevia glycosides stimulate insulin production for diabetes patients, improve the condition of polycystic kidney disease, they have a strong antibacterial and antioxidative effect (Peteliuk *et al*., 2021). The negative aspect of using steviol glycosides in food products is the bitter aftertaste disliked by consumers. Therefore, interest in steviol glycoside taste profile improvement is growing. The use of taste enhancers is the approach to improve the steviol glycoside taste profile. To disguise bitter aftertaste maltodextrin (powder from rice, corn, wheat or potato starch), erythritol, xylitol, maltitol, sorbitol, vegetable glycerin, fructooligosaccharides, inulin, dextrose or sucrose are added in commercially available stevia extract products (Gerwig *et al*., 2016).

Table 1

Concentrations of steviol glycosides in various products (European Parliament and Council, 2011)

Products	Maximum level (mg kg^{-1} or mg L^{-1})
Carbonated soft drinks	80
Flavoured fermented milk products	100
Edible ices	200
Jam, jellies, and marmalades	200
Cocoa and Chocolate products	270
Chewing gum	3300
Breakfast cereals and bakery wares	330

Thaumatin

Thaumatin is a sweet protein derived product from *Thaumatococcus daniellii* tropical fruit (Kant, 2005). In its composition, thaumatin has 207 amino acids. Commercially thaumatin is extracted from fruit seeds, and it exists in five isoforms. They are thaumatin I, II, III, A, and B. The basic forms are thaumatin I and II (Fry, 2012). Thaumatin keeps stability up to 120 °C and endures pasteurisation and high-temperature sterilisation processes (Joseph *et al*., 2019). Thaumatin is used in the production of chewing gums, dairy, ice cream, sweets and flavoured drinks (European Parliament and Council, 2011). Thaumatin is often used in combination with other sugar substitutes. Low-concentration thaumatin is a flavor enhancer, thus it is suitable for mixing up with other intensive sweeteners and polyols (Mora & Dando, 2021). Thaumatin does not cause tooth damage, it is not toxic, and does not cause allergy (Joseph *et al*., 2019). Thaumatin is a confirmed food additive and its highest possible dosage in products is from 0.5 up to 400 mg kg^{-1} (Table 2).

Table 2

Highest possible thaumatin quantity in food products (European Parliament and Council, 2011)

Food category name	Restrictions/exception	Maximum level (mg L^{-1} or mg kg^{-1} as appropriate)
Flavoured fermented milk products including heat-treated products	Flavour enhancer	5
Edible ices	Only energy-reduced or with no added sugar	50
Other confectionery including breath freshening micro sweets	Only cocoa or dried fruit based, energy-reduced or with no added sugar	50
Chewing gum	Only with added sugar or polyols, as a flavour enhancer	10
Flavoured drinks	Only water-based flavoured non-alcoholic drinks, as flavour enhancers only	0.5
Cocoa and Chocolate products	Only energy-reduced or with no added sugar	50
Desserts	Flavour enhancer	5
Food supplements supplied in a solid form, excluding food supplements for infants and young children	Only food supplements in chewable form	400

Polyols

Polyols are low-calorie sweeteners that are naturally found in fruit, vegetables, mushrooms, and seaweed, or chemically synthesized. Polyols have been acknowledged to be safe food additives (Grembecka, 2015). Polyols are allowed to be used in food production. They are maltitol, mannitol, sorbitol, xylitol, erythritol, isomalt, and lactitol. Polyols energy value is from 0.2 to 2.6 kcal g^{-1} (Table 3). Polyols are characterised by high chemical thermal stability up to 180 °C (Shah & de Jager, 2016).

Maltitol is hygroscopic non-reductive sugar and disaccharide polyol. Small quantities of maltitol are naturally found in seeded malt and chicory leaves. It is commercially produced from crop starch such as corn, wheat, and potatoes. Producers use D-maltose catalytic hydrogenation to create hydrogenated disaccharides consisting of interconnected glucose and sorbitol molecules (Rozzi, 2007). *Maltitol* is used in the production of bread, dairy, chocolate, chewing gums, and sweets. Products have a pleasant taste, and no unpleasant aftertaste is felt in the mouth. Usage of increased doses can lead to diarrhea, bloating and flatulence in the digestive tract. (Awuchi, 2017). *Maltitol* has a low glycemic reaction, few calories, and low glycemic index (Saraiva *et al*., 2020). In food products and drinks, *maltitol* is used as a volume magnifier, emulsifier, sweetener, stabiliser, thickener, or humidifier (Grembecka, 2015).

Mannitol is a 6-carbon polyol that is naturally found in big quantities in olives, carrots, figs, pineapples, and sweet potatoes. *Mannitol* industrial production is the catalytic hydrogenation of a glucose/fructose mixture. The process is performed under high temperature and pressure (Ghoreishi & Shahrestani, 2009). *Mannitol* improves the taste, texture, and storage features of food products. *Mannitol* is used in the production of chocolate, ice cream, confectionery, chewing gums, and sugar-free products (Grembecka, 2015). In food products, it is used as an anti-sticking agent, volume

Table 3
Sugar alcohols' relative sweetness (Awuchi, 2017)

Name	Sweetnes relative to sucrose	Food energy (kcal g^{-1})
Erythritol	0.7	0.2
Isomalt	0.8	2.21
Lactitol	0.4	2.0
Maltitol	0.9	2.1
Mannitol	0.5	1.6
Sorbitol	0.6	2.6
Xilitol	1.0	2.4

magnifier, moisture maintainer, stabiliser, sweetener, and thickener (Grembecka, 2018).

Sorbitol is mannitol isomer. In nature, it is found in different fresh and dried fruit as well as in different vegetables. In industrial production catalytic hydrogenation is used. For this process, glucose or sucrose substrates are necessary. They are hydrogenated under high temperatures by applying nickel catalysts (Grembecka, 2015). *Sorbitol* is important in C vitamin production. In the human system, it is not absorbed in the metabolic process, it produces fewer calories. In the food industry, it is used for the production of drinks, ice cream, sweets, and chewing gums (Marques *et al*., 2016).

Xylitol possesses high chemical and biological stability. It is widely used separately as well as in combination with other sweeteners for product taste improvement (Mohamad *et al*., 2015). Products give a refreshing sensation in the mouth; therefore, they can be used for enhancement of peppermint taste or for ensuring product refreshing aftertaste. It does not foster insulin secretion in diabetes patients (Chattopadhyay *et al*., 2014). *Xylitol* helps in the bone mineralisation process stimulating calcium absorption as well as increasing the biostability of minerals (Xiao *et al*., 2015). In products, it is used as an emulsifier, humidifier, stabiliser, sweetener, and thickener (Grembecka, 2015).

Naturally, *erythritol* is found in fruit and vegetables, for example, in grapes and mushrooms, as well as in fermented food products. It is widely used as a sweetener for low-calorie food products, as well as in sweets and confectionaries (Regnat *et al*., 2018).

Naturally, *isomalt* is not available and it is produced industrially. In food production, it is used as a sweetener, thickener, stabiliser and volume magnifier (Grembecka, 2018).

Naturally, *lactitol* is not available, and it was first synthesised in 1920 from lactose. In products, it can be used as a sweetener, emulsifier or thickener (Grembecka, 2015).

Conclusions

For patients with diabetes, it is essential to decrease the quantity of consumed simple sugars to improve their treatment results, decrease complication risk factors and improve life quality. Steviol glycosides, thaumatin, sorbitol, maltitol, isomalt and erythritol are good alternatives for fructose substitution, as this is the way to decrease the number of calories in food products and reduce the risk of obesity. Additional research is necessary aiming at the development of new food products with alternative sweeteners for people with diabetes.

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A REVIEW: USING LEGUMES TO DEVELOP PRODUCTS FOR PATIENTS WITH PSYCHIATRIC DISORDERS

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Abstract
Mortality rates and co-morbidities are high in people with psychiatric disorders. These patients have unhealthy dietary habits, which include increased consumption of fast food, snacks, sweets, saturated fats, and reduced consumption of protein, fruits, vegetables, and legumes, which contributes to the risk of developing chronic diseases such as obesity, type 2 diabetes, and cardiovascular disease. Unhealthy and monotonous eating habits lead to a significant lack of nutrients such as protein, omega-3 fatty acids, B-group vitamins, and fibre. The aim of the literature review is to investigate the main diet problems of patients with psychiatric disorders and, based on the studies on the nutritional value of legumes, to evaluate their suitability for the development of new products for patients with psychiatric disorders. Studies show the beneficial effects of legumes on the regulation of rapid fluctuations in cholesterol, blood pressure, excess body weight, and glucose levels, which in general delay the formation of inflammation and reduce the risk of psychiatric disorders. The benefits of legumes are due to their high protein and fibre content, low fat content, and content of iron, copper, magnesium, zinc, and B-group vitamins. In addition, legumes contain bioactive compounds that contribute to the prevention of chronic diseases.
Key words: psychiatric disorders, legumes, health, nutrients.

Introduction

Mental and behavioural disorders are divided into – organic mental disorders, including symptomatic, schizophrenia, schizotypal disorders and nightmares, mental retardation, neurotic, stress-related, and somatoform disorders, mood disorders, mental developmental disorders, behavioural and emotional disorders that usually begin in childhood and adolescence, adult personality and behavioural disorders and behavioural syndromes related to physiological disorders and somatic disorders (Šica, Pulmanis, & Taube, 2017). Each of the mentioned disorders has symptoms characteristic of its group of diagnoses, which can worsen the general well-being of the patient and contribute to other co-morbidities, which create the need for food adapted to them, respecting physiological needs. In the following text, two groups of diseases will be discussed – schizophrenia and depression (mood disorders), which often can be combined. Therefore, psychoeducation is an essential and integral part of them, which also includes the application of appropriate, high-quality nutrition to patients.

Individuals with depression have a 30% increased risk of cardiovascular disease compared to non-depressed individuals. A prospective cohort study (n=323.709) found that depression was associated with a 31% increased risk of myocardial infarction and a 36% increased risk of coronary death compared to people without depression (Wu & Kling, 2016). Sympathetic hyperactivity may increase the risk of poor cardiovascular outcomes, including sudden death (A. B. Levine, L.M. Levine, & T.B. Levine, 2013).

Depressed patients typically have higher levels of circulating catecholamines – a marker of sympathetic activation – causing an increase in heart rate and blood pressure, while reducing coronary blood flow and increasing systemic vascular resistance, and contributing to the risk of coronary heart disease (Nasiłowska-Barud *et al*., 2017). Stress and anxiety cause excessive activation of the HPA (Hypothalamic-pituitary axis) and the sympathetic nervous system, increasing cortisol and catecholamine levels respectively – these changes can result in inflammation, metabolic disorders, platelet activation, endothelial dysfunction, hypertension, and insulin resistance, leading to an atherosclerosis and coronary development or progression of heart disease (Tully *et al*., 2013; Fiedorowicz, 2014; Goldstein *et al*., 2015). Patients with depression and anxiety are mostly characterized by loss of energy, anhedonia (inability to feel pleasure), and inability to concentrate, which interferes with daily activities. In severe cases, this can lead to a lack of self-care and loss of personal hygiene, such as infrequent dental and oral hygiene, which contributes to gingivitis, xerostomia, and oral candidiasis (Torales *et al*., 2017). Depressed patients have marked loss of appetite and nutrients due to malnutrition. Against the background of depression, eating disorders often develop, which contribute to weight loss. The exclusion of important protein-rich products from the diet, such as meat, fish, and dairy products, hinders the recovery process (Lin *et al*., 2021; Cao *et al*., 2019). Nutrition plays an important role in reducing psychiatric symptoms because there are hypotheses that certain nutrients, which are necessary for the effective functioning of

the brain, also affect the biological and neurochemical activities related to one of the nosological entities – the development and progression of depression (Popa & Ladea, 2012). Studies report that a high levels of vegetable, fruit, nuts, cereal, legumes, and a low consumption of meat or meat products and whole fat dairy gave greater importance to the synthesis of the monoamines, glutamate and GABA (Gamma-amino acid), which are responsible for the distribution of serotonin, dopamine, and noradrenaline, which in turn are responsible for mood regulation (Lopresti *et al*., 2013). The dopaminergic system is improved by polyunsaturated fatty acids, especially omega-3, proteins, B-group vitamins, and minerals but hindered by fats and sugars. Changes in amino acids such as tryptophan, valine, leucine, isoleucine, phenylalanine, and tyrosine have been observed in depressed patients (Lim *et al*., 2016).

Schizophrenic patients, depending on their accompaying symptoms, may develop a lack of interest, apathy, and fatigue, which leads to a reduced appetite, leading to long-term weight loss (Oudman *et al*., 2021). Studies have shown that 61% of schizophrenic patients have poor dental health due to dry mouth from antipsychotic medications, infrequent teeth brushing, extrapyramidal symptoms (hand tremors), and frequent smoking, which is more common than in the general population or patients with other mental health conditions and disorders (Torales *et al*., 2017). Early death in patients with schizophrenia may be associated with preventable medical conditions, namely cardiovascular disease, chronic obstructive pulmonary disease (COPD), metabolic syndrome, type 2 diabetes, and cancer risk (Crump *et al*., 2013; Smith *et al*., 2013; Laursen *et al*., 2019). Cross-sectional studies show that patients who suffer from schizophrenia consume more refined and processed products in their diet, which worsens the overall symptomatology of the diagnosis (Lichtenthal *et al*., 2018; Laursen *et al*., 2019). In patients with schizophrenia, the use of antipsychotic drugs is an integral part of the treatment of clinical symptoms. Many of these drugs are associated with significant weight gain, central obesity, and the development of metabolic disorders. Meta-analysis studies emphasize that one of the main factors that determine cardiometabolic abnormalities is related to increased food calories and unhealthy food choices, which interact with antipsychotic drugs and cause health problems. The use of antipsychotic medications may increase the risk of coronary heart disease by increasing sympathetic nervous system activity and blocking peripheral dopamine receptors (Correll *et al*., 2015). Mental disorders are associated with comorbidities such as obesity, hypertension, dyslipidaemia, increased triglyceride levels and decreased high-density lipoprotein cholesterol (HDL), impaired glucose tolerance, or insulin resistance. Lifestyle (smoking, physical inactivity, unhealthy dietary habits), as well as medications, may play a role in the prevalence of metabolic syndrome (A.B. Levine, L.M. Levine, & T.B. Levine, 2013). Patients taking antipsychotic medications have increased appetite and cravings for sweet foods and beverages, and decreased intake of healthy foods such as vegetables and fruits, leading to an increased risk of inflammation and worsened overall diagnostic status (Teasdale *et al*., 2018). Patients with schizophrenia generally have poor dietary habits characterized by increased intake of sodium, cholesterol, saturated fat, sugar (refined foods, white sugar) and reduced fibre intake, omega – 3 fatty acids, and vitamin D levels, which worsens mental disorders and contributes to other diseases, such as obesity and metabolic syndrome (Onaolapo & Onaolapo, 2021). Studies report that reduced omega-3 fatty acids and increased omega-6 fatty acids cause or worsen neuroinflammation, worsening the severity of schizophrenia symptoms (Onaolapo & Onaolapo, 2021). In schizophrenic patients, unhealthy eating practices are due to dysregulation of the reward circuitry due to increased dopamine activity in the mesolimbic pathway and brain regions responsible for cognitive control (Onaolapo & Onaolapo, 2021). Dysregulation of the reward circuit has also been linked to obesity, eating disorders, food cravings, and addictive behaviours. Food sensitivity, characterized by elevated levels of immunoglobulin G antibodies to wheat gluten, beef, and casein, has also been observed in schizophrenia (Severance *et al*., 2012; Lionetti *et al*., 2015). Many studies report high levels of homocysteine, as well as low levels of vitamins B_9, B_{12}, vitamin C, and vitamin E in patients with schizophrenia. Deficiencies or excesses of essential micronutrients, including calcium, zinc, selenium, copper, and manganese, have been observed in patients with schizophrenia (Onaolapo & Onaolapo, 2021). Research shows that the diet taken by patients with psychiatric disorders is of great importance, which includes more intake of plant products, such as legumes. Legumes have a positive effect on health due to their low glycemic index, high content of fiber, protein, B-group vitamins and minerals, which could improve the health of patients with psychiatric disorders.

The literature review aims to investigate the main diet problems of patients with psychiatric disorders and, based on the studies on the nutritional value of legumes, to evaluate their suitability for the development of new products for patients with psychiatric disorders.

Materials and Methods

The information was searched in *Google Scholar*, *Web of Science*, and *Scopus* original studies and reviews published in English and Latvian in the period from 2005 to 2022. The search for information was based on the following conditions: the main health problems of patients with psychiatric disorders, the provision of necessary nutrients, and the health effects of leguminous products. Full-text papers were included in this review. The monographic method was used in this study. The following keywords were used to select scientific literature: psychiatric disorders, mental health, schizophrenia, depression, symptoms, nutrition, nutrients, protein, B-group vitamins, fibre, minerals, legumes, peas (*Pisum*), beans (*V. faba*), and antioxidants.

Results and Discussion

Protein is one of the essential nutrients in mental health, and its insufficiency leads to abnormal levels of neurotransmitters and disturbances in cognitive behaviour (Sato *et al*., 2020). Dietary protein is made up of about 20 different amino acids, of which tryptophan and tyrosine are abundant in milk, cheese, meat, eggs, chicken, fish, beans (*V. faba*), oats, nuts, and whole grains. A poor tryptophan diet reduces serotonin levels in the brain, leading to anxiety, obsessions, and compulsions, which are symptoms of depression (Chávez *et al*., 2017). Dietary intake of tryptophan reduces stress and cortical hormones associated with depression (Koopmans *et al*., 2005). A study testing three different legume pastes together with wheat semolina and two control groups of a casein and soluble milk proteins drink found equivalent results associated with increased lean mass and maintenance of muscle mass in the legume and casein group (Berrazaga *et al*., 2020). Depending on the legume variety, the protein content varies widely from 20 to 35%, the essential amino acid being lysine, leucine, and phenylalanine (Kumari & Deka, 2021). Sulphur-containing amino acids, such as methionine and cysteine, are in reduced quantities compared to meat products. A recent study showed that pea protein hydrolysates can inhibit a metabolic by-product, nitric oxide, which can cause excessive cell damage (Lu *et al*., 2020). One of the proteins found in legumes, called lectins or phytohemagglutinin, is able to agglutinate the red blood cells found (Kumari & Deka, 2021). Lunasin is a peptide found in legumes that has multiple health-promoting effects, such as anti-inflammatory, cholesterol-lowering, anti-cancer, and antioxidant effects. The resistance of lunasin to gastric enzymes preserves its functionality and thus promotes its bioavailability (Hernandez-Ledesma, Hsieh, & Lumen 2016).

Legumes, as good sources of slow-release carbohydrate including dietary fiber and slow digestive starches reduce blood glucose response, cholesterol, create a favourable microbiome for *Lactobacillus* and *Bifidobacterium* bacteria, and reduce appetite (Kadyan *et al*., 2022). The low glycaemic index of legumes is a possible mechanism involved in the modulation of the inflammatory process. Considering that the gut microbiota is altered in patients with psychiatric disorders, legumes contribute to their improvement due to the resistant starch and fibre they contain (Teasdale, Mörkl, & Müller-Stierlin, 2020).

Legumes contain about 16% to 20% of the soluble fibre fraction, which plays an essential role in the absorption of water in the intestines, facilitating the faster movement of intestinal contents and reducing constipation. Clinical studies and epidemiological studies show that dietary fibre in legumes reduces blood cholesterol levels (Becerra-Tomás *et al*., 2019; Martín-Cabrejas, 2019). This fact is very important in the prevention of cardiovascular diseases.

Legumes are low in sodium (3–41 mg 100 g^{-1}) and high in potassium (616–2300 mg 100 g^{-1}), which is very important for maintaining normal blood pressure. The most important minerals in legumes are calcium (32–394 mg 100 g^{-1}), phosphorus (203–800 mg 100 g^{-1}), magnesium (58–472 mg 100 g^{-1}), iron (3.2–10 mg 100 g^{-1}), and zinc (1.6–6.3 mg 100 g^{-1}) (Martín-Cabrejas, 2019). These trace elements are essential in the metabolic processes of many cells and are antioxidants that slow down the natural ageing process. The presence of phytic acid in legumes causes the formatted of insoluble complexes with divalent cations (Ca^{2+}, Fe^{2+}, Zn^{2+}), which interferes with their absorption and thus reduces their bioavailability. Although legumes are high in iron, their bioavailability is lower than in animal products. The vitamin content of legumes varies widely and includes B-group vitamins such as B_1 (0.3–1.6 mg 100 g^{-1}), B_2 (0.12–0.33 100 g^{-1}) and B_3 (4.7 mg 100 g^{-1}). (Martín-Cabrejas, 2019), which play an essential role in energy metabolism. The importance of vitamins, especially B-group vitamins, has been given great importance in psychiatric disorders. A large number of observational studies show that patients with psychiatric disorders have reduced levels of B_9, B_{12}, B_6, and choline. Meta-analysis studies show that a positive effect that improved the overall psychological state was a dose of vitamin B_6 of 1200 mg day^{-1}, a dose of vitamin B_{12} of 400 µg day^{-1}, and a dose of B_9 of 0.5–15 mg day^{-1} (Firth *et al*., 2017). The level of vitamin C in legumes is quite low 0.4–27.7 mg 100 g^{-1} dry matter.

The amount of phytosterols in legumes depends on the variety of the legume. The main phytosterols are β-sitosterol and D5-avenasterol (Abbas & Ahmad, 2018). Plant secondary metabolites have

a potential effect on obesity, and atherosclerosis, as well as reducing total cholesterol and low-density lipoprotein cholesterol (LDL) serum levels, as well as causing a significant increase in high-density lipoprotein cholesterol (HDL) (Becerra-Tomás *et al*., 2019; Martín-Cabrejas, 2019).

The pea fatty acid profile mainly has a component of linoleic, linolenic, and palmitic acids, showing a promising antihyperlipidemic effect, reducing the risk of diabetes, including the level of oxidative stress, and preventing organ damage, namely the liver, kidney, and testis (Kumari & Deka, 2021). In the body, α-linolenic acid is converted to docosahexaenoic acid and eicosapentaenoic acid (Sublette *et al*., 2011). Research shows that depressed patients have lower blood levels of omega-3 fatty acids and lower levels of docosahexaenoic acid and eicosapentaenoic acid (Liao *et al*., 2019). A deficiency of omega-3 fatty acids leads to neural functional impairment by changes in the structure or function of membrane-bound enzymes, protein receptors, and ion channels (Sinclair *et al*., 2016). Dietary intake of omega-3 fatty acids improves depression scores (Banikazemi *et al*., 2015) and also improves adaptive coping in stressful situations (Gonzales *et al*., 2015). Omega-3 fatty acids protect against depression, possibly by modulating serotonergic, dopaminergic, and adrenergic transmission (Liperoti *et al*., 2009).

Magnesium is essential as a cofactor in many enzymatic reactions in the body, and the nervous system is involved in nerve transmission and neuromuscular regulation (Gröber *et al*., 2015). Magnesium deficiency is associated with symptoms of depression and other mood disorders, while the moderate intake is associated with depression risk (Li *et al*., 2018). Zinc deficiency impairs the accumulation of polyunsaturated fatty acids throughout the body and causes rapid mood swings (Ekong & Iniodu, 2021).

The phenolic compounds in legume seeds act as anti-nutritional compounds, but they can also act as antioxidants due to their ability to chelate metal ions, inhibit lipid peroxidation, and scavenge free radicals. The phenolic compounds found in legume seeds include tannins, phenolic acids, anthocyanins, and flavonoids. The phenolic compounds in legume seeds have antibacterial, antiviral, anti-inflammatory, and anti-allergic activities, as well as reducing the risk of cancer, heart disease, and diabetes. In total phenolics versus antioxidant activities, fermented legume seeds have higher antioxidant potential. The balance between anti-nutrient and antioxidant effects present in legume seeds will help improve nutrient utilization, thereby providing potential nutritional agents for human health (López-Amorós *et al*., 2006., Bosi *et al*., 2019). The antioxidant saponin present in legumes has shown anticarcinogenic, antimutagenic, hypoglycaemic, hypocholesterolaemic, liver otoprotective, immunomodulatory, and neuroprotective activity in animal (*in vivo*) and *in vitro* studies (Kumar & Pandey, 2020).

Studies have shown that legume intake has a positive effect on cardiovascular risk by reducing triglycerides, LDL blood levels and increasing HDL levels. All the results obtained are highly dependent on the number of servings of legumes consumed, the duration of the studies (from weeks to years), as well as the type of legumes consumed. Systematic reviews, where a total of 371 randomized and controlled trials were evaluated, emphasize that positive results have been observed with the intake of 150 g of cooked legumes per day, for at least eight weeks (Becerra-Tomás *et al*., 2019; Ferreira *et al*., 2021; Gao *et al*., 2019; Martín-Cabrejas, 2019). Epidemiological and clinical studies have shown the positive effects of bean (*V. faba*) consumption in reducing the risk of coronary heart disease and cardiovascular disease, which can be attributed to the high content of soluble fibre, which reduces blood triglyceride and cholesterol levels. The low glycaemic index of legumes is a possible mechanism involved in the modulation of the inflammatory process. Considering that the intestinal microbiota is altered in patients with psychiatric disorders, legumes contribute to their improvement thanks to the resistant starch and fibre they contain.

Epidemiological and clinical studies have shown the positive effects of bean (*V. faba*) consumption in reducing the risk of coronary heart disease and cardiovascular disease, and generally reducing the progression of psychiatric diseases (Teasdale *et al*., 2020).

Conclusions

Patients with psychiatric diseases have pronounced unhealthy eating habits which do not contribute to recovery but also increase the risk of developing chronic diseases. Due to their protein, low glycemic index, fiber, B-group vitamin content, minerals and phenols, legumes could be a good raw material for the development of new products for patients with psychiatric disorders. Many studies clearly show the beneficial effects of legumes on blood cholesterol levels, blood pressure regulation, reducing excess body weight, maintaining muscle mass and reduction glucose levels. However, further research is needed to be able to develop an appropriate product for this group of patients, taking into account legume digestibility and patients' eating issues.

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THE ANTI-NUTRITIONAL FACTORS OF LEGUMES AND THEIR TREATMENT POSSIBILITIES: A REVIEW

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Abstract
Today the demand for plant-based protein is growing rapidly due to increased awareness of animal protein growing costs and limited supply and has been highly related to biodiversity loss, climate change, and freshwater depletion. Legumes are in demand for their high content of protein, minerals, vitamins, and carbohydrates, also including dietary fibre. Legumes are rich not only in macronutrients and micronutrients but also contain anti-nutritional factors. One of the most important anti-nutritive properties of legumes is their high trypsin activity. The length of time required for the preparation of legumes has limited their frequency of use compared to recommended intake levels. By heat treatment, an anti-nutritional component in legumes can be mostly separated. The possibility of using extrusion cooking, microwave dryer, roasting equipment, etc., is widely studied. Roasting is one of the widespread methods for treatment of legumes that significantly enhances the texture, flavour, colour, and product appearance. The latest studies in the legume treatments report valuable results after the combined treatments, wet roasting, which includes: dehulling, soaking, and roasting. Heat treatment can be a potential way to improve legumes use in food production: reducing the time required for treatment, preparation and improving nutritional value.
Key words: legumes, protein, plant-based, roasting, heat treatment, anti-nutrients.

Introduction

The need for plant-based proteins is rapidly growing with raised awareness of the carbon footmark caused by meat and dairy-based foods, as plant-based foods have smaller carbon footmarks. Legumes are in the spotlight among all plant-based protein sources and play an important role in human nutrition for their high composition of protein, minerals, starch, vitamins, and carbohydrates, including dietary fibre. Legumes are particularly important since the utilization of animal-based proteins is limited due to restricted affordability or ethical, religious, and nutrition habits (Pasqualone *et al*., 2020; Park *et al*., 2020; Lignicka & Galoburda, 2022).

Although many legumes are nutritious, it is difficult to cook them. This is due to high amylose content starch forming up to 32% of the legumes composition (Gani *et al*., 2016). Among these starch molecules, there are hydrogen bonds that make the legumes, especially beans, very dense, and a high energy capacity is required to smash this hydrogen bonds structure by cooking treatment (Du *et al*., 2014). There are many treatments performed to carry off, that legumes for the human organism are eventually digestible, mainly fully free of anti-nutritional factors, such as lipoxygenases, trypsin inhibitors, and glycoproteins, as lectin, vicin or convicin. Compounds in legumes such as tannins, polyphenols, and phytic acid have been mentioned in terms of their effect on the human organism and should be considered too. Anti-nutrients are the binders that make a bond with the nutrient substances in the food and make those food compounds less accessible for absorption in the human body (Samtiya *et al*., 2021).

Anti-nutrients can be removed or decreased via numerous treatments of the legumes such as soaking, germination, heating, and fermentation. Soaking is the most economical and easiest treatment, in addition, to considering the anti-nutritional factors inactivation. The dehull is used in terms of protein enrichment in peas and beans (Mohamed *et al*., 2011a; Jiang *et al*., 2016; Samtiya *et al*., 2021). To tackle these anti-nutritional issues, there is an increasing demand to develop an efficient treatment methods for advanced legume utilization; thus, the present study aimed to review research findings for treatment methods for legumes as well as innovative and structured technology resolutions for cost reduction including maximum removal of anti-nutritional compounds.

Materials and Methods

Monographic method was used for this review. The review recapitulates results of advantages and disadvantages of legumes and their treatment possibilities. Literature mainly from nutritional scope of different scientific journals from Scopus, Web of Science and ScienceDirect data bases was used in development of the study. Studies were selected by key words, like legume anti-nutritional factors, treatments of legumes. More than 100 research was found, but only 38 research from the last ten years and 8 research older than ten years were used for the review, because they contained valuable information related to this study's aim. The review includes material from research conducted in India, China, Australia, Greece, Egypt, Iran, Germany, etc.

Results and Discussion

Advantages and disadvantages of legumes

In the menu of legumes for humans, lentils, peas, millet, peanuts, lupines and varied botanical classifications different types of beans, also soy (Kinyanjui *et al*., 2015; Park *et al*., 2020; Schmelter, Rohm, & Struck, 2021) are included. Soybeans

(*Glycine max L.*) are the first most harvested legumes in the world, next second place is taken by peanuts (*Arachis hypogaea L.*) providing an important nutrition source for humans (Jiao *et al*., 2014). The legume protein content depends on botanical classification and is 50%–200% higher compared to grain protein content (Simons & Hall, 2018). The legume fat content is low and purely exceeds 4 g per 100 g of dry matter, but not for soybeans (*Glycine max L.*) (Schmelter, Rohm, & Struck, 2021). Lupines (*Lupinus L.*) contain a higher fat content up to 15 g per 100 g and chickpeas (*Cicer arietinum L.*) contain up to 7 g per 100 g. Legumes have a relatively low fraction of sulphur-containing amino acids, such as methionine and cysteine. Legumes are a good source of dietary fibre, proteins, B group vitamins, starch and minerals. Starch is the main component in the dry matter of legumes, like all plant-based seeds and legume mineral content is between 3-5 g per 100 g of dry matter (Rebello *et al*., 2014; Simons & Hall, 2018; Lignicka, & Galoburda, 2022).

A nutritional disadvantage of legumes is that they contain anti-nutrients, they are known as compounds that by themselves or through their metabolic products arise in living systems, obstruct food utilization and have an effect on the health of animals and humans (Mohamed *et al*., 2011a). Non-protein amino acids, protease inhibitors, lecithins, phenolic substances, flatulence produces, saponins, and non-starch polysaccharides are the most popular anti-physiological compounds in legumes (Mohamed *et al*., 2011a). Protease inhibitors are widespread compounds reducing digestibility by blocking trypsin or chymotrypsin. Trypsin inhibitors inhibit the proteolytic activity of the digestive enzyme trypsin, thus reduce or prevent protein digestibility (Gulewicz *et al*., 2014). Phytic acid decreases mineral absorption. The complex formed from phenolic compounds or their oxidized products connected with enzymes, essential amino acids, and other proteins, thereby decreasing protein digestibility and nutrition value (Grela *et al*., 2017). Human organism does not have the capability to hydrolyse phytate and has no capability to absorb it; thus, phytate implicates in causing less bioavailable minerals. Phytate negatively acts on the bioavailability of positive ions such as Fe^{2+}, Fe^{3+}, Zn^{2+}, Ca^{2+}, and Mg^{2+} divalent and trivalent minerals by being negatively charged (Gemede & Negussie, 2014; Samtiya *et al*., 2021). Phenolic compounds in legumes can span from simple molecules (phenolic acids) to highly polymerized compounds (tannins) that may impair protein bioavailability (Karkanis *et al*., 2018). Tannins could decrease iron absorption by setting up a bond with protein and creating a complex. Intake of high concentrations of tannins can cause side effects such as proteins, essential amino acids, and specific tissue elimination from the human body, and induce gastrointestinal tract damage (Adeyemo & Onilude, 2013). Flavonoids are announced to be the most plentiful polyphenols in human nutrition and legumes contain them, too (Mohamed *et al*., 2011b). In the human colon, high quantity of polyphenols may inhibit reproducing of significant colon microorganisms (Samtiya *et al*., 2021). Lingyan et al. (2017) emphasize that some polyphenols in high amounts can also have a genotoxic or carcinogenic trait. Dietary polyphenols can inhibit iron absorption and decrease folic acid and thiamine motion in human organism (Samtiya *et al*., 2021).

Additional disadvantage is also the unpleasant 'beany flavour' of untreated faba bean (*Vicia faba L.*); thus in food use, this bean has been commonly limited. Faba bean (*Vicia faba L.*) is rich in proteins and due to the activity of endogenous enzymes can cause unpleasant 'beany flavour'; thus, their utilization in foods gives challenges regarding the quality of the sensory of legumes. Lipoxygenase is an enzyme which catalyses the oxidation of fatty acids, like linolenic and linoleic acids into hydroperoxides. Bean tissues also have peroxidases that catalyse various oxidation-reduction reactions that have an impact on lipids. Peroxidase is generally used to appoint the conformity of heat treatments, because it is usually the most heat-stable enzyme in plants. To resolve the faba beans (*Vicia faba L.*) 'beany flavour' issue, it is suggested to use treatment with microwave heating, steaming, kilning, oven heating, and autoclaving (Jiang *et al*., 2016; Sun *et al*., 2020). Besides, not fully cooked kidney beans (*Phaseolus vulgaris L.*) can be toxic to human health, since the existence of the naturally occurring toxin phytohemagglutinin. The usage of partially cooked kidney beans (*Phaseolus vulgaris L.*) in human food can guide to food poisoning, including nausea, gastroenteritis, and diarrhoea. The inactivation of phytohemagglutinin is also disturbed by the dense structure of the kidney bean (*Phaseolus vulgaris L.*) (Sun *et al*., 2020).

Another reason is that legumes require prolonged soaking and cooking treatments; thus, they are not valued by all consumers (Karkanis *et al*., 2018). Also, the application of legumes in baked products has increased significantly due to the challenges of the growing amount of population that has coeliac disease (Simons & Hall, 2018). Legume flour is noticed as an alternative raw material for baked products because of its high content of fibre and protein (Karkanis *et al*., 2018).

The reasons for the strengthened growth of legumes are mostly high agricultural sustainability aspects like the fact that they can be considered as highly nutritious and the symbiotic fixation of atmospheric nitrogen (Schmelter, Rohm, & Struck, 2021). Thus, to get rid of disadvantages and highlight valuable in legumes, it is important to use the correct treatment methods.

Treatment possibilities of legumes

Separation of unpleasant components in legumes

is highly required to improve sensory acceptability and nutritional quality, and help effectively cultivate their potential as plant-based food for humans (Mohamed *et al*., 2011b). Various food treatment methods such as soaking, germination, cooking, dehulling, and fermentation are known to increase the nutritional quality of legumes and also decrease anti-nutritional factors successfully (Mohamed *et al*., 2011a). The most effective treatment to get rid of anti-nutritional compounds in legumes are germination and fermentation, but their usage remains limited due to the certain sensory properties they cause and the additional work-load they involve (Mohamed *et al*., 2011b).

Different physical treatments have been proposed to remove or decrease anti-nutritional factors in legumes. The physical treatment involving soaking and cooking strongly improve legume nutritive value; see used methods in Table 1.

Table 1

Summary of the most productive treatment methods of legumes

Treatment	Procedure	Legumes	Reference
Pretreatment methods			
Soaking	Soaked in distilled water 1:10 w v^{-1}. Room temperature ~25 °C. 24 h.	Soybean *(Glycine max L.)*, mung bean *(Vigna radiate L.)*, kidney bean *(Phaseolus vulgaris L.)*	Mohamed *et al.*, 2011a, Mohamed *et al.*, 2011b
	Soaked in different brine solutions with different pH (4, 5, 6, 8, 8.5). Included: 0.1 mol L^{-1} monovalent (Na_2CO_3, $NaHCO_3$, NaCl), 0.1 mol L^{-1} divalent ($CaCl_2$) salts and deionized water. At 25 °C for 6 h.	Beans *(Phaseolus vulgaris L.):* rose coco, red haricot, zebra, canadian wonder, soya fupi, pinto, Mwezi moja, gwaku, new mwezi moja	Kinyanjui *et al*., 2015
Dehulling	Hulls were removed manually after soaking	Soybean *(Glycine max L.)*, mung bean *(Vigna radiate L.)*, kidney bean *(Phaseolus vulgaris L.)*	Mohamed *et al.,* 2011a, Mohamed *et al.,* 2011b
	The hulls were removed manually after being cracked with stones in a stone mill	Faba bean *(Vicia faba L.)*	Jiang *et al*., 2016
Biotechnological methods			
Germination	Soaked in ethanol for 1 min, then soaked in distilled water (ratio 1:10 w v^{-1}). ~25 °C temperature. 12 h. Germinated in the dark for 5 days	Soybean *(Glycine max L.)*, mung bean *(Vigna radiate L.),* kidney bean *(Phaseolus vulgaris L.)*	Mohamed *et al.,* 2011a, Mohamed *et al.,* 2011b
Lactic Acid Fermentation	Samples 1:10 (dry legumes: water w v^{-1}). Sterilized for 15 min at 121 °C. The flasks were inoculated with 0.5 ml of activated Lactic Acid bacteria strains (1%) and fermented at 37 °C for 72 h	Soybean *(Glycine max L.)*, mung bean *(Vigna radiate L.)*, kidney bean *(Phaseolus vulgaris L.)*	Mohamed *et al.,* 2011a, Mohamed *et al.*, 2011b
Milling methods			
Pin-disc milling	Beans were milled with a laboratory pin-disc mill set up to achieve minimum gap between pin-discs	Faba bean *(Vicia faba L.)*	Jiang *et al.,* 2016
Roller milling	Milled with a roller mill to gain "roller milled flours"	Faba bean *(Vicia faba L.)*	Jiang *et al*., 2016
Ultra-centrifugal milling	Beans were milled with a high speed rotor ultra-centrifuge mill equipped with a ring sieve (pore size 0.5 mm) and with 12000 rpm rotation speed	Faba bean *(Vicia faba L.)*	Jiang *et al.*, 2016

Continuation of the Table 1

Treatment	Procedure	Legumes	Reference
Cooking methods			
Boiling	Beans were boiled in distilled water at 100 °C (ratio of 1:10 w v^{-1}) on a hot plate until 90 min	Soybean *(Glycine max L.),* mung bean *(Vigna radiate L.),* kidney bean *(Phaseolus vulgaris L.)*	Mohamed *et al.,* 2011a, Mohamed *et al.,* 2011b
	Beans were boiled at 96 °C in a thermostatic water bath (WBU–45; Memmert, Schwabach, Germany) for 2 h	Beans *(Phaseolus vulgaris L.):* rose coco, red haricot, zebra, canadian wonder, soya fupi, pinto, mwezi moja, gwaku, new mwezi moja	Kinyanjui *et al.,* 2015
Sterilization	Beans were sterilized in distilled water (ratio 1:10 w v^{-1}) at 15 atm, 121 °C for 10 min	Soybean *(Glycine max L.),* mung bean *(Vigna radiate L.),* kidney bean *(Phaseolus vulgaris L.)*	Mohamed *et al.,* 2011a, Mohamed *et al.,* 2011b
Microwave cooking	Beans were added in a Birex pot filled with distilled water (ratio 1:10 w v^{-1}), then cooked for 15 min in a microwave oven	*Soybean (Glycine max L.), mung bean (Vigna radiate L.), kidney bean (Phaseolus vulgaris L.)*	*Mohamed et al., 2011a, Mohamed et al., 2011b*
	Microwave oven used at 950 W. With 2, 3, 4, 6, 8 heating rounds, for 1, 1.5, 2, 3, 4 min, accordingly	Faba bean *(Vicia faba L.)*	Jiang *et al.,* 2016
Drying	A pilot-scaled fluidized bed dryer with inert particles with dielectric heating source. 35–65 °C.	Broad bean *(Vicia faba L.)*	Hashemi, Mowla, & Kazemeini, 2009
	Dried with microwave hot air rolling bed dryer. Hot air speed 0.5 m s^{-1} and 60–80 °C, drum 5 rpm	Faba bean *(Vicia faba L.)*	Li *et al.,* 2022
Roasting	Roasting was performed in an infrared roaster. The power was 250–450W for 10–30 min	Peanut kernels *(Arachis hypogaea L.)*	Bagheri *et al*., 2019
	45 min of hot air assisted radio frequency roasting at 110–130 °C	Peanut *(Arachis hypogaea L.)*	Jiao *et al.*, 2015
	Roasted in batches until surface of the peas achieved 150 °C and the moisture content reached ~7.0%.	Chickpea *(Cicer arietinum L.)*	Kotsiou *et al*., 2022
Oven heating	Beans were heated in an oven at 170 °C for 30 min	Faba bean *(Vicia faba L.)*	Jiang *et al.*, 2016
	Heating was done dry, in a hot air oven at 75–175 °C for 60 min	Faba bean *(Vicia faba L.)*, Soy bean *(Glycine max L.)*	Bühler *et al.,* 2020
Extrusion cooking	Single-screw extrusion at 120–170 °C temperature with 50–240 rpm	Bean *(Phaseolus vulgaris L.)*	Espinoza-Moreno *et al.*, 2016
	Twin-screw extrusion at 150 °C temperature with 200 rpm	Pea *(Pisum sativum L.)*	Koksel *et al.*, 2018
	Single-screw extrusion at 160 °C temperature with 250 rpm	Chickpea *(Cicer arietinum L.)*	Hegazy *et al.*, 2017
	Single-screw extrusion at 180 °C temperature with 210 rpm	Lentil *(Lens culinaris L.)*	Rathod *et al*., 2016
	Single-screw extrusion with 160–200 rpm heated up to 160–180 °C temperature	Cowpea *(Vigna unguiculata L.)*	Jakkanwar *et al.*, 2018

Continuation of the Table 1

	Twin-screw extrusion with 200 rpm heated up to 140 °C temperature	Faba bean *(Vicia faba L.)*	Smith *et al.*, 2011
	Twin-screw extrusion at 130–170 °C temperature with 400–550 rpm.	Mung bean *(Vigna radiate L.)*	Yagci *et al.*, 2020
	Single-screw extrusion with 100–140 rpm heated up to 160–200 °C temperature	Pigeon pea *(Cajanus cajan L.)*	Chakraborty *et al.*, 2014

Pre-treatment of legumes

Legumes are mainly soaked in water for a few hours before cooking, fermentation or germination methods are used for treatment (Kinyanjui *et al*., 2015). Soaking is a convenient way to decrease anti-nutrients (Samtiya *et al*., 2021). Mohamed et al. (2011a) have explored that soaking beans could decrease the amount of trypsin inhibitor activity below the control value. Trypsin inhibitors activity was lower in kidney beans (*Phaseolus vulgaris L.*) around 18%, by soaking (Ramakrishna *et al*., 2006). Khattab & Arntfield (2009) showed that peas (*Pisum sativum L.*) and kidney beans (*Phaseolus vulgaris L.*) notably decreased their trypsin inhibitor level by up to 10–19% by using a soaking treatment. Their results also represented variations in the level of trypsin inhibitor loss by different tested legumes soaking, and the highest loss of trypsin inhibitor was gained for kidney beans (*Phaseolus vulgaris L.*) (Mohamed *et al*., 2011a). Soaking can be adopted by bean canners, particularly used by bean breeds that easily gap in the canning treatment. Soaking in low pH and in $CaCl_2$ solutions promote to enhance the firmness of the cooked beans and thereby prolong the cooking time (Kinyanjui *et al*., 2015). The mechanism why cooking time in beans is prolonged is very complex. Gained results from Kinyanjui et al., (2015) study indicate that either bean hulls or pectin is the reason for such a long bean cooking time. Briefly, soaking beans for 24 hours gives a loss in total phenolic compounds reaching up to 31–55%. A less effective decrease in total phenolic compounds by soaking is in soybeans (*Glycine max L.*) compared to other tested beans like kidney (*Phaseolus vulgaris L.*) and mung beans (*Vigna radiate L.*) (Mohamed *et al*., 2011b). Similar results in phenolic compound level changes were gained by Paramjyothi & Anjali (2005) for chickpeas (*Cicer arietinum L.*), Khandelwal et al. (2010) for Indian legumes, and Ramakrishna et al. (2006) for mung beans (*Vigna radiate L.*). Total phenolic compound reduction by soaking could simply be because phenolic compounds leach out in the soaking substance by the concentration gradient (Ramakrishna *et al*., 2006). Xu & Chang (2008) mentioned that the situation of difference in a decrease in total phenolic compounds during the soaking treatment may be due to a contrast in the distribution and amount of phenolic compounds in the bean hulls, and cotyledon among the examined beans.

Dehulling means the outer covering removal of the legumes. It could be carried out manually by the usage of pestle and mortar. Nowadays, milling equipment is implemented. The application of dehulling reduces the amount of anti-nutritional compounds, such as phytic acid, tannins, and polyphenolic content (Samtiya *et al*., 2021).

Biotechnological methods

Biotechnological methods such as germination and fermentation are used also for legume treatment.

Germination is an effective phase of metabolism wherein anti-nutrients are decreased; it is a biotechnological method where proteases break down cellular proteins, but it has only an average effect with regard to the decrease in the trypsin inhibitor especially. Germination may boost legume nutritional value by modifying the chemical composition and decreasing the anti-nutrient factors (Kumari, Krishnan, & Sachdev, 2015; Samtiya, Aluko, & Dhewa 2020).

Fermentation is also a biotechnological method where complex biomolecules are converted by microorganisms (specially selected yeast or bacteria strains) into simple molecules. Fermentation improves antioxidant properties and nutritional value of legumes. The fermentation effectiveness depends on the legume and the microorganism strain used on the lower level of anti-nutritional factors. Fermentation could eliminate few anti-nutritional factors, like phytic acid, and besides gives a positive result on bioavailability and protein digestion (Samtiya *et al*., 2021).

Besides, genetic engineering methods are created to remove the genes which are responsible for metabolic pathways for decreasing the output or inactivation of the anti-nutrients (Kumar *et al*., 2019).

Cooking methods

Different heating methods, such as boiling, sterilization, roasting hot air drying, and microwave cooking were used to reduce anti-nutrients significantly (Samtiya *et al*., 2021).

The roasting application is more popular in nuts than in beans. Roasting forms desirable

sensory properties and significantly improves the colour, flavour, texture, and appearance of nuts. Peanuts (*Arachis hypogaea L.*) after roasting have the potential to be used as snacks (Bagheri *et al*., 2019). The usage of the roasting method has more advantages, such as advanced product quality, high roasting capacity, prolonged shelf-life of product, and less environmental pollution. In general, the infrared roasting treatment is a successful alternative treatment for utilizing peanuts (*Arachis hypogaea L.*) as a snack and can be adapted also to roasting the beans (Bagheri *et al*., 2019). Overall, frying, electric furnace roasting, hot air roasting, and coal-fired furnace roasting are usually applied roasting treatments. All mentioned roasting treatment methods are time-consuming, have reduced production rates, and have high energy costs (Jiao *et al*., 2014).

Mostly all grain flours sold in food markets are milled with a roller-milling equipment, which could be applied to legumes too. Ultra-centrifugal milling mills produce fine flours with equable particle size dispensation, which is usually used in chemical compound analyses (Jiang *et al*., 2016). Microwave heating method successfully and quickly inactivates peroxidase and lipoxygenase in faba bean (*Vicia faba L.*), which are related to unpleasant 'beany flavour' (Jiang *et al*., 2016). Microwave heating for 1.5 min at 950 W power is sufficient to inactivate undesirable enzymes associated with 'beany flavor' and advance the milling quality of the legumes. Microwave heating has few preferences as it can reach high heating rates and has lower treatment time compared to oven-based heating methods (Chandrasekaran, Ramanathan, & Basak, 2013). Conventional oven heating for 30 min at 170 °C as well inactivates the lipoxygenase and peroxidase enzymes in legumes flour. All heating methods create starch protein aggregates from legumes flour, and they all are insoluble in water (Jiang *et al*., 2016).

Hydrothermal methods like extrusion using no chemicals are able to enhance the functional properties of legume flours, too (Patil *et al*., 2018). Extrusion cooking technology is known to decrease the amounts of several anti-nutrients contained in legumes such as trypsin inhibitors, tannins, phytic acid, and lectins. In addition, extrusion cooking is able to increase the digestibility of protein and starch, too (Pasqualone *et al*., 2020). Extrusion is a short time and high temperature method in which food is cooked in high temperature and automatic under pressure shear combination. This outcome with chemical reactions and molecular modification with the help of which functional properties, phytochemical structure, and nutrients of the food are transformed (Patil *et al*., 2018). Therefore, the extrusion of legumes is an applicable strategy to add value to underexploited legumes and shorten home preparation time, thus also increase the consumption of these sustainable legumes (Pasqualone *et al*., 2020).

The hot air-drying treatment for beans can be effective to gelatinize starch on their surface area, and also for moisture migration. The major reasons limiting the evolution of the hot air-drying method are as follow: drying is time-consuming and consumes high energy although this method is easy to operate and has low manufacturing cost, too (Li *et al*., 2022). However, the microwave radiation in the microwave drying treatment heats the surface and interior areas of the legumes at the same time, and these properties relieve starch gelatinization and free moisture removal by drying. Thus, the microwave drying method has the advantage of high drying productivity and low energy consumption compared with the conventional drying treatment (Haghi & Amanifard, 2008). Li and others (2022) explored that in a relatively short time the dried beans (*Vicia faba L.*) are fully cooked. Briefly, the optimum treatment properties to the dried beans (*Vicia faba L.*) are firstly beans should be soaked for 4h and steamed for 15 min, further followed by hot air drying at a microwave with 70 °C hot air.

All these cooking methods also reduce phytate, tannin, trypsin inhibitor and a protease inhibitor, and they eliminate tannins and phytates from legumes (Samtiya *et al*., 2021). Besides, the physico-chemical properties of starch transform performing treatment via reaction with macronutrients like lipids and proteins, and this gives a significant result on the texture of legume products (Lignicka & Galoburda, 2022).

To achieve greater results and obtain a set of several properties, mainly the sensory quality, and increase anti-nutrient removal, there is a need to apply legume treatment methods by combining them.

Conclusions

This study has shown the good traits of legumes using them as a source of protein. Legumes contain some anti-nutritional factors like tannins, polyphenols, phytate, and trypsin inhibitor; these may inhibit mineral absorption, induce toxicity. Accordingly, to gain beneficial nutrients from legumes, several treatments should be applied, such as soaking, dehulling, roasting, extrusion, boiling, germination, hot air drying, and fermentation which have proven to be effective. These are suitable treatments for eliminating anti-nutritional factors from legumes. Biotechnological methods are used on legumes to obtain legumes with low phytate levels. The most effective results could be gained by combining these treatments and reaching out with pleasant sensory quality and inhibited anti-nutritional factors fully from legume-based products.

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A REVIEW: APPLICATION OF FREEZE-DRYING IN MEAT PROCESSING

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Abstract
Meat products play an important role in the human diet. They are one of the main sources of proteins, trace elements, structural components, as well as vitamins that stimulate human growth and physical activity. Raw meat refers to perishable food. There are many methods of preserving the quality and shelf-life of meat products, however, in recent years, freeze-drying is becoming more and more popular, and it combines two technological steps -freezing and vacuum drying. During the process, the product undergoes dehydration by removing water to a humidity level of 2-5%. The principle of the process involves transforming the product from a frozen phase to a gaseous phase, bypassing the liquid phase. The purpose of the article is to study the possibility and relevance of the freeze-drying process in the meat industry and to examine its advantages and disadvantages, as well as the probability of growth. During this research it was revealed that in the use of freeze-drying in the meat industry for certain purposes, it is still necessary to study and adjust in order to introduce it into a particular production. However, with regard to large enterprises where various production problems often arise this technology would not only help solve these problems, but also increase the range of innovative products and expand sales markets.
Key words: freeze-drying, shelf-life prolonging, quality assessment, rehydration.

Introduction

Meat is a valuable source of nutrients such as protein, fats, iron, and zinc that are necessary for healthy growth and development of humans, but their concentration may vary depending on the type of meat and its processing type (Dal Bosco *et al*., 2022). Additionally, meat contains important fatty acids and B-group vitamins that are necessary for maintaining nervous system health (Giromini & Givens, 2023; Biesalski, 2005). For example, beef usually contains around 20% protein and 10% fat (United States Department of Agriculture, 2021), pork contains around 14% protein and 30% fat, and chicken contains around 20% protein and 2-3% fat (United States Department of Agriculture, 2018). Carbohydrates are usually present in small amounts in meat. However, it should be noted that cooking meat or industrial processing of meat can decrease its energy value (Lebret & Čandek-Potokar, 2022). It is more difficult for meat processing enterprises to meet quality standards in order to maintain the level of consumer appreciation of the safety of products. One of the methods of preserving the quality and ensuring shelf-life and nutritive value of the product and value, as well as the creation of new innovative products, is the freeze-drying process. The process combines two methods-freezing and vacuum drying. Freeze drying is the process of dehydration of a food product, during which moisture is removed from the product. Where the principle of the process is to transfer moisture from the frozen phase to a gaseous state bypassing the liquid stage (Wang *et al*., 2020). The product is quickly frozen after in a special vacuum chamber, during which the resulting condensates are immediately pumped out and removed, resulting in a product with a humidity of 2–5% (Komarova, 2020). In the food industry, such food processing methods are evaluated in the ability to swell and return the original properties of the product, also preserving its nutritive value if possible.

The freeze-drying process as a whole has many advantages, which are increasingly increasing the tendency of this process in the food industry (Harguindeguy & Fissore, 2019). *Preservation of nutrients* – the process is unique in that it preserves up to 95% of nutrients, vitamins, enzymes, biologically active substances in the product (Vetrov *et al*., 2005).

Shelf-life of products – in this process, the final moisture content of the product is 2–5%, which prevents the growth of microorganisms and allows the product to be stored for a long time in conditions of unregulated temperatures, which facilitates the production stages (Vetrov & Aniskevich, 2021).

Preservation of consumer qualities–during rehydration, the product returns its original organoleptic parameters, which increases the vastness of the use of this process in the food industry (Boicova, Alenin, & Patonina, 2020).

Low product weight–during freeze-drying process it is possible to remove 90–98% of water from the product, which significantly reduces the weight of the product. The freeze-dried product has a low weight, shape and compactness. Thus, facilitating and optimizing the processes of production chains logistics, storage (Chen *et al.*, 2020).

The rate of restoration of the original parameters–restoration of the qualities of the original product with the help of rehydration takes from 5 to 40 minutes depending on the size and pre-treatment (Ma *et al*., 2019).

Trends in the production of freeze-dried products on the global market are estimated at ~ 46.94 billion dollars in 2016 and are projected to increase at an average annual rate of 7.4% (Boicova, Alenin, &

Patonina, 2020).

The purpose of the present review is to study the possibility and relevance of the freeze-drying process in the meat industry and to examine its advantages and disadvantages, as well as the probability of growth.

Materials and Methods

The monographic method was used to summarize and analyze the information and research articles dedicated to study of the use of the freeze-drying process in the meat industry. Information published from 2005 till 2023 in total 35 full text research articles and databases were analysed and summarize. To select and analyse full text research articles and monographs Scopus, Web of Science, Science Direct and ResearchGate, Google scholar research databases were used.

Results and Discussion

The main goal of the meat industry is to provide high-quality products that are convenient for consumers. Unfortunately, ensuring product safety at all stages of the supply chain-starting from slaughter, through production and logistics, and ending with consumers-is not always achievable (Pateiro *et al*., 2021).

As mentioned earlier, meat belongs to the category of perishable products, and for various reasons, a significant proportion of the edible parts of meat products are disposed of (Bogataj *et al*., 2020).

Food waste and spoilage represent a substantial problem in today's world, too. The magnitude of this issue is significant enough to be treated as a serious concern. The problem of food loss and waste in the meat sector is particularly important from economic and environmental perspectives (Karwowska, Laba, & Szczepanski, 2021). The production of meat and meat products has a negative impact on the environment (meat has the highest emissions per kilogram of food compared to other food products), which necessitates rational management of these products throughout the entire chain (stages of production, processing, transportation, and consumption) (Karwowska, Laba, & Szczepanski, 2021).

As research on food losses and waste, with a particular focus on the meat sector, has shown: it is estimated that up to 23% of the production in the meat sector of edible parts is lost and wasted (Ishangulyyev *et al*., 2019).

The highest proportion is at the consumption stage, accounting for 64%, followed by production (20%), distribution (12%), and primary production and post-harvest processing (3.5%) (Karwowska, Laba, & Szczepanski, 2021). Losses and spoilage occur for various reasons, including improper management of raw material and product distribution, time constraints, regime constraints, logistics, trimmings, and consumer apathy (which increased particularly in 2019 due to the pandemic). These are substantial figures, especially considering that a high percentage of people worldwide lack access to nutritionally dense food, and even more so to protein (Cooper, 2023).

Given the above-mentioned subset of issues in the meat sector, it is possible to posit the potential use of freeze-drying technology on a large scale for more extensive applications. Beyond the potential to alleviate meat loss issues through the widespread use of freeze-drying technology, such as freeze-drying scraps, raw meat necessary for long-term storage and use in sausage products, highly-demanded raw materials during large-scale purchases (which could also reduce costs and simplify logistics), and other bottlenecks where spoilage and product loss most often occur. Moreover, this technology could open the potential for introducing new innovative products with enhanced protein content, such as protein snacks made from scraps, products made from inexpensive by-products, semi-prepared marinated products for grilling, ready-made meat products, and others. These products can offer consumers convenience and flexibility, making them ideal for quick meal preparation or use in culinary arts, and for long-term storage if necessary in emergency situations, without leading to waste in the long run (Chen *et al*., 2021). Considering that demand for freeze-dried products is projected to grow by 6.8% from 2022 to 2032, consumers are opting for ready meals and packaged food products for quick and easy consumption amid hectic schedules (FMI, 2022). This could also open up new markets in places where there is a need for nutrient-dense protein foods, thereby increasing productivity. Freeze drying is considered an expensive dehydration procedure for food, and for this reason, it has only been used when necessary or when the high added value of the final product could justify the costs. (Stratta *et al*., 2020).

When comparing the capital and operating costs of freeze-drying on a large scale with experimental laboratory equipment, it was found that, with the correct implementation and operation of the equipment (continuous cycle and full load), despite the total cost of the cycle for industrial sublimation drying being 25 times higher, the cost per product is six times lower due to increased productivity. This is clearly expected, as the main aim of the scaling process is to reduce costs and increase productivity (Stratta *et al*., 2020). However, there isn't much research assessing the economic data on the implementation of sublimation technology on a large scale, suggesting a need for further in-depth study of the economic aspect of implementing this equipment in the meat sector.

The product to be freeze dried must be completely

frozen. The freezing process is the first stage of the freeze-drying process, which affects the outcome of the process (Assegeheng *et al*., 2019). The speed of the process contributes to the maximum preservation of the initial properties of the product, with the help of properly formed ice crystals (Babic & Arroqui, 2009). The freezing process usually occurs up to -20 till -30 °C. The faster and deeper freezing process goes, the less ice crystals form in the product, the faster they will evaporate at the next stage of 'drying', the higher the result of the quality of the final product will be (Yang, Zhang, & Liandong, 2021). Freezing is possible both in individual aggregate equipment and in the freeze-dried equipment itself (if it has such a function) (Ciurzynska & Lenart, 2011).

In the freeze-drying equipment, the dried material supplied to vacuum pumps is under vacuum for the entire freeze-drying process (Nowak & Jakubczyk, 2020). At the beginning of this stage, air is pumped out and pressure is created. The required absolute pressure will depend on the physical characteristics of the product. If the pressure is increased, the sublimation rate will slow down and the temperature of the product will increase (Chen *et al*., 2020).

In the process of vacuum freeze-drying, heat is supplied to the product. The process is aimed at eliminating moisture. Vacuum drying occurs with a degree of vacuum below the 'triple point' (~6 mBar) (Vetrov & Aniskevich, 2021). Due to this, water (moisture) is present only in two phases – ice and steam. The vacuum allows the ice in the product to turn immediately into steam without passing through the water phase. In this process, the ice contained in the product turns into a gaseous state and accumulates inside the chamber by a condensation system (Eur food technologies, 2020). The drying temperature varies from -10 to -35 °C.

In the process of all freeze drying the products undergo their own physico-chemical changes (Figure 1).

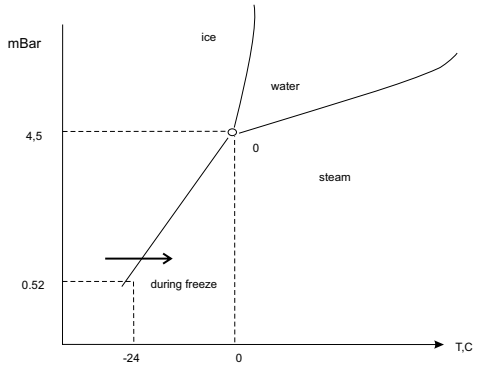

Figure 1. Physical process in products during freeze drying (Kasyanov, 2018).

The product is frozen in the solid phase. With a gradual increase in pressure and temperature, the regions in the graph are divided into 3 adjacent parts: the region of solid, liquid, and gaseous states, which all intersect at a common point-which is called the 'Triple Point' (Vetrov & Aniskevich 2021). All 3 phases have the possibility to exist, are in equilibrium with each other only at certain values of temperature and pressure of the triple point. This is followed by the transformation of the solid phase into a gaseous one with an increase in pressure and an increase in temperature to the desired totals (Wolkers, 2021).

Most products and their raw materials can be freeze-dried without significant changes in the output properties for this regulation and selection of modes of all stages from freezing to freeze-drying itself, it is necessary to know the properties of the drying object (product) itself (Kasyanov, 2018). The freeze-drying process in the meat sector depends on the quality of the products dehydrated by sublimation, which in turn depends on the initial properties of the raw materials, the conditions and modes of their technological processing, and the conditions of storage and rehydration. A key factor in the freeze-drying of meat is the selection of raw material. Likewise, the presence of a higher percentage of fat tissue can slow down the process and the quality of rehydration, as fatty acids block the pores in muscle capillaries which are important for rehydration. Multiple tests have shown that the raw material intended for drying must be well-aged, as the presence of dense connective tissue and cartilage complicates the drying of meat pieces and slows down their rehydration process. The quality of dehydrated meat depends on the level of development of autolytic processes in the raw material. Meat dehydrated in a state of rigor mortis has the worst properties. When rehydrated, it poorly absorbs water and remains tough (Zhang *et al*., 2021).

The freezing process influences not only the quality of the dried products and the duration of the drying process, but also the structure of the pores in the meat tissue. For freezing raw meat for subsequent drying, the most effective temperature reduction rate is 1-2 °C per hour; prior to sublimation, the temperature should be set 10-20 ° C below the product's eutectic point (Ma *et al*., 2018).

The shape and slicing of meat products also affect the process and its optimization. For example, to increase the drying speed and uniformity of dehydration of different pieces of meat, it is better to slice the frozen meat across the muscle fibres. In this way, freeze-drying gradually removes moisture from macro and micro capillaries and maintains the porosity of the dehydrated product, which is very important for an efficient rehydration process (Farkas & Singh, 2006).

During freeze-drying, denaturation changes in protein substances can occur, accompanied by a decrease in their solubility and decrease in enzymatic activity. As a result of these changes, the colour of the meat changes due to the conversion of myoglobin into metmyoglobin and the development of melanoidin formation reactions. The nature and depth of changes in meat properties depend on the temperature and duration of the process. The parameters depend on the type, part, and processing of the product, as well as the ultimate goal and the required final characteristics of the product (Oyinloye & Yoon, 2020). In cyclical experiments with variable pressure, the lower the pressure in the system, the faster the drying process occurs. Moreover, a variable pressure cycle contributed more to reducing the time of freeze-drying and lowering energy costs (Ma *et al*., 2019).

The freeze-drying effectively preserves and dehydrates the acidity in low-acidity products.

Water activity affects the rate of freeze-drying where when it decreases, the drying process is accelerated sodium chloride in meat facilitates and accelerates the drying process and reduces the water activity (a_w) level of the meat (Mediani *et al*., 2022).

During the drying process, structural changes occur in the muscle tissue of the raw material due to the removal of moisture. When properly set parameters are used, the moisture is gently removed through the tissue's micro and macro capillaries, leaving porosity. Muscle fibres retain their integrity compared to raw meat but become denser and shorter while preserving their cross-striation.

Research shows that the B-group vitamins contained in meat after freeze-drying are lost at approximately 5-10% compared to the levels present in the raw material (Zhang *et al*., 2021).

The freeze-drying process of meat products and its improvement vary individually especially on an industrial scale and depends on numerous factors such as physicochemical characteristics, types of meat, slaughter and cleaning, processing, the end product's purpose, and others that are especially crucial in creating new products.

Conclusions

In many segments of the food industry, the freeze-drying process is fully implemented and effectively used. As for the meat industry, many successful experiments have been carried out to modernize and ensure this process of meat processing plants, but there is no extensive use of the process in this industry at this stage.

Despite many advantages and prospects, this process is still very expensive, and it is very difficult for small and medium-sized enterprises to implement it in large volumes from an economic point of view.

With regard to large enterprises where various production problems often arise, this technology would not only help solve these problems, but also increase the range of innovative products and expand sales markets. Thus, the progressive technology still deserves its more extensive application in modern and large-scale meat processing, considering the fact that meat is an expensive and perishable product.

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CAROTENOID EXTRACT AND OIL FROM PUMPKIN (*CUCURBITTA SPP.*) BY-PRODUCTS FOR FACIAL CREAMS WITH HIGH ANTIOXIDANT ACTIVITY

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Abstract
Nowadays, different sun protective creams are available in the market, but most of them contain harmful synthetic chemicals and minerals which can induce skin allergies and premature ageing. Usage of sunscreens and photoprotectors of natural origin and natural antioxidants can reduce skin damage caused by excessive sun exposure. The effectiveness of the use of β-carotene – vitamin's A precursor against excessive irradiation caused by oxidative stress cell damages has been proven of its very good antioxidative properties and leading to sooner regeneration of the skin after several environmental damages. Carotenoids and high value oil can be extracted from pumpkin (*Cucurbitta* spp.) by-products – peel and seeds with SC CO_2. The objective of this study was to incorporate pumpkin seed oil (PSO) and carotenoid extract (CE) from pumpkin by-products in to facial creams for UV protection. Two types of creams with PSO and CE were prepared emulsion o/w and w/o. A cream without extracts and natural ingredients was used as control sample. The sun protection factor values *in vitro* (SPF = 0.92 to 1.18), total content of carotenoids (TCC = 1.08–17.95 μg mL^{-1}), β-carotene content (0.64–0.72 μg mL^{-1}), total phenolics content (TPC = 62.64–95.82 mg GAE g^{-1}), antiradical scavenging activity (11.26–43.66 %) and rheological behaviour of facial creams were determined. Although creams with CE and PSO show comparatively low SPF values, ß-carotene and phenolic compounds found in samples demonstrated very high antioxidant abilities valuable for skin protection.
Key words: antioxidants, SC CO_2, ß-carotene, by-products, pumpkin, sun protection factor.

Introduction

Skin damage is induced in various ways – through environment, consumption of unhealthy food, drugs, alcohol and nutrient deficiency, exposure of solar radiation (Rasul *et al*., 2011). The effects of excessive irradiation include the development of wrinkles, loss of skin firmness, phototoxic and photoallergic reactions, increased risks of developing various forms of skin cancer (Arct & Mieloch, 2020). Therefore, it is crucial to prevent photo ageing and protect human skin from sunburns and to use moisturizers in form of creams, tonics or gels (Rasul *et al*., 2011). Additional value to cream formulations can be given by including active ingredients with specific cosmetic or dermatological effects, essential oils, antioxidants in form of carotenoids (Rodoplu *et al*., 2021). For example, plant extracts, vegetable oils and essential oils are rich sources of provitamins, pigments, pyrazine (Sabir *et al*., 2005), squalene (Idouraine, Kohlhepp, & Weber, 1996), saponins, phytosterols, triterpenoids (Černiauskiene *et al*., 2014), phenolic compounds, unsaturated fatty acids (Sabir *et al*., 2005), flavonoids and proteins (Akhtar, Iqbal, & Nawazish, 1980). Lutein, α-carotene and β-carotene, violaxanthin, neoxanthin, zeaxanthin are the main carotenoids in vegetables, and they are prone to isomerization and/ or oxidation due to their unsaturation (Murković *et al*., 2004).

Carotenoids have been extensively studied because of their beneficial effect on human health. Carotenoids, such as β-carotene and lutein are transformed by the body into the important antioxidant - vitamin A, violaxanthin, neoxanthin, xanthophylls (Soengas *et al*., 2011). Vitamin E, including both ɣ-tocopherol and α-tocopherol, has important antioxidant properties and health benefits (Henriques, Guiné, & Barroca, 2012; Rawson *et al*., 2013; Secil & Berrin, 2011; Seo *et al*., 2005). Carotenoids reduce the risk of different diseases (Berna *et al*., 2011), act as singlet oxygen quenchers (Kuncewicz, 2008; Hughes, 2000) and function as chain-breaking antioxidants, protecting cells from free radical attack (Munarin, Tanzi, & Petrini, 2012). In epidermis, β-carotene is transformed into retinol and its esters, it is very well tolerated by the skin; therefore, these properties qualify this compound as a particularly valuable active ingredient in protective and anti-ageing cosmetics (Arct & Mieloch, 2020). Systematic sun screening agents used are ß-carotene, α-tocopherols, retinol, green tea polyphenols (Latha *et al*., 2013).

ß-carotene is a structural analogue of vitamin A (Patil *et al*., 2009) and is found in various fruits and vegetables mainly in dark orange and red coloured plants (Hughes, 2000). Pumpkins (*Cucurbitta* spp. L) are rich sources of carotenoids (Sook *et al*., 2005), Total content of carotenoids (TCC) in the peel and pomace was 68.07 mg $100g^{-1}$ to 91.28 mg $100g^{-1}$ (Konrade *et al*., 2018). Pumpkin seed oil is rich in unsaturated fatty acids (Seo *et al*., 2005), such as oleic acid, linolic acid, palmitic and stearic acid. Under the influence of sunlight, extraction temperature and oxidation, the pigments can be destroyed and have less protection efficiency (Soengas *et al*., 2011).

Carotenoids and high value oil can be extracted from pumpkin (*Cucurbitta* spp.) by-products – peel and seeds with SC CO_2.

The objective of this study was to incorporate pumpkin seed oil (PSO) and carotenoid extract (CE) from pumpkin by-products in to facial creams for UV protection and determination *in vitro* sun protective

factor values, total content of carotenoids, ß-carotene, antioxidant scavenging activity, the total phenolic compounds content and rheological behaviour of facial cream samples.

Materials and Methods

Pumpkin (*Cucurbita pepo* L, Pink Banana Jumbo) by-products – peel and pomace were obtained from Lat Eko Food Ltd., 2021. For formulation of facial creams (Table 1) were used the following: pumpkin seed oil (PSO) and carotenoid extracts (CE) from peel extracted with supercritical CO_2 (Konrade & Spalvins, 2022); bee wax; cacao seed butter (La Saponaria, L221879); shea butter (La Saponaria, 221451 06-24); calendula oil (Farfalla, NO1F000); cetyl, glycerol, Tween80 and Span80 (Sigma Aldrich, Germany).

Carotenoid extract is water-insoluble and thus was used as an oil phase in the test formulations (Akhtar, Ahmed, & Mahmood, 2008). Cetyl and water were used as aqueous phase in formulations (Korhonen *et al*., 2001; Mbanga *et al*., 2014).

Table 1

Formulation of facial creams

Ingredients	C1.1*.	C1.2*.	C2.1**.	C2.2**.	Control**
Span80, g	-	-	-	-	6
Tween80, g	-	-	-	-	6
Bee wax, g	6	6	6	6	6
Cetyl, g	-	-	2	2	2
Glycerol, g	-	-	3	3	3
Pumpkin seed oil, mL	-	1.5	-	1.5	-
Carotenoid extract, mL	-	2	-	2	-
Cacao seed butter, g	6	6	6	6	-
Shea Butter, g	6	6	6	6	-
Calendula oil, g	6	2.5	6	2.5	6
Water, mL	-	-	18	18	18

creams – *oil/ water; ** – water/oil

Determination of ß-carotene and total content of carotenoids (TCC)

To determine ß-carotene content and total content of carotenoids (TCC) 1±0.01g of each sample was separately homogenized with 10 mL of solvent for 2 minutes (acetone and hexane (2:3) were used for ß-carotene determination, and cyclohexane was used to determine TCC). The samples were sonicated for 3 minutes (Ultrasound processor Hielscher Ultrasound Technology, Ultrasonic Processor UP200S), vortexed and absorption at different wavelength was read: for ß-carotene absorption was read at λ = 453; 505; 663 and 645 nm; and for TCC at λ = 456 nm. The absorption coefficients ($A_{1cm}^{1\%}$) of common food carotenoids were used for calculations. (Braniša *et al*., 2014; Konrade & Spalvins, 2022).

Calculation for ß-carotene (μg mL^{-1}) (Equation 1).

ß-carotene = C (0.216 A_{663}-1.22 A_{645}-0.304 A_{505} + 0.452 A_{453}), where: (1)

C = concentration of sample, mg mL^{-1}, A = absorbance, nm (Braniša *et al*., 2014).

TCC was calculated from Equation 2.

$$TCC = \frac{A}{2505C}, \mu g\ mL^{-1} \quad (2)$$

TCC – total content of carotenoids;

2505 – coefficient of extinction ($E^{1\%}$);

A – absorbance at 456 nm;

C – concentration of sample solution, mg mL^{-1}.

Determination of total phenolic compounds (TPC)

Total phenolic compounds (TPC mg GAE g^{-1}) were determined according to the Folin-Ciocalteu Colorimetric Method with minor modifications (Kampuss *et al*., 2009; Priecina & Karklina, 2014).

20±0.1 mg of the sample was extracted with acetone and ethanol (1:1) in a 100 mL volumetric flask in a US bath for 10 min. 2.5 ml of Folin-Ciocalteu reagent (diluted 10 times with water) was added to 0.5 mL of the extracted sample in test tubes and after 3 minutes 2.0 ml of 10% saturated sodium carbonate solution was added. The resulting solution was mixed and allowed to stand for 30 min at 20 ± 1 °C in the dark, afterwards, the absorbance was read at 765 nm.

Gallic acid (0–100 mg L^{-1}) was used to calibrate the standard curve.

The results were expressed as milligram gallic acid equivalent per 100 g of sample (mg GAE 100 g^{-1}).

Quantification of TPC was based on a standard curve (Equation 3).

$$y = 0.0875x+0.0676, R^2 = 0.998, \quad (3)$$

y – total content of phenolics, TPC, mg GAE 100g^{-1}, x – Absorption at λ = 765nm, R^2 – coefficient of determination.

Antiradical scavenging activity determination

Antiradical scavenging activity was determined with the method based on scavenging activities of the stable 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical. 4 ± 0.01 mg DPPH reagent was dissolved in 100 mL MeOH (solution concentration – 40 µL mL^{-1}) (Kruma *et al*., 2016; Tirzitis & Bartosz, 2010). 200 µL DPPH reagent was mixed with 200 µL of sample extract in a test tube, incubated at room temperature for 30 min, and, after incubation, the absorbance was measured at λ = 514 nm. The antiradical scavenging activity (A, %) of selected material was expressed (Equation 4).

$$A = \frac{(Abs1\text{-}AbsS)}{Abs1} * 100, \% \quad (4)$$

A – antiradical scavenging activity, Abs1 – absorbance of blank, AbsS – absorbance of sample extract.

2,2-diphenyl-1-picrylhydrazyl reagent (Sigma-Aldrich (Germany), CAS Number 1898-66-4), Gallic acid monohydrate (3,4,5-trihydroxybenzoic acid monohydrate), Folin-Ciocalteu′s phenol reagent (Sigma-Aldrich, Cat. No. F9252), sodium carbonate, (Merck, Cat No. 106392) were used for determination of TPC and antiradical scavenging activity.

Sun protection factor values determination in vitro

In *vitro* sun protection factor (SPF) values determination was performed with method described by Mbanga (2014) with minor modifications: 0.1±0.01g of sample was diluted with ethanol (96% concentration) to 100 mL in volumetric flask, sonicated for 5 min, filtered and the absorption spectra of samples in solution were measured every 5 nm in the range of 290 to 320 nm (Mbanga *et al*., 2014).

Triplicate determinations were performed at each point using ethanol as a blank. SPF values were determined using the Mansur equation (Equation 5).

$$SPF = CF \times \sum_{290}^{320} (EE(\lambda) \times I(\lambda) \times Abs(\lambda)), \quad (5)$$

where EE – erythemal effect spectrum; I – solar intensity spectrum; Abs – absorbance of sunscreen product (λ); CF – correction factor (CF = 10). EE * I are constants (Sayre *et al*., 1979) (Table 2).

Table 2

Calcuion of SPF (Mbanga *et al*., 2014)

Wavelength (nm)	EE * I (normalized) (Sayre et al., 1979)
290	0.0150
295	0.0817
300	0.2874
305	0.3278
310	0.1864
315	0.0837
320	0.0180

Antioxidant activity, sun protective factor values (SPF), ß-carotene and total content of carotenoids (TCC) in *vitro* of cream samples were measured with UV/ Visible Spectrophotometer, M501 Single Beam (Campsec UV, United Kingdom), equipped with 1 cm quartz cell.

Rheological measurements of facial creams

Rheological properties of facial creams were determined with Modular Compact Rheometer Anton Paar, Smart Pave 102, Germany, the amplitude sweep mode, with constant oscillation, and angular frequency of 10 rad s^{-1}. In this mode, the shear deformation is changed. G' – the storage modulus, G'' – the loss modulus, and loss factor, $\tan(\delta) = G''/G'$ were determined with shear rate from 0.1 to 100 s^{-1} at 25 °C (Dabbaghi *et al*., 2021; Zhang *et al*., 2016).

Data Analysis

All measurements were performed on three independent samples (n = 3) and results were expressed as mean values ± standard deviation (SD). A mathematical analysis of the data has been performed using MS Excel Data Analysis, ANOVA, a Single-factor, correlation and regression analysis were used. The proposed hypotheses had been tested with the p-value method and the factors had been evaluated as significant if $p < \alpha = 0.05$. Analysis of variance used the Tukey and Friedman test to justify differences in results between the studied samples.

Results and Discussion

Antioxidants have important protective factor effects on skin (Mbanga *et al*., 2014; Rasul *et al*., 2011; Rawson *et al*., 2013). Their main role is to scavenge free radicals such as peroxides that contribute to tyrosinase activation and melanin formation; therefore, facial creams were tested for total phenolic compounds (TPC) and antiradical scavenging activity. β-carotene content and its antioxidant activity in biological systems is one of the most valuable active ingredients used in cosmetics as β-carotene reveals potent antiradical activity properties. Furthermore, it is one of the few agents that effectively neutralizes the singlet form of oxygen (Arct & Mieloch, 2020). β-carotene content in the skin is low, and exposition to sunlight reduces the content of this compound in the skin. In our previous studies of carotenoid and chlorophylls content in extracts from pumpkin peel TCC reached 32.43 ± 2.09 μg mL^{-1}, ß-carotene content was 5.37 ± 1.12 μg mL^{-1} Moreover, these extracts contained lutein, zeaxanthin, Chl a, Chl b (Konrade & Spalvins, 2022). Though carotenoids are very sensitive to temperature changes and light exposure, incorporated into facial creams there was found higher sun protective factor values (SPF) for facial creams with carotenoid extract (CE) and pumpkin seed oil (PSO) than in Control from Tween80 and Span80. SPF values of prepared cream samples and control is attached in Figure 1.

Ultraviolet radiation (UVA (320 – 400 nm), UVB (290 – 320 nm) and UVC (200 – 290 nm) is the primary environmental factor that seriously affects human skin and β-carotene reveals strong antioxidative properties that enable it to effectively neutralize two most reactive oxygen species: molecular singlet oxygen and superoxide radicals. Moreover, β-carotene is nearly 50 times more effective than α-tocopherol (Arct & Mieloch, 2020).

There were significant differences of SPF values in all samples of creams ($p = 0.006 < 0.05$).

Highest SPF was determined for creams C1.2. with carotene extract and pumpkin seed oil, C2.2. showed lower SPF, while Control was the lowest SPF (Figure 1).

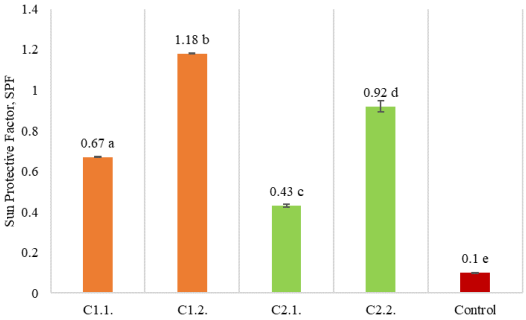

Figure 1. Sun protective factor values (SPF) for facial creams and Control sample.
Different letters (a, b, c, d, e) indicate significant difference among samples ($p < 0.05$). The data is presented as a mean (n = 3).

Pumpkin seed oil (PSO) is valuable source of phenolic compounds as tyrosol, vanillic acid, vanillin, luteolin and sinapic acid having high antioxidant activities (Mala & Kurian, 2016). PSO showed antiradical scavenging activity (DPPH assay) 20.2% and high content of TCC (47.67 ± 2.09 μg mL^{-1}), especially ß-carotene and lutein (Konrade & Spalvins, 2022).

TCC, β-carotene, TPC content and antiradical scavenging activity of creams are summarized in Table 3.

There were significant differences in TCC and β-carotene content ($p<0.05$) among samples; furthermore, β-carotene was not detected in Control and in samples C1.1., C2.1., though, showing little amount of TCC because of chemical composition of calendula oil (Miguel *et al*., 2004) and bee wax. Phenolic compounds (TPC) were not detected in Control sample (Table 1) and samples without carotenoid extract and pumpkin seed oil (C1.1. and C2.1.), while in samples with carotenoid extract and pumpkin seed oil TPC were 95.82 ± 1.18 mg GAE g^{-1} for sample C1.2. (o/w) and 62.64 ± 2.14 mg GAE g^{-1} for C2.2. (w/o). According to researchers, Folin Ciocalteu reagent can react non-specifically with phenolic compounds;

Table 3

Total Content of Carotenoids, β-carotene, Total Phenolics Content and Antiradical Scavenging Activity of Facial Creams

	C1.1.	C1.2.	C2.1.	C2.2.	Control
TCC, μg mL^{-1}	3.04 ± 0.03^{a}	17.95 ± 1.14^{c}	1.08 ± 0.03^{b}	12.22 ± 0.03^{d}	n.d.
β-carotene, μg mL^{-1}	n.d.	0.72± 0.11	n.d.	0.64 ± 0.03	n.d.
TPC, mg GAE g^{-1}	n.d.	95.82 ± 1.18^{a}	n.d.	62.64 ± 2.14^{b}	n.d.
Antiradical scavenging activity, %	15.49 ± 1.06^{a}	43.66 ± 2.76^{c}	11.26 ± 0.82^{b}	36.62 ±2.99^{d}	n.d.

Different letters in rows (a, b, c, d) indicate significant difference among samples ($p<0.05$). Each sample was prepared and subsequently analysed in triplicate (n = 3), ± standard deviation (SD), n.d. – not detected.

it can also be reduced by a number of nonphenolic compounds, e.g., vitamin C, Cu (II), etc. (Tomsone, Kruma, & Galoburda, 2012).

Strong correlation between TPC and DPPH (R^2 = 0.987), TPC and SPF (R^2 = 0.952), DPPH and SPF (R^2 = 0.985) was found.

The rheological parameters can be influenced by several factors such as the chemical composition and temperature (Faustino & Pinheiro, 2021). Cosmetic products require different rheological behaviour for different testing: texture, spreadability, foamability, washability, texture (Yao & Patel, 2001); therefore, rheology can be applied to help in formulation on consistency; prediction of flow behaviour under manufacturing or production environment conditions. Furthermore, rheological analysis is more suitable for the storage stability as sensory (Korhonen *et al*., 2001). Rheological properties of UV protecting facial creams and Control sample are attached in Figure 2.

Figure 2 a) shows plots of complex viscosity (CV), Figure 2 b) shows results of loss factor for samples – the behaviour of emulsions under similar conditions was different, sample w/o without carotene extracts was of the highest loss factor, when tan δ > 1 (G″ > G′). Therefore, viscous properties and a liquid-like or fluid state prevail (Simões *et al*., 2020). There were no differences in complex viscosity and storage modulus or elasticity of creams. Behaviour was similar for all samples as all samples showed similar results. Figure 2 c) shows plots of shear stress – sample 2.1. without extracts (w/o) showed highest shear stress. Figure 2 d) gives information about storage modulus – elasticity of samples, samples without CE and PSO remained more elastic, though more studies and experiments are necessary for evaluation of rheological properties to obtain samples for good viscoelastic and sensory attributes.

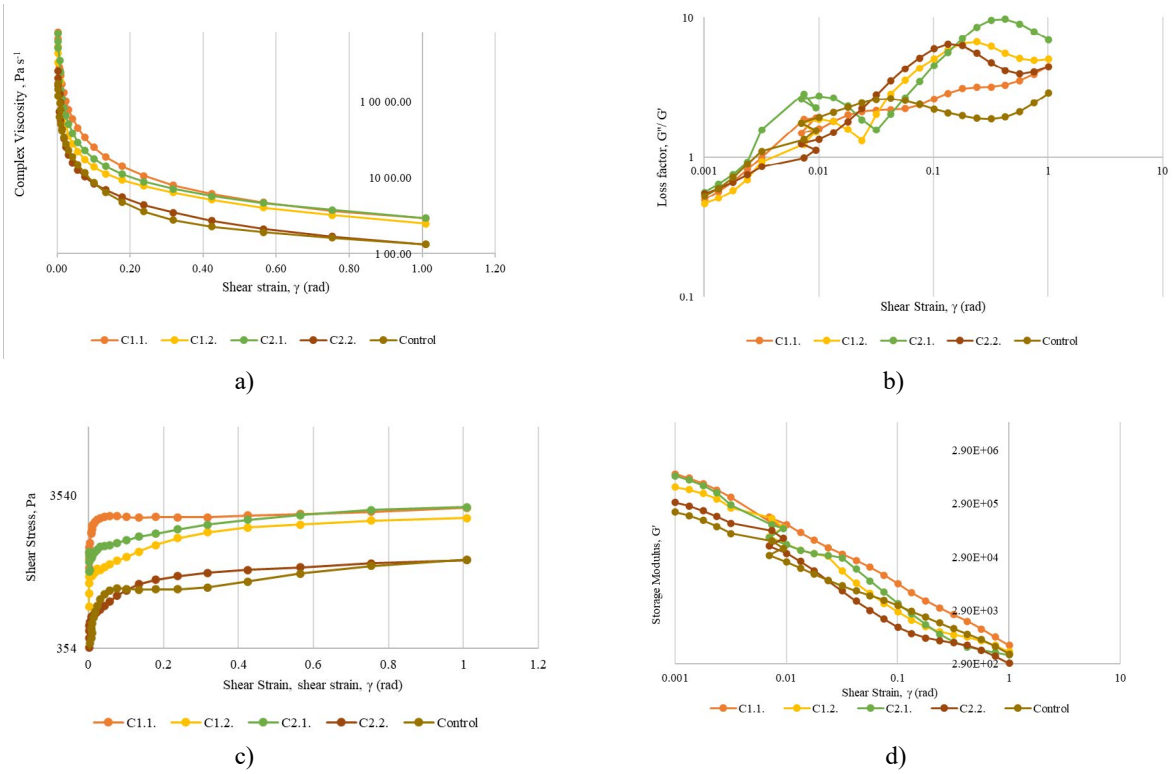

Figure 2. Rheological properties of creams:
a) – Complex Viscosity; Pa s^{-1}, b) Loss Factor tan δ = G''/ G'; c) Shear Stress, Pa; d) Storage Modulus G´.

Conclusions

Facial creams with added carotenoid extracts and pumpkin seed oil showed high antioxidative properties due to their total phenolic content. Sun protective factor value was high in comparison to those without carotenoid extracts and pumpkin seed oil addition. Effectiveness would be considerable when such creams are used for skin protection as the content of total carotenoids and especially ß-carotene was high. In terms of rheological properties, there was no significant difference between the control sample containing Tween80 and Span80 and between the samples containing natural origin raw materials with carotenoid extracts and pumpkin seed oil.

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DETERMINING OPTIMAL CONDITIONS FOR GROWING RECOMBINANT VECTORS TO BE USED IN DEVELOPING A BOVINE TUBERCULOSIS VACCINE

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Abstract
Two recombinant influenza A virus vectors expressing the ESAT 6 and TB10.4 mycobacterial proteins from the non-structural (NS) gene were constructed via reverse genetics technique to develop a specific means of prophylaxis for bovine tuberculosis.
We experimented to determine optimal conditions for growing recombinant vectors in Vero cell culture and chick embryos.
This study established that the maximum amount of virus builds up in a Vero cell culture with the Dulbecco′s Modified Eagle′s Medium (DMEM) serum-free medium. However, using cell culture to produce vector vaccines is labour-intensive and inefficient. An alternative way, a traditional, time-tested technique, is provided by growing samples in chick embryos. One of the advantages of this technique is its affordability and availability, enabling easy scale-up of vaccine production.
In the optimization experiments, the FLU-ΔNS_ESAT 6 and FLU-ΔNS_TB10.4 viruses constructed were inoculated into 10-day-old chick embryos. It was determined that the optimal incubation temperature that led to the highest virus build-up was 37 ± 0.5 °C. And the infectious activity level of the FLU-ΔNS_ESAT 6 recombinant vector was at 8.95 ± 0.07 log10EID_{50} 0.2 cm^{-3}, while that of the FLU-ΔNS_TB10.4 was at 9.20 ± 0.07 log10EID_{50} 0.2 cm^{-3}, what was provided by infectious doses of 1000–10000 EID_{50}, which makes it possible to create a virus-containing material with a hemagglutination activity level of 1:64.
The size of recombinant vector amplicons expressing proteins TB10.4 and ESAT 6 was 1170 bp and 1175 bp, respectively. Electron microscopy images confirm that the developed virions are morphologically similar to the avian influenza virus.
Key words: vector vaccines, *M. bovis*, proteins, recombinant vector, Vero cell culture, chick embryos.

Introduction

Vector vaccines are a safe type of vaccine used for preventing infections both in humans and animals (Buzitskaya *et al*., 2022). The use of an influenza vector's genetic structure is characterized by a truncation of the translated region of the NS1 protein by 50% and a replacement of its carboxyl portion with a sequence that encodes tuberculosis proteins. The choice of the target proteins is determined by the fact that these proteins are expressed at different phases of the mycobacterium's life cycle and contain characterized epitopes recognizable by CD4+ and CD8+ cells for a balanced cell-type protective immune response (Sergeeva *et al*., 2017).

Out of a great variety of proteins encoded by *M. tuberculosis* epitope genomes, only a small group is directly involved in the onset and development of the disease. The ESAT 6, TB10.4, and HspX mycobacterial proteins are highly noteworthy among this group. These proteins are the most effective immunogens widely used as potential candidates for heterologous vaccination worldwide. They are predominantly utilized in vector and DNA vaccines. These proteins are present in the *M. bovis* strain of the Bacillus Calmette-Guérin (BCG) vaccine and can be administered as a booster vaccine. Additionally, they are not incorporated into contemporary diagnostic test systems (Kuchur, 2018).

Until today, Kazakh researchers have not undertaken studies to develop a bovine tuberculosis vaccine. This poses a real nationwide biosecurity threat of a potential panzootic. The Research Institute for Biological Safety Problems has started working on a vaccine for bovine tuberculosis of the *M. bovis-8* strain to tackle this. Determining optimal conditions for growing recombinant vaccine vectors and enhancing their build-up is an important step in these efforts.

There are known techniques utilized to increase the amount of influenza virus in cell cultures during standard processes of producing influenza vaccines (Jawinski *et al*., 2019). However, influenza vaccines produced using cell cultures have significant limitations in production upscaling. This requires an alternative technique, such as one involving chick embryos (Sedova *et al*., 2012).

This study aims to determine optimal conditions for growing recombinant vectors in Vero cell culture and various days-old chick embryos to develop a vector vaccine for bovine tuberculosis.

Materials and Methods

Recombinant vectors construction

The recombinant vectors expressing the ESAT 6 and TB10.4 *M. bovis* proteins were constructed through reverse genetics in proportion genes with 5:3 H5N1 reassortants. Interferon-deficient Vero cells were transfected with a set of 8 plasmids expressing avian influenza proteins by using a Cell Line Nucleofector® Kit (Lonza, USA) (Hoffmann *et al*., 2002). Influenza virus genes were cloned into the pHW2000 plasmid. These included PB1, PB2, PA, NP, and a chimeric NS gene expressing *M. bovis* proteins ESAT 6 and TB10.4 from the A/Puerto-Rico/8/34 (H1N1) strain; hemagglutinin (HA) and neuraminidase (NA), as well as the M gene taken from the recombinant A/chicken/Astana/6/05(H5N1) strain. The synthesis and cloning were conducted at Evrogen LLP, Moscow.

Growing influenza vectors in Vero cell cultures

Vero cell cultures were acquired from the American Type Culture Collection (Sereinig *et al*., 2006).

To determine the optimal incubation temperature, the Vero cell cultures were inoculated with the FLU-ΔNS_ESAT 6 and FLU-ΔNS_TB10.4 viruses at a dose of 1000 log10$TCID_{50}$ cm^{-3} at 37 ± .5 ℃. They were then incubated at 37 ± 0.5 ℃, 33 ± 0.5 ℃ and 35 ± 0.5 ℃ and relative air humidity of 55 ± 5% with an access of 5% carbon dioxide for 24, 48, 72 and 96 hours (Ferko *et al*., 2001; Sergeeva *et al*., 2017).

Growing influenza vectors in chick embryos

Influenza vectors were grown in 10-, 11-, and 12-days old chick embryos delivered from local poultry farms free from avian influenza. Chick embryos were inoculated into the allantoic cavity with a virus in a volume of 0.2 cm^3 and checked daily by ovoscopic method using an ovoscope. The death of an embryo within the first 24 hours was considered non-specific, and such embryos were discarded. At the end of the incubation period, inoculated eggs were cooled at 2–8 °C for 16–18 hours. Embryos were inoculated via the allantoic cavity in doses of 100 to 1000000 EID_{50} to determine the optimal inoculating dose.

Determining biological activity of recombinant vectors in Vero cells

Biological activity was determined by limited dilution assay in Vero cells. The cells were seeded into 96-well plates and left to grow for 24 hours until they formed a complete monolayer. Afterwards, the cell culture medium was removed and washed 3 times with this same medium. Samples were applied to the wells in four repeats with a 10-fold dilution (0.2 cm^3 $well^{-1}$). Titers were calculated each day using the Reed-Muench method, and the results were reported as 50% tissue infectious dose ($TCID_{50}$ cm^{-3}) Reed & Muench, 1938; Korochkin *et al*., 2010).

Assessing infectious activity of recombinant vectors grown in chick embryos

The infectious activity was determined by titration on 10-12 days-old chick embryos. Embryos were infected into the allantoic cavity with a 10-fold dilution of 0.2 cm^3 in four repetitions. Infected embryos were incubated for 72 h at 26, 34, 35, 36 and 37 ± 0.5 °C, then cooled at 2–8 °C for 16–18 h. The infectious activity was calculated using the Reed-Muench method, and the results were reported as a 50% embryonic infectious dose of the virus (EID_{50} 0.2 cm^{-3}). The hemagglutination titer was determined by the hemagglutination assay. The hemagglutination titer shows the limiting dilution of the virus that causes complete agglutination of rooster erythrocytes (Reed & Muench, 1938; WHO, 2002).

PCR

The molecular weight of the chimeric NS segment of the generated recombinant vectors was analyzed by RT-PCR using a direct primer – AGCAAAAGCAGGGTGACAAAG and reverse primer – GAAACAAGGGTGTTTTTTATTA TTAAAT (Abay *et al*., 2023).

Electronic microscopy

Samples were adsorbed on Formvar-coated grids stabilized with carbon. Negative contrasting was carried out using a 2% phosphorus-tungsten water solution, and a microscopy examination was done using a transmission electron microscope JEM-100 CX-II (JEOL, Japan) at an accelerating voltage of 80 kV at 100000 magnifications. Photos were made from developed and fixed negatives on an Azov enlarger.

Statistical analysis

In this study, average values and the standard error of the examined parameters were determined. The significance of variance between results was determined in GraphPad Prism 8 (GraphPad Software, Inc., La Jolla, CA, USA) statistics software. A $P < 0.05$ was considered as significant.

Results and Discussion

A reverse genetic engineering technique was used to construct the FLU-ΔNS-ESAT6 and FLU- ΔNS_TB10.4 recombinant vectors (5:3 H5N1 reassortants with a modified HA cleavage site) with an NS chimeric genome fragment that encodes protective *M. bovis* proteins within the NS1 truncated protein's reading frame. Influenza virus genes were cloned into the pHW2000 plasmid (Figure 1).

Figure 1 shows a map of the pHW-NS-ESAT 6 plasmid encoding a modified NS gene of the A/Puerto Rico/8/34 virus (H1N1), into which a sequence of *M. bovis* protein ESAT 6 was inserted (after 124th aminoacid) (A); and the pHW-NS-TB10.4 plasmid encoding a modified NS gene of the A/Puerto Rico/8/34 virus (H1N1), into which a sequence of *M. bovis* proteins TB10.4 was inserted (after 124th amino acid).

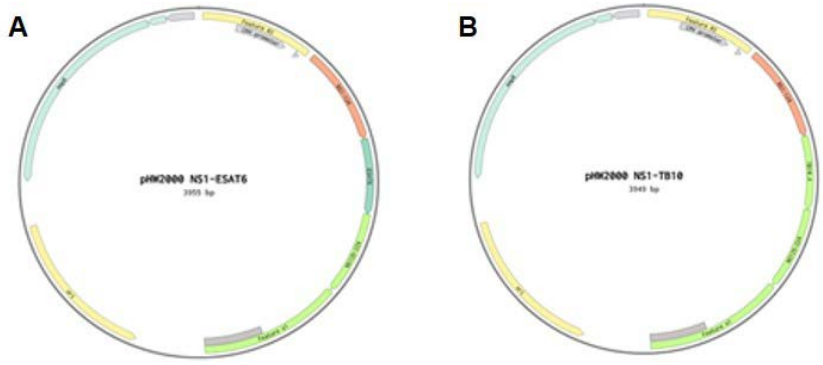

Figure 1. Map of FLU-ΔNS – ESAT 6 (A) and FLU-NS_TB10.4 (B) recombinant vectors in the pHW2000 plasmid.

A portion of transfected material was passed into cell cultures while the other portion was used to inoculate chick embryos. The culture and allantoic fluid samples obtained at this stage contained a 'zero' passage of viral samples.

The first signs of cytopathic activity in the Vero cell culture for both samples began to show 36 hours after transfection. In 48 hours, the cell monolayer was completely destroyed as a result of viral cytopathic activity (Figure 2). The presence of recombinant viruses in culture fluid samples through a hemagglutination assay (HA) were confirmed.

Then, an assessment of optimal conditions for growing viruses after transfection was performed. A day after inoculating a cell culture with the viruses, no significant cytopathic activity was observed. The first signs of cytopathic activity in the Vero cell cultures appeared after 48 hours of incubation. In 72–96 hours, the Vero cell monolayer in both cultures was completely destroyed due to viral cytopathic activity (Figure 2).

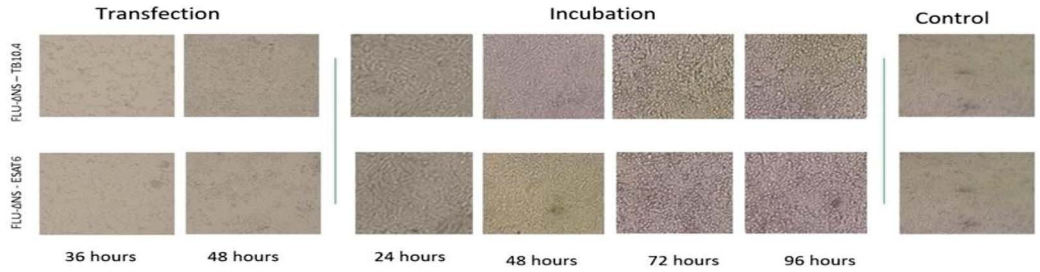

Figure 2. The cytopathic activity of recombinant influenza viruses in a Vero cell culture after transfection. The image was made on a light MicroOptix microscope at a 10x magnification.

As seen in Figure 2, recombinant strains were inoculated into Vero cell culture. The activity of the virus manifested itself starting from 48 hours, and by 96 hours of incubation, destruction of the cell monolayer was observed.

Then, several passages of recombinant vectors were performed on the Vero cell cultures to assess the virus's biological activity at each passage and different incubation temperatures (33 ± 0.5 °C, 35 ± 0.5 °C, 37 ± 0.5 °C) were examined to establish the optimal one (Figure 3).

Thus, after the incubation of recombinant vectors at various temperatures, cytopathic activity was observed in the Vero cell culture at 37 ± 0.5 °C.

Recombinant vectors' infectious activity was observed at several temperatures. However, the temperature of 37 ± 0.5 °C was optimal for incubating the vectors in the Vero cell culture monolayer because it provided the highest infectious activity, which averaged 7.50 ± 0.08 log10TCID$_{50}$ cm^{-3} for FLU-ΔNS_ESAT 6 and 7.75 ± 0.08 log10TCID$_{50}$ cm^{-3} for FLU-ΔNS_TB10.4 (Figure 3, A).

Then, experiments were conducted to assess the optimal duration of incubating recombinant vectors in a Vero cell culture monolayer. Inoculated Vero cell cultures were incubated for 24, 48, 72 and 96 hours at 37 ± 0.5 °C with relative air humidity of 55 ± 5% (Figure 3, B).

Vector growth in the Vero cell cultures was analyzed, and cytopathic activity was observed to occur in 48 hours and last for 96 hours. Both vector samples had their biological activity peak at the 72nd

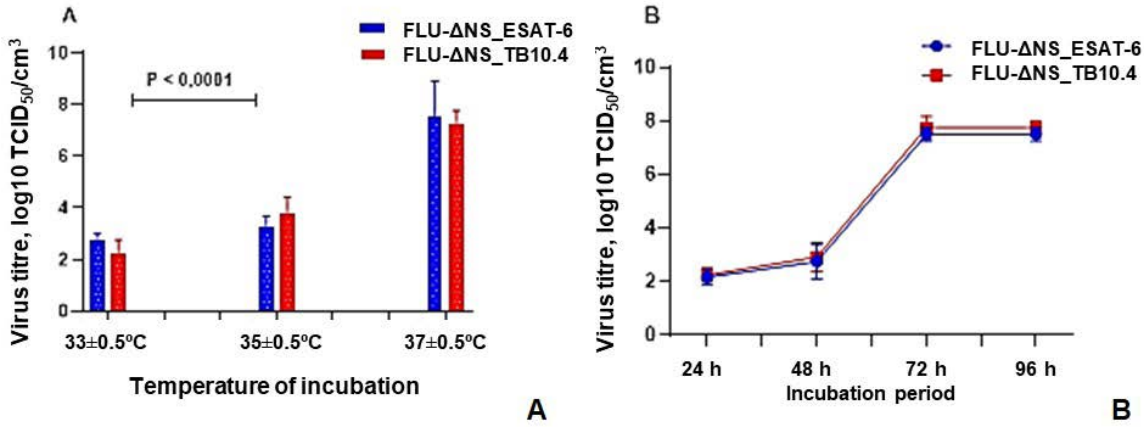

Figure 3. Selection of optimal cultivation parameters in Vero cell culture. (A) Optimal incubation temperatures (33, 35 and 37 ± 0.5 °C). (B) Biological activity levels vs duration of incubating recombinant vectors in a Vero cell at 37 ± 0.5 °C.

hour of the experiment and maintained it for 96 hours. The biological activity of FLU-ΔNS_ESAT 6 was at 7.50 ± 0.08 log10TCID$_{50}$ cm^{-3}, and that of FLU-ΔNS_TB10.4 was at 7.75 ± 0.08 log10TCID$_{50}$ cm^{-3}.

In the above experiments, the maximum damage to the monolayer in the Vero cell culture occurred after 72 hours of incubation in a DMEM serum-free nutritive medium in a CO_2 incubator at 37 ± 0.5 °C with 5% CO_2 access.

To assess the optimal conditions for incubating recombinant vectors in chick embryos, the optimal age of embryos had to be determined. At the same time, the impact of incubation temperature on the amount of recombinant vector build-up was assessed. Inoculated chick embryos were incubated at various temperatures (26, 34, 35, 36 and 37 ± 0.5 °C) in a relative air humidity of 55±5% and incubated for 72 hours (Figure 4). Experiments involving incubation at 26 ± 0.5 °C and 34 ± 0.5 °C yielded negative results as almost no viral growth was observed in these temperatures.

As shown in Figure 4, the FLU-ΔNS_ESAT 6 and FLU-ΔNS_TB10.4 recombinant vectors were inoculated into embryos, and the embryos did not die during the incubation. The highest build-up amounts were observed in 10 days old embryos incubated at 37 ± 0.5 °C. The FLU-ΔNS_ESAT 6 recombinant vector showed a high hemagglutination activity level (of 1:64) with the infection activity at 8.95 ± 0.07 log10EID$_{50}$ 0.2 cm^{-3}. The FLU-ΔNS_TB10.4 recombinant vector also had its hemagglutination activity level at 1:64, while its infectious activity was at 9.20 ± 0.07 log10EID$_{50}$ 0.2 cm^{-3}.

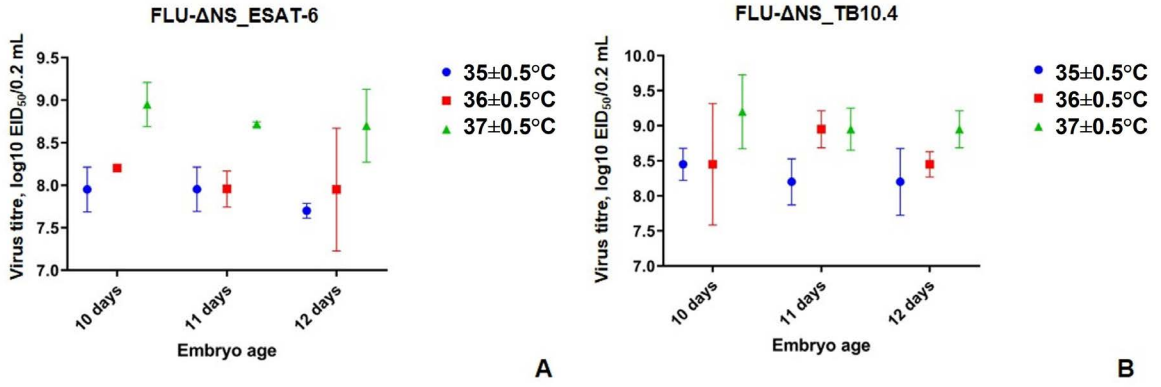

Figure 4. Characteristics of recombinant vectors' growth in 10-, 11- and 12-day' chick embryos and incubated at 35.0, 36.0 and 37.0 °C ± 0.5. (A) growth of FLU-ΔNS_ESAT 6. (B) growth of FLU-ΔNS_TB10.4. The infectious titres are expressed in EID$_{50}$ cm^{-3}.

The rate of virus build-up was determined to be associated with the inoculating dose. The experiment used the following incubation parameters: temperature of 37 ± 0.5 °C, relative air humidity of 55 ± 5%, and

chick embryos age of 10 days. The embryos were inoculated via the allantoic cavity in doses of 100 to 1000000 EID_{50} (Table 1).

All of the above doses (with the other incubating parameters remaining the same) led to an increase of both the infectious activity (from 7.45 ± 0.14 to 9.20 ± 0.12 log10EID_{50} cm^{-3}), and hemagglutination activity (from 1:16 to 1:64). However, the use of minimal doses (10 and 100 vs. ≥1000EID_{50}, with P value <0.0001 to 0.01) led to predominantly lower hemagglutination activity results, while the use of higher doses (1000000 vs. ≤ 100000 EID_{50}, P value <0.0001 to 0.02) led to lower infectious activity results. Based on these, 1000-10000EID_{50} was selected as the optimal dosage for inoculating chick embryos. Both doses provided equally high infectious activity titers for all of the recombinant vectors tested (difference between strains, P value >0.99 to 0.13). Also, with these doses, hemagglutination activity titers were comparable to those produced by higher doses (P value 0.99 to 0.24) (Table 1).

Table 1

Viral build-up rate based on the inoculation dose (X ± m, n=3)

Embryonated egg inoculation dose, EID_{50}	Hemagglutination		Infectious log10EID_{50}/cm3	
	FLU NS_ESAT 6	FLU NS_TB10.4	FLU NS_ESAT 6	FLU NS_TB10.4
~10	1:32	1:16	7,45 ± 0.14	8.95 ± 0.14
~100	1:32	1:32	7.95 ± 0.08	9.45 ± 0.08
~1000	1:64	1:32	8.45 ± 0.17	9.70 ± 0.17
~10000	1:64	1:64	8.95 ± 0.24	9.70 ± 0.24
~100000	1:64	1:64	8.45 ± 0.2	9.45 ± 0.2
~1000000	1:64	1:64	8.20 ± 0.12	9.20 ± 0.12

An assessment of the stability of the mycobacterial insertion in the NS gene was performed using RT-PCR. The NS gene of the studied recombinant vector samples was compared with that of a wild avian influenza virus. The RT-PCR investigation confirmed that the length of the NS gene's segment containing protein inserts was elongated and comprised 1170 b.p. for TB10.4 and 1175 b.p. for ESAT 6.

The recombinant vector samples were examined by electron microscopy (Figure 5).

The electron microscopy examination shows that the virus assembly was completed successfully. The virions are sphere-shaped and coated with a supercapsid formed by a lipid bilayer with 10 nm glycoprotein spikes responsible for hemagglutination activity.

The most economically viable means of preventing infections is immunization. Animal vaccines using causative agents' genetic material delivered by virus vectors is a new vaccine technology. The potential of virus vectors as candidates for new vaccines is based on their ability to express any foreign proteins in vivo with or without modification (de Vries & Rimmelzwaan, 2016).

Influenza viruses as a vector are safer than other viruses because of influenza's inability to integrate

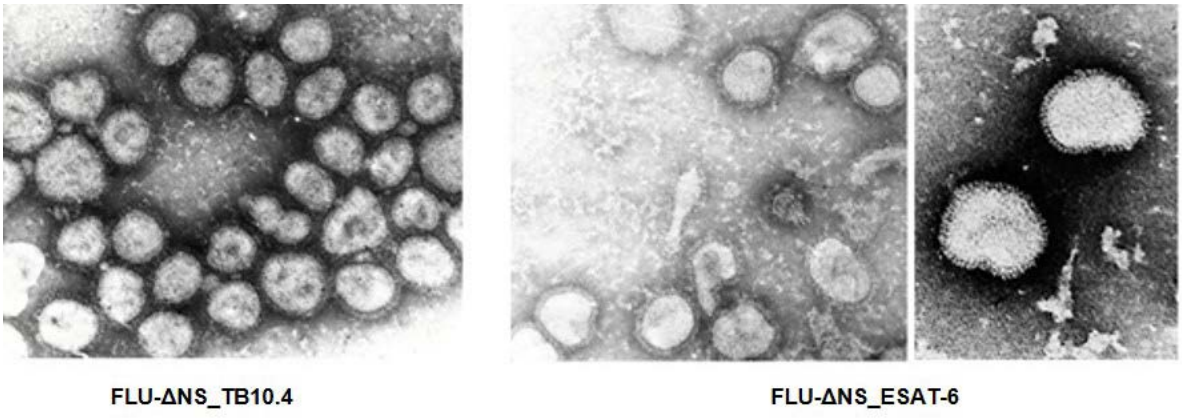

Figure 5. Electron microscopy image of recombinant vectors.
The photo was taken at 100000x magnification with a JEM-100 CX-II JEOL transmission electron microscope (Japan).

into the recipient's chromosomes (Ferko *et al*., 2001).

This study examines an influenza vector with a modified NS genome containing a sequence encoding a *M. bovis* protein.

In the study, the maximum amount of viruses built up when grown in a Vero cell culture using the DMEM serum-free medium at 37 ± 0.5 ℃ with an access of 5% carbon dioxide. Both recombinant vector samples peaked their biological activity at 72 hours of the experiment and maintained it for 96 hours, with the biological activity of FLU-ΔNS_ESAT 6 reaching 7.50 ± 0.08 $log10TCID_{50}$ cm^{-3} and that of FLU-Δ NS_TB10.4 reaching 7.75 ± 0.08 $log10TCID_{50}$ cm^{-3}.

It should be noted that RIBSP researchers successfully used this approach previously to create a human tuberculosis vaccine based on influenza virus vectors expressing proteins ESAT 6 and Ag-85 (*M. tuberculosis*). Viruses were also grown in a Vero cell culture in a DMEM serum-free medium to produce this human vaccine. Research on animal models, such as mice and guinea pigs, showed the vaccine to be completely safe (Buzitskaya *et al*., 2022). Moreover, it was established that vaccinated animals developed a strong antigen-specific T-cell immune response and a high level of protection, one that is not inferior to that offered by a commercial Bacillus Calmette–Guérin (BCG) vaccine (Shurygina *et al*., 2014; Stukova *et al*., 2014).

If the above incubating conditions are observed, it is possible to consistently produce virus-containing material with an infectious activity level not less than 7 $log10TCID_{50}$ cm^{-3}, which is well suited for preparing a vector vaccine for bovine tuberculosis. However, the production of vector vaccines using primary animal cell cultures is characterized by a high level of labour intensity and low efficiency and requires rigorous aseptic techniques and highly skilled personnel. Moreover, animal cells may not survive in isolation and, therefore, are incapable of independent sustainable existence without an artificially created complex environment. One of the key limitations of cell cultures is their high cost and a small number of resulting cells. In cell cultures, the heterogeneous cells undergo multiple manipulations in consecutive passages, eventually departing from the original composition (Grachev & Khapchaev, 2008; Anaya *et al*., 2013).

The use of chick embryos to grow viruses in vaccine production is a conventional process that has stood the test of time. The advantage of this culturing system is the fact that it is economically affordable and readily available whenever there is a need to grow viruses, which makes vaccine production highly scalable. Also, studies of A-type recombinant influenza viruses grown in chick embryos have established the stability of NA and HA genes (Nakowitsch *et al*., 2013; Rajaram *et al*., 2020).

In 10-day-old chick embryos, the optimal temperature for the highest virus growth was 37 ± 0.5 °C. At this temperature, the FLU-ΔNS_ESAT 6 recombinant vector's infectious activity level was at 8.95±0.07 $log10EID_{50}$ 0.2 cm^{-3} while that of FLU-ΔNS_TB10.4 was at 9.20 ± 0.07 $log10EID_{50}$ 0.2 cm^{-3}. According to the study, the optimal infectious dose for the recombinant FLU NS_ESAT 6 and FLU NS_TB10.4 vectors in 10 days old chick embryos is 10000 EID_{50}. This dose makes it possible to produce virus-containing material with a hemagglutination activity level of 1:64 (Figure 4 and Table 1).

M. bovis protein inserts in the NS gene remained stable when passaged in both the Vero cell culture and chick embryos.

The conditions for growing recombinant vectors in chick embryos determined by this study to be optimal are suited for preparing a safe and effective new-generation vaccine for bovine tuberculosis.

Conclusions

Developing a domestic vaccine for bovine tuberculosis remains a priority for Kazakhstan's veterinary biotechnology industry. Different vaccine production technology and composition options are available. Vector vaccines are considered to be the safest vaccines, especially those using influenza vectors. In this study, recombinant vectors were constructed and inoculated in cell cultures and chick embryos to grow viruses. The vectors produced were highly stable and biologically active and, therefore, could be used to develop a vaccine for bovine tuberculosis.

Acknowledgements

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BASIC CHARACTERISTICS OF LATVIA'S E-SHOPPERS

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Abstract
Information technology is increasingly permeating the lives of every modern individual, profoundly impacting them as consumers. With e-commerce and online shopping now firmly entrenched in daily routines, it becomes imperative to conduct research and establish a comprehensive e-shopper/e-buyer profile. The purpose of this article is to study modern Internet shoppers in Latvia and describe the profile of a typical e-buyer to identify possible problems and prospects for the development of e-commerce for Latvian companies during the relevant period. The article highlights some aspects that characterize Latvian e-buyers and their behaviour as consumers, analyzing their buying habits by age structure in dynamics and comparing data for the period from 2010 to 2021. The frequency of online purchases by Latvian users is also examined. The key characteristics of several basic portraits of the typical e-shopper in Latvia are substantiated. The analysis employs monographic and statistical methods, and visual images are presented based on Eurostat data. The research authors conclude that the Latvian segment of online buyers is rather conservative, but it is becoming more and more active in exploring the possibilities of online shopping. The key characteristics of several basic profiles of an average e-shopper in Latvia are also justified.
Key words: e-commerce, customer, e-shopper/e-buyer, online shopping.

Introduction

The widespread use of information technologies in absolutely all spheres of economic activity has led to radical changes in the ways of doing business and to the massive development of e-business. E-commerce, in light of recent years, has become one of the most promising areas of business development, which naturally brings to the forefront the issues of justifying the most effective ways and methods of its application by business entities. The effective implementation of e-commerce by a business depends on many factors, among which special attention should be paid to studying the target audience – defining a profile of existing and potential customers. In this regard, when it comes to the country's e-commerce market as a whole and its development prospects, studying the profile of domestic e-customers is of particular relevance.

There are various studies about e-buyers/e-shopers and their behavior worldwide. Several synonyms of terms are used, starting with e-customers, e-shopers, e-buyers, e-clients, etc. Of course, there are some differences, for example, between e-customer and e-buyer, because a customer is not always a buyer. Therefore, the authors of the article use two terms – e-buyer and e-shopper. In addition, due to the limited scope of the article, only some aspects of the topic are covered.

E-shopping drivers are indeed influenced by e-shopping service quality, and these drivers lead to e-shopping intentions and eventually the adoption of online shopping. Furthermore, offline brand trust is a key factor that moderates the relationship between e-shopping drivers and e-shopping intentions (Rehman *et al*., 2022). E-shopping intentions strongly influence actions and effectively specify and mediate e-shopping behavior and its context (Honglei *et al*., 2021). Shopping online via mobile phones is becoming increasingly popular, though it presents challenges for companies due to the multifaceted approach needed to ensure effectiveness (Volenkins, Sloka, & Cipane, 2019).

Due to the tremendous prospects of e-commerce for business development, particularly in the post-Covid world, an increasing number of researchers are focusing on the challenges of effective online commerce development, including Latvia.

At the same time, scientific studies devoted to e-shopper profiling or the examination of characteristics of online shoppers in Latvia are scarce, and some aspects of this subject are only fragmentarily explored in other research. For instance, a collaborative study (Kruzmetra *et al*., 2020) by Latvian and Lithuanian researchers partially focuses on comparing the online behavior of consumers in the two countries. This study places more emphasis on e-shoppers' preferences and the justification of differences between Latvian and Lithuanian e-buyers. Additionally, the researchers conclude that Latvian manufacturers do not allocate sufficient attention to advertising and promoting their products online, resulting in Latvian e-shoppers being predominantly service-oriented.

As a result, researchers (Kruzmetra *et al*., 2020; Litavniece & Znotiņa, 2017; Volvenkins, Sloka, & Cipane, 2019) do not primarily focus much attention on a deeper study of the e-shoppers themselves, their characteristics, etc. This is partly explained by the fact that defining an e-shopper's profile (target audience) is a practical task for each business entity. However, the need to develop a strategic vision for the further development of the Latvian e-commerce

market identifies ways to improve the efficiency of local businesses, and, as a result, ensures a stable increase in the share of the country's GDP from e-commerce, requires studying the characteristic features of domestic e-shoppers, the dynamics of changes in e-buyers' preferences, etc.

Materials and Methods

To achieve the aim of the research, the article analyzes information about consumers who have been shopping online in Latvia over a 12-year period (2010–2021), based on the official statistics of the European Union. The input database contains information on key age and economic characteristics of Latvian online consumers.

The research is based on general scientific and specific methods of economic theory and economic analysis.

Specifically, the authors made the analysis of an increase in the proportion of e-buyers who have made online purchases in the past three months in the respective age category in Latvia for the period from 2010 to 2021. The analysis was conducted by comparing the percentage shares of e-buyers in each specific age group over the study period (Figure 1).

The structural analysis of the frequency of online purchases in Latvia was conducted using a mathematical approach of summing the percentage shares of each group of e-buyers, identified based on a specific criterion, and subsequently calculating their proportion in the obtained aggregate value. This approach was applied as our research did not aim to account for the share of individuals who do not engage in online purchases. The authors calculated the proportions relative to each other (Figure 2).

The same approach was used in calculating the proportions of e-shoppers in Latvia in 2021 according to the frequency of online purchases by age group.

Additionally, when calculating the increase in the proportion of e-buyers in Latvia from 2010 to 2021, who make purchases online at least once every three months, the education criterion was employed with the supplementary statistical method for calculating the relative growth indicator (Figures 3 and 4).

Results and Discussion

Anticipating consumer behavior is not an easy task because it is influenced by several factors (Litavniece & Znotina, 2017). This task becomes even more challenging when it is necessary to anticipate the behavior of online consumers, which is a prerequisite for effective e-commerce business. Considering that the volume of e-commerce in Latvia has significantly increased in recent years, growing by 27% in 2020 alone, but adding only 1.03% to GDP, according to the European Digital Commerce Association (European e-commerce report, 2021), there is a clear need to develop the e-commerce sector, especially when the European average is 4.5% of GDP. Thus, in terms of e-commerce development, Latvia ranks 21st out of 27 European Union member states, and in terms of e-GDP, it ranks 23rd (European e-commerce report, 2021).

Thus, the development of the e-commerce market in the country is an important direction for increasing Latvia's GDP. However, one of the main obstacles is the lack of representation of national businesses' products and services online, with only 17% of Latvian companies using e-commerce tools in their activities (Babics & Zvirgzdina, 2022). According to the evaluation of the Executive Board of the International Monetary Fund (Republic of Latvia: 2021 article IV consultation: Report No. 21/194, 2021), the level of development of the e-commerce infrastructure and e-business activity in Latvia is relatively low. Therefore, there is a need for significant work with business representatives, primarily aimed at understanding the audience of online shoppers, which can then serve as a basis for selecting the target audience in accordance with the peculiarities of the products or services sold by the business.

The formation of a basic set of information on active online shoppers in the country will enable the outlining of clearer characteristics of e-shoppers for further practical use by businesses when selecting their target audience. Additionally, developing an average profile of an active e-shopper will help identify key characteristics of Internet users that facilitate or hinder online purchases, thus enabling the government to take targeted actions to boost the e-commerce market.

In this research context, the focus is on studying the profile of e-shoppers in Latvia and their key characteristics, such as income level, economic activity, education, etc., linked to age categories, rather than online behavior. Moreover, the research specifically targets active e-shoppers, those who make online purchases at least once every three months.

According to Eurostat data (Eurostat: official website), the number of Latvian online buyers who have made online purchases in the past three months increased from 8% in 2010 to 51% of online users in 2021. At the same time, the growth figures differ significantly by age group and are presented in Figure 1.

Thus, it is the older user groups that are characterized by the highest growth. For instance, less than 1% of internet users aged 65 and over have made online purchases in the last three months before the survey was conducted in 2010, while in

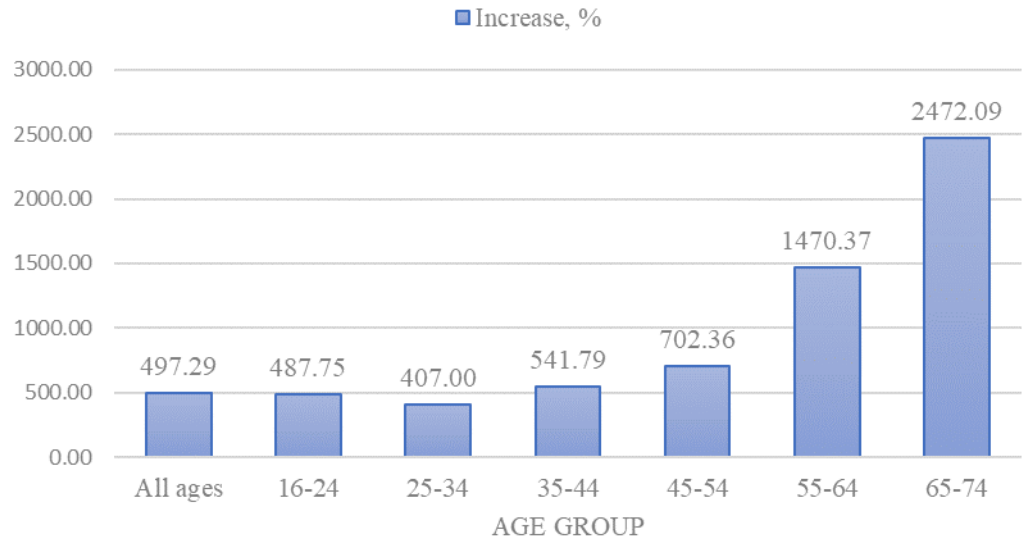

Figure 1. The increase in the proportion of e-buyers who have made online purchases in the past three months in the respective age category in Latvia for the period from 2010 to 2021.
Source: Authors' analysis based on data from Eurostat's official website.

2021 we have 11% of such users in Latvia. Similarly, the number of active online shoppers aged 55–64 increased from 2% in 2010 to 24% in the 2021 survey.

The smallest increase in the number of active online shoppers during the study period was recorded in the age group of 25–34. However, according to the 2021 data, among the Internet users in this age category in Latvia, there is the largest number of active e-shoppers, accounting for 77%.

A study of changes in the frequency of online purchases by users who have made at least one purchase within three months is presented in Figure 2. It shows two periods of dramatic change – in 2016 and in 2020–2021.

If in 2016, the impetus for increased activity of e-shoppers was served by objective reasons – the development of e-business, the mass emergence of online venues to sell a variety of products, chatbots, etc., then in 2020–2021, it is the quarantine restrictions that are the catalysts of changes in the purchasing behavior of Latvians.

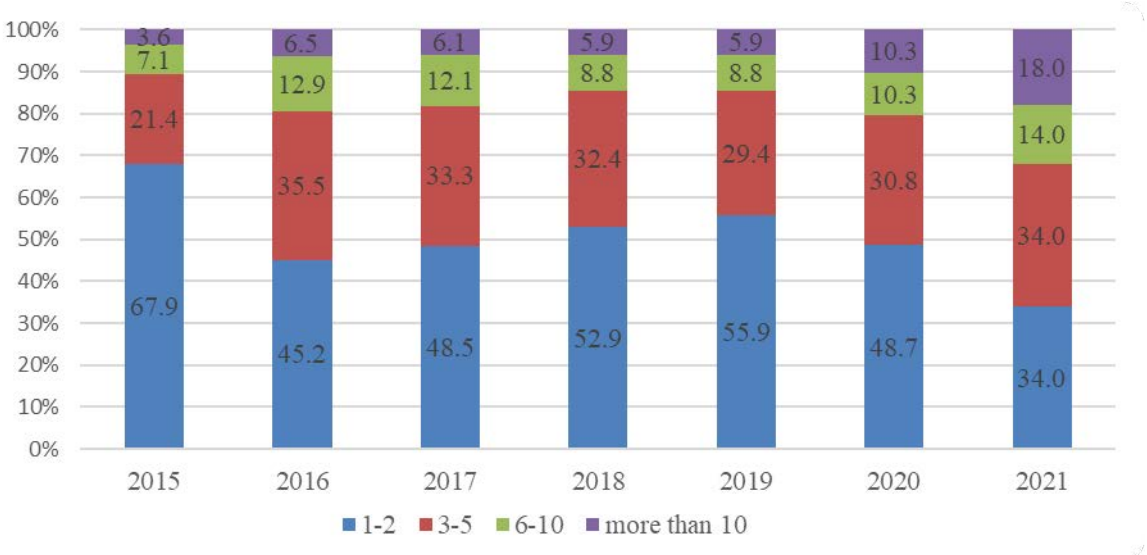

Figure 2. Evolution of the frequency of online purchases by Latvian users in the last three months in 2015–2021, %.
Source: Authors' analysis based on data from Eurostat's official website.

The proportion of e-shoppers making 1–2 online purchases in a three-month period has fallen to 34%. The same proportion of e-shoppers made 3–5 purchases in the last three months in 2021.

In turn, the proportion of consumers making more than 10 purchases over a three-month period – up to 18% – has increased significantly. If we consider all of Latvia's surveyed users – not just active e-shoppers – the proportion of individuals who make online purchases more than 10 times in three months is 9% (according to Eurostat data), which corresponds to at least 153 thousand individuals based on the number of Internet users in the country.

In terms of age categories of e-shoppers in 2021, the situation is presented in Figure 3. The analysis of the data shows that the greatest differences in the shares of buyers of different ages are among individuals who make 1–2 online purchases in three months. The highest number of these e-shoppers is in the group of users over 65 years old – 56.3%, and the lowest is in the group of users aged 35–44 years old – 30.9%. Therefore, it is possible to assume that online shoppers in Latvia who are in the group of users over 55 years old, and especially those over 65 years old, are still less active e-shoppers.

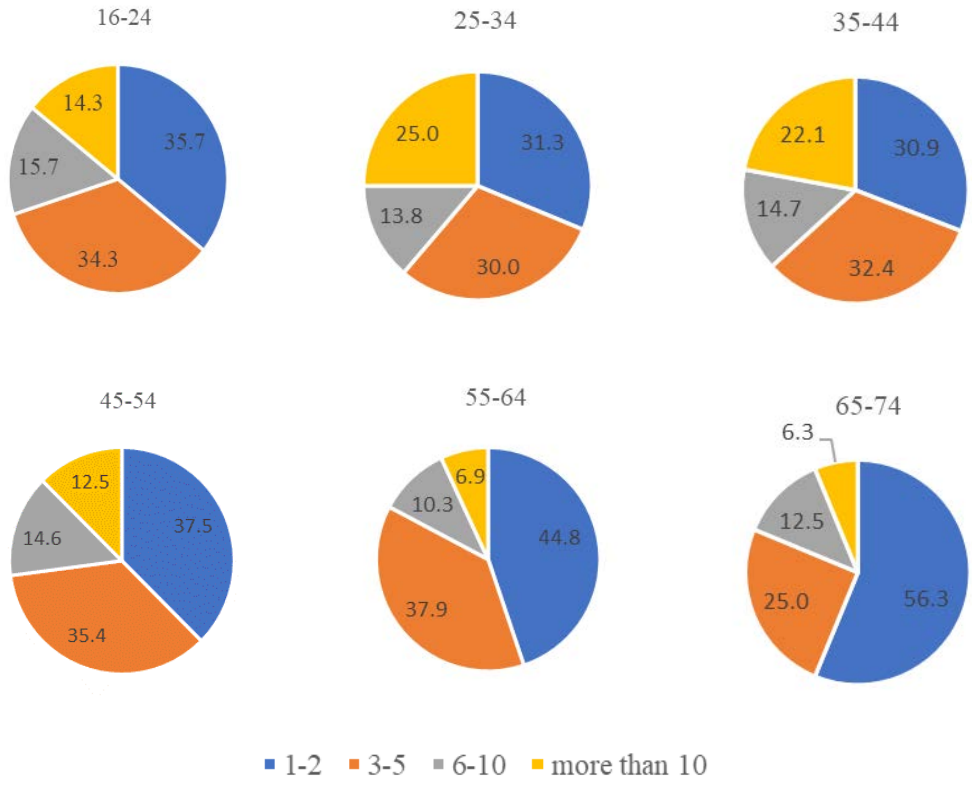

Figure 3. Structure of e-shoppers in Latvia in 2021 according to the frequency of online purchases by age group, %.
Source: Authors' analysis based on data from Eurostat's official website.

Characterizing the growth dynamics of the number of e-shoppers in each of the groups of education criteria in Latvia, based on official statistics (Eurostat: Individuals' internet use) presented in Figure 4, it is worth noting that there is a clear dependence on the level of activity of online shopping individuals – persons with higher education are much more likely to use e-business services. However, there is also a trend towards a significant increase in the number of active e-shoppers among persons with a low level of education, rising from 4% in 2010 to 39% in 2021.

Since 2010, the structure of Latvian e-shoppers in terms of age and education criteria has undergone noticeable changes, particularly in the share of individuals with a low level of education. Firstly, this is a consequence of the significant simplification of access to many digital solutions and technologies among ordinary Internet users, as well as the simplification of electronic platforms and tools for the sale of goods and services. Secondly, from the author's point of view, this situation characterizes the Latvian segment of online buyers as a rather conservative community, which requires businesses operating in the e-commerce segment of the country to take this into account to achieve their business goals, including the choice of online marketing tools.

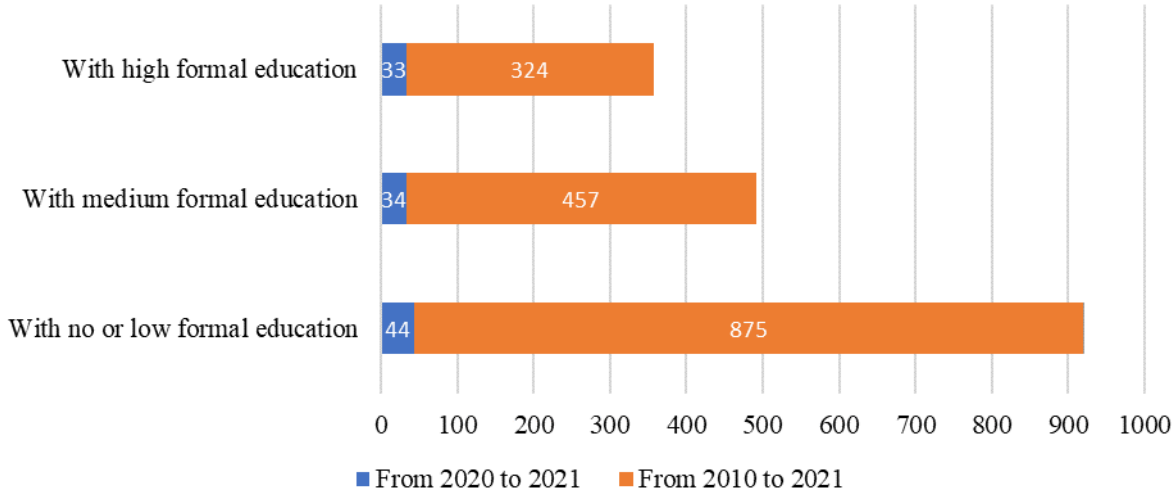

Figure 4. The increase in the proportion of e-shoppers in Latvia from 2010 to 2021, who make online purchases at least once every three months, based on the criterion of education, %.
Source: Authors' analysis based on data from Eurostat's official website.

Conclusions

1. The Latvian segment of Internet users is becoming more and more active in mastering the possibilities of online shopping. Not only the number of e-shoppers increases, but also the frequency of online purchases. The number of Latvian online buyers who have bought online in the past three months increased from 8% in 2010 to 51% of online users in 2021.
2. Online shoppers in Latvia who are in the group of users over 55 years old and especially over 65 years old are still less active e-shoppers.
3. At the same time, the key features of Latvian e-buyers include the predominance of e-shoppers with higher education across all age categories and a clear dependence of the frequency of online purchases on the age group. However, there is also a trend towards a significant increase in the number of active e-shoppers among persons with a low level of education: from 4% in 2010 to 39% in 2021.
4. Further research in this direction should include the analysis of the presence of correlations in the purchasing behavior of online consumers in the context of different criteria and marketing tools used by businesses, which will allow to establish the presence or absence of certain trends, as well as the optimal list of marketing tools to influence the target audience of consumers in Latvia.

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USING TERRITORIAL MARKETING TO ENSURE SPATIAL DEVELOPMENT OF REGIONAL AGRICULTURAL SYSTEMS IN UKRAINE DURING MARTIAL LAW

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Abstract
Ensuring the spatial development of regional agricultural systems in Ukraine during martial law requires a comprehensive study and implementation of urgent effective tools and mechanisms. The hostilities had a negative impact on agriculture, disrupting the regional structure of agricultural production and consumption, destroying agricultural land, assets, enterprises in certain regions of Ukraine, and reducing the volume of agricultural exports through traditional logistics channels. The aim of the study is use territorial marketing to ensure the development of regional agricultural systems in Ukraine. It is based on the analysis of regional structure of agricultural systems in Ukraine, clustering of regional agricultural systems in terms of relative security of sustainable agriculture, and mechanisms of land use development. The regional structure of agricultural systems in Ukraine is analyzed and the territories where the ecosystem is destroyed and unsuitable for agriculture, which are temporarily occupied are identified. The dynamics of planted area of agricultural crops under the harvest were assessed, clusters of regional agricultural systems of Ukraine during martial law were identified. Based on research results, the use of territorial marketing is proposed, a mechanism for sustainable agriculture and strategic land use planning is developed. Prospects intend to ensure spatial development of regional agricultural systems in Ukraine during martial law by relocating agricultural enterprises to relatively safe regions, creating of integrated entrepreneurial agricultural structures, developing of public-private partnerships, attracting investments and introducing innovations, digitalization in agriculture, developing exports within the framework of cross-border cooperation, increasing employment in agriculture due to internal migration processes, etc.
Key words: region agricultural systems, territorial marketing, spatial development, Ukraine, war.

Introduction

The formation of regional agricultural systems in Ukraine is influenced by economic, social, administrative, environmental, spatial and institutional factors. The system of spatial development, which combines the resource capabilities of the country's regions, the sectoral factor and indicators of the socio-economic and environmental status of business entities, is becoming increasingly important. Ensuring the spatial development of regional agricultural systems in Ukraine is carried out on a balanced basis of realising the interests of participants.

During the period of full-scale aggression by Russia on the territory of Ukraine, production and commercial relations between agricultural entities and contractors were disrupted, the ecosystem was disrupted due to pollution in certain regions of the country as a result of hostilities, the blocking of seaports led to delays in the export of agricultural products abroad, and illegal export of agricultural products to Crimea and Russia, etc. All of this has led to negative consequences for the functioning of regional agricultural systems in Ukraine, the impossibility of their further development and food security.

Given the current state and the next marketing year during martial law, there is a need to find tools to ensure spatial development of regional agricultural systems, based on the state of the resource potential of agricultural enterprises and the security of the territories.

In our opinion, territorial marketing can become such a tool, but scientific publications do not sufficiently cover research in this area to ensure spatial development of regional agricultural systems. Therefore, there is a need for a scientific research of the use of territorial marketing to ensure spatial development of regional agricultural systems in Ukraine during martial law.

In the scientific literature, territorial marketing is considered as a tool for the development of territories – formation of a positive image, branding of territories, means of implementing the territorial (regional) policy of self-government bodies. Territorial marketing serves as a management tool for local governments, which makes it possible to create additional values through their own identity, create their own unique image – a brand of the territory, which allows them to meet the needs of residents and business entities, ensure the development of the territory in accordance with the principles of sustainable development (Kondratowicz-Pozorska, 2018). On the other hand, territorial marketing combines elements of industrial and social marketing, marketing of services aimed at meeting the needs of specific target groups of the territory and encourages self-government bodies to develop programmes and relevant policies to create conditions for the effective functioning of target groups, ensuring the quality of various types of services (Knapik, 2009).

Other authors in their studies consider only the elements of territorial marketing in ensuring spatial development of agricultural systems by levels of management – territorial planning, monitoring, and information infrastructure. The use of territorial

planning concerns agricultural land and contributes to the implementation of a balanced regional agricultural policy and management of territorial resources, sustainable agricultural development within a particular region (Borisov, 2015). Spatial planning uses a system of diagnostics (monitoring) of the territory based on multidimensional indicators and clustering to substantiate optimal forms of management in agriculture and make effective management decisions to ensure its development (Abrantes, Marques da Costa, & Gomes, 2023). Spatial planning is considered in the system of sustainable development of territories and agricultural recovery; practical orientation is focused on the French model of urban agriculture management based on urban plans and legislative framework, conservation of natural resources (Plonka, Heczko-Hylowa, & Sroka, 2021). The use of spatial planning is closely related to the level of food insecurity, access to food resources and the role of agriculture in this process, taking into account the state of agricultural production, land use, environment (Meenar, 2017). In order to ensure territorial development of agrarian systems, there is a need to form and function a spatial information infrastructure, in particular; this concerns land use management – creation of a database of agricultural land in the region, its processing, analysis, storage, use (Szafranska *et al*., 2020).

In our opinion, in the context of the author's scientific research on territorial marketing as a tool to ensure spatial development of regional agricultural systems, it is worth paying attention to the sectoral affiliation of Ukraine to the agricultural sector of the economy and various resource opportunities for economic activity in the regions of the country where there are promising opportunities for growing agricultural crops. This thesis is also reinforced by the opportunities for agricultural producers to expand their operations, available production resources (especially agricultural land), export potential, production costs, growth in regional and gross national product, and improved macroeconomic indicators due to foreign exchange earnings. The spatial development of regional agricultural systems in Ukraine is complicated by the territorial security. Therefore, the use of territorial marketing to ensure spatial development of regional agricultural systems is possible only in those regions of the country where there are no relatively dangerous conditions for economic activity in the agricultural sector and there is an available resource potential.

Materials and Methods

The methodological basis of the study is the general economic principles and methods of a systematic approach to studying the process of using territorial marketing to ensure spatial development of regional agricultural systems of Ukraine during martial law. The methods of analysis and synthesis are applied, which allowed identifying problems and determining ways to ensure spatial development of regional agricultural systems of Ukraine. OpenStreetMap was used to build a map of the destruction of regional agricultural systems in Ukraine. Sources of statistical information on the agricultural sector were used, and the volume of planted area of agricultural crops under the harvest by region of Ukraine was studied using the method of dynamic comparisons. The cluster analysis was used to divide relatively safe regions of Ukraine into clusters of regional agricultural systems during martial law. The abstract-logical method was used to justify the need to apply territorial marketing, develop a mechanism for sustainable agriculture and strategic land use planning in the newly created regional agricultural systems in Ukraine.

Results and Discussion

Agricultural systems are resource-limited ecosystems that have specific properties. Ensuring spatial development of agricultural systems has a positive impact on natural, economic, social, etc. resources, while unsustainable systems deplete these resources and require their restoration, conservation and rational use (Pretty & Bharucha, 2014).

By regional agricultural systems, we mean a set of entities and objects covered by a certain territory of the country, characterised by distinctive properties that manifest themselves in the ability to form resource potential and are able to use it effectively in accordance with the needs of consumers and the specifics of the territorial formation. Given the martial law situation in Ukraine, there are limitations in the effective functioning of regional agricultural systems due to the impossibility of agricultural production in the temporarily occupied territories of the country, security threats to people and assets of agricultural producers, production and sale of agricultural products and their preservation. Figure 1 shows the regions of Ukraine where agricultural land has been destroyed and is temporarily occupied; the most affected regions are Donetsk, Luhansk, Kharkiv, Kherson, Zaporizhzhya, Chernihiv, and Kyiv. In these regions of Ukraine, regional agricultural systems are being destroyed, including the destruction of production facilities and infrastructure of agricultural producers, disruption of the sowing campaign, ecosystem disruption and soil contamination, and a significant volume of agricultural land is mined.

The destruction of regional agricultural systems in Ukraine caused by the hostilities is leading to agricultural land degradation and environmental disasters, which can lead to a decline in soil fertility. This can be compared to the development of urban settlements, industry, and transport infrastructure,

which involves soil compaction (Oliveira, Tobias, & Hersperger, 2018).

Given the above, there is a need to diagnose the regional agricultural systems of Ukraine that have sufficient resource potential to relocation of agricultural production in the affected areas and temporarily occupied territories.

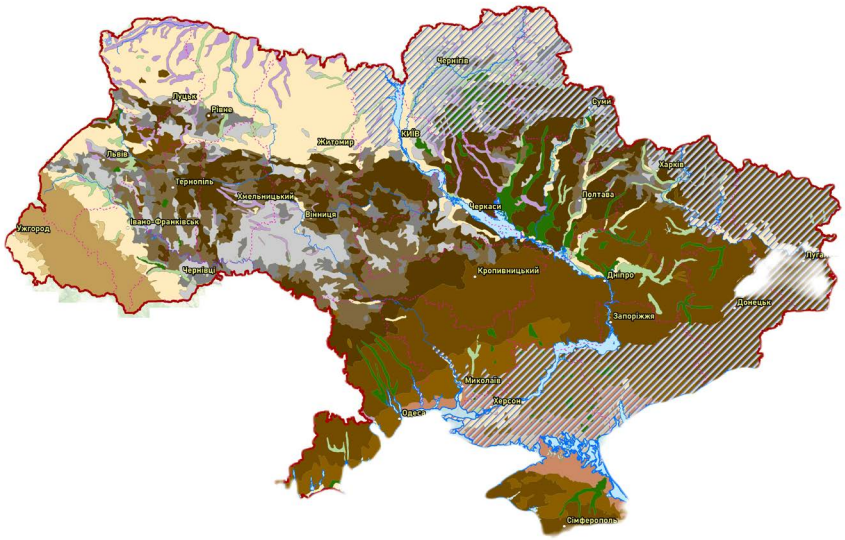

Figure 1. Map of destruction of regional agricultural systems in Ukraine (Zalavskyi *et al*., 2022).
Note: ▨ – territories that have been destroyed as a result of hostilities.

In addition, there is a need to develop agricultural production in order to provide food for these territories and other regions of Ukraine, as internal migration increases the demand for agricultural products. This can be a key point in the formation of mechanisms for spatial planning and development of regional agricultural systems in Ukraine on the basis of territorial marketing. In this regard, there is a need to study the regional structure of planted area of agricultural crops under the harvest in Ukraine (Table 1). It should be noted that, given the intensity of hostilities on the territory of Ukraine, the adjacent regions to the temporarily occupied territories and border regions in the east, south and north of Ukraine can also be potentially dangerous.

Based on the data presented in the table, the following regions of Ukraine can be considered promising for agriculture: Vinnytsia, Dnipropetrovsk, Kirovograd, Poltava, Khmelnytsky, Cherkasy, Zhytomyr. In these regions of Ukraine, there are significant volumes of agricultural land that can be intensively used and the tools of territorial marketing can be applied to ensure spatial development of regional agricultural systems. In addition, we believe that the regions of western Ukraine (Lviv, Volyn, Ternopil) can be used for organic farming, as they have favourable natural and climatic conditions and can attract foreign investment and innovations from neighbouring European Union countries. These territories determine the prospects for the spacious development of regional agricultural systems in Ukraine.

Using cluster analysis, in accordance with the identified regional agricultural systems, it is proposed to identify four clusters by region of Ukraine: booming, prosperous, moderate, and transition (Meyer *et al*., 2021). The criterion for clustering regional agricultural systems in Ukraine is the rate of change in the volume of agricultural land in the dynamics. The results are presented in Table 2.

Using the tools of territorial marketing to ensure spatial development of regional agricultural systems in Ukraine during martial law, a mechanism for sustainable agriculture and strategic land use planning is proposed (Figure 2). Let us describe the individual elements of the mechanism in more detail.

Territory branding plays an important role in the context of territorial marketing to ensure spatial development of regional agricultural systems in Ukraine. Public authorities in most regions of Ukraine have developed programmes for the development of business entities, including agricultural enterprises, investment passports for attracting domestic and foreign investment in the regions, standards for investment and post-investment support for investors, and established development agencies and a single investment window. These structural elements of territorial marketing can serve as an effective tool

to ensure relocation of agricultural enterprises from regions where there are no business opportunities. In addition, local governments in cooperation with non-governmental international organisations, support relocated enterprises, providing them with information support, financial support for the operation and development of agricultural enterprises.

The newly created regional agricultural systems have the opportunity to increase the supply of agricultural products due to internal migration, the cessation of agricultural supplies from the occupied territories, meeting the needs of the Armed Forces of Ukraine, and changes in the structure of consumption during martial law. This will increase the volume of planted area of agricultural crops under the harvest in relatively safe regions of Ukraine and allow for their rational use.

Table 1

Planted area of agricultural crops under the harvest

Region	2021	2021 % to 2020
Ukraine	**28387.5**	**100.9**
Vinnytsia	1653.1	101.6
Volyn	611.7	101.0
Dnipropetrovsk	1971.8	99.6
Donetsk	1041.0	100.8
Zhytomyr	1153.7	97.0
Zakarpattya	173.8	94.3
Zaporizhzhya	1711.8	100.2
Ivano-Frankivsk	383.4	101.4
Kyiv	1191.7	99.7
Kirovograd	1705.2	99.5
Luhansk	855.9	99.8
Lviv	706.3	99.1
Mykolaiv	1600.9	102.3
Odesa	1841.6	108.4
Poltava	1732.0	100.2
Rivne	619.0	100.0
Sumy	1209.6	101.1
Ternopil	840.7	100.0
Kharkiv	1823.2	99.8
Kherson	1476.8	104.1
Khmelnytsky	1205.1	99.6
Cherkasy	1217.7	100.4
Chernivtsi	308.0	100.7
Chernihiv	1353.5	101.2

Source: created by authors based on State Statistics Service of Ukraine for 2021.

Table 2

Clustering of regional agricultural systems in Ukraine during martial law

Booming regions	*Prosperous regions*
Vinnytsia Poltava	Dnipropetrovsk Kirovograd
Moderate regions	*Transition regions*
Cherkasy Khmelnytsky Zhytomyr	Lviv Volyn Ternopil

Source: authors' proposal.

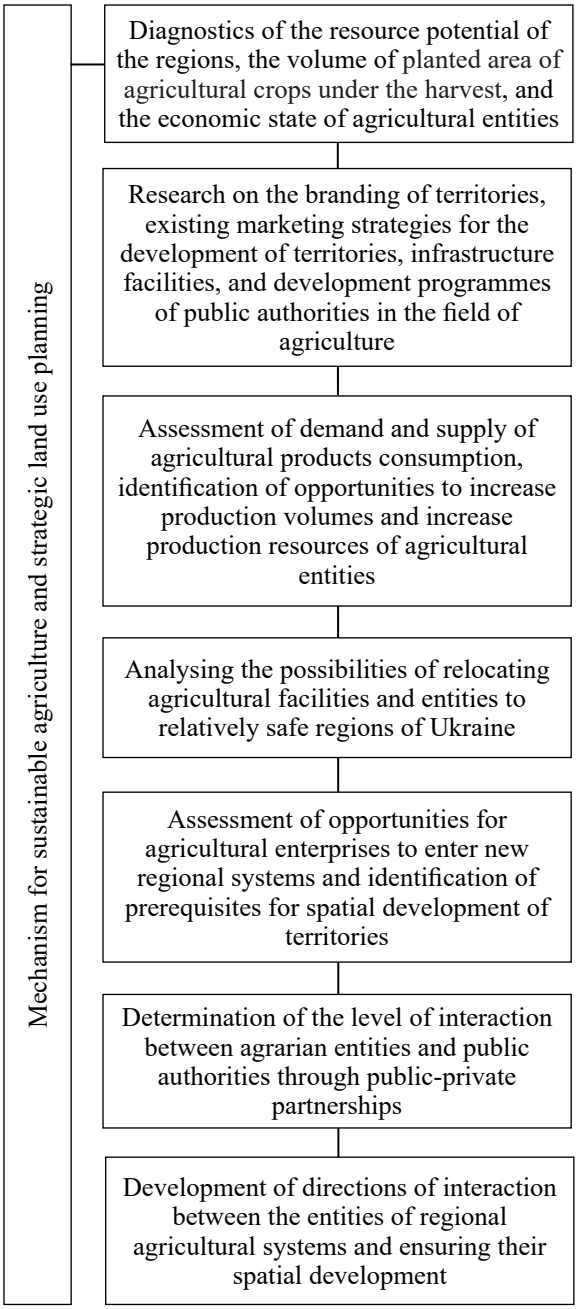

Figure 2. Mechanism for sustainable agriculture and strategic land use planning (authors' proposal).

The formation of integrated regional agricultural systems in the respective territories of Ukraine will contribute to the effective integration of production potential, the introduction of innovative technologies in agriculture, the establishment of new sustainable supply chains (especially within the framework of cross-border cooperation with the European Union countries), the development of small and medium-sized enterprises in agriculture, rural development, and digitalisation in agriculture, which will manifest itself in the achievement of a synergistic effect.

At the national level during martial law state support for regional agricultural systems in Ukraine is aimed at optimising taxation, abolishing VAT and excise on petroleum products, introducing preferential lending and a declarative principle of customs operations for agricultural exports.

All of these measures contribute to spatial development of regional agricultural systems in Ukraine and will ensure food security in the future.

Conclusions

1. Based on the review of scientific sources, it was found that territorial marketing is considered as a tool for the development and management of territories by public authorities. Another group of researchers considers territorial marketing as a tool for meeting the needs of consumers of a certain territory, which is characterised by specific features and resource potential. The authors' generalisations allowed to focus on the expediency of use territorial marketing to ensure spatial development of agricultural systems in Ukraine.
2. Based on the analysis of the map of destruction of regional agricultural systems in Ukraine, the territories of the country that have suffered the most from military operations and are dangerous for agriculture are identified. These include Donetsk, Luhansk, Kharkiv, Kherson, Zaporizhzhya, Chernihiv, and Kyiv regions of Ukraine. These regional agricultural systems need to be transformed by relocating to relatively safe regions of the country.
3. The dynamics of the regional structure of sown areas of agricultural land in Ukraine are assessed. Based on results of research, four clusters have been identified by regions of Ukraine: booming (Vinnytsia, Poltava), prosperous (Dnipropetrovsk, Kirovograd), moderate (Cherkasy, Khmelnytsky, Zhytomyr), and transition (Lviv, Volyn, Ternopil), where new regional agricultural systems can be formed during martial law.
4. Based on the principles of territorial marketing, a mechanism for sustainable agriculture and strategic land use planning to ensure spatial development of regional agricultural systems in Ukraine during martial law is proposed. The key aspects of the mechanism are the marketing analysis of the resource potential of territories and the developed strategies for the development of territories, the possibilities of relocation of agricultural systems to relatively safe regions of the country, intensification of the use of planted area of agricultural crops under the harvest, an increase in the volume of activities of agricultural enterprises and satisfaction of consumer needs for agricultural products during martial law.
5. Prospects for spatial development of regional agricultural systems in Ukraine during martial law can be achieved through creating of integrated entrepreneurial agricultural structures, attracting internal and external investment, developing public-private partnerships, using opportunities for cross-border cooperation in the export of agricultural products, introducing sustainable environmental technologies and organising organic production, developing rural areas, increasing the level of employment in agriculture through internal migration processes, and introducing digital technologies in agriculture.

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CONSTRUCTION CHALLENGES IN RURAL AREAS OF LATVIA: COSTS, FINANCING AND HOUSING STOCK

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Abstract
Not only does construction activity in the regions play a crucial role in the regional development, as it not only provides employment opportunities and thus contributes to the well-being of the population, but also creates favourable conditions for access to modern housing and requires the mobility of human resources to the regions. At the same time, construction in regions and rural areas often implies more difficult conditions than in urban environments, which are associated with both funding opportunities and working conditions. The availability of financial investments to the private sector is limited for the construction of housing outside Riga and Pierīga region, which significantly reduces construction opportunities in the regions of Latvia. The study evaluates the possibilities of obtaining new housing in the regions of Latvia, analyses the trends in construction volume and costs from 2015, modelling forecasts until 2026. The study looks at various economic instruments that could contribute to the development of construction and new housing in the regions. The study uses surveys of municipalities, entrepreneurs and experts in the field of construction, in-depth interviews, focus groups and statistical data processing methods. It has been concluded that Latvian entrepreneurs tend to postpone investments or invest only in the economically strongest moments, which further aggravates the gap between urban and rural areas. The trends identified in the study indicate a possible further direction of stagnation or recession in the construction sector of new housing in the regions of Latvia, which will directly affect regional development in the next five years. The study highlights the necessary interventions for more productive regional housing stock cohesion.
Key words: rural development, construction, cost forecasting, housing stock.

Introduction

Construction activity in the regions plays a crucial role in regional development, as it not only provides employment opportunities and, as a result, contributes to the well-being of the population, but also creates favourable conditions for the availability of a place of residence that meets modern requirements (OECD, 2014). Taking into account the lack of human resources in the regions not only in Latvia, but throughout the European Union, it is important for policy makers to create innovative support instruments (Storper, 2018) that would directly target the development of housing construction in the regions. The unavailability of modern and affordable housing in the regions is one of the main hindering factors for the development of regions.

At the same time, construction in regions and rural areas often implies more difficult conditions than in urban environments, which are associated with both funding opportunities and working conditions. For the construction of housing outside Riga and Pierīga region, the availability of financial investments to the private sector is limited, which significantly reduces construction opportunities in the regions. Consequently, in the regions, construction mainly takes place within the framework of the public sector for public buildings, which further highlights the differences in the availability and quality of building infrastructure and premises between public and private buildings. In order to successfully address the challenges of regional cohesion, it is necessary to balance public and private capital investment in construction, in particular by promoting the construction or restoration of quality housing. For policymakers to carry out effective interventions, it is necessary to assess the current housing affordability situation in the regions, the factors affecting it and current construction development trends. The current study evaluates housing opportunities in the regions of Latvia, analyses the trends in construction volume and costs from 2015, modelling forecasts until 2026. The study looks at various economic instruments that could contribute to the development of construction and new housing in the regions.

Materials and Methods

The study begins with the analysis of secondary data: a review of the availability and construction of housing described in various reports and scientific sources, statistical data on housing, construction trends and the structures that make it up. Support measures to promote housing construction in the regions are discussed. Based on extrapolation of statistical data and expert opinions, an assessment of the development trends of construction until 2026 has been carried out. Expert opinions on regional construction and housing development and construction promotion activities have been

gathered and analysed using in-depth interviews and focus group discussions. To achieve the diverse objectives of the study, a five-stage research design was applied, which included the following stages – analysis of secondary data, retrieval and analysis of primary data, extrapolation of statistical data, comparative analysis of synthesized information and development of conclusions and proposals. The following methods were used in the study – a survey of representatives of 41 regions – municipal experts, a survey of 83 construction experts, 5 focus groups, 55 in-depth interviews, 5 focus group discussions and statistical data processing methods, which included statistical data analysis from 2015 to 2021. Construction development forecasts were made for the period from 2022 to 2026. Autoregressive moving average – ARIMA (autoregressive integrated moving average), SARIMA (incl. seasonality) and ARMA (autoregressive moving average) – have been used to extrapolate the construction volume and cost time series. These models were adapted to the data of the construction dynamics rows in order to predict future scenarios for the development of construction costs and volume.

Results and Discussion

The general economic development of regions depends on **the construction of available housing** (Wardrip *et al*., 2011). **The initial construction of affordable housing generates short- and long-term employment possibilities as well as extra income for the community**, supported by the household expenses of new residents. The benefits of the development of the projects themselves are useful for the local area, provided that the maximum use is made of building materials and labour from local enterprises (Braslina *et al*., 2021). An additional multiplier effect may arise from the daily spending of those involved in construction, which can revive the local service sector (Braslina *et al*., 2020). **The construction and renovation of affordable housing brings fiscal benefits to local authorities** – benefits from VAT, income taxes and levies (Stefenberg *et al*., 2022). Due to the specifics of the Latvian tax system, the most significant benefits would be from new residents, which would increase the income of the municipality from income tax payments (Sloka *et al*., 2022). **Buyers of affordable housing may face risks of insolvency with a lower probability** (Wardrip *et al*., 2011). New homeowners who opt for luxury properties or generally invest in more expensive real estate are more exposed to insolvency risks (Batraga *et al*., 2019). **The existence of affordable housing in the municipality makes it easier for employers to attract skilled labour from other areas** (Girma *et al*., 2008). Highly motivated and mobile workers are flexible in choosing their place of residence and ready for geographical mobility to areas with lower living costs, lower traffic volumes and higher job opportunities. It is precisely the strengthening of county centres that is essential, since it is not rational to promote the construction of housing for every less densely populated area (Danusevics *et al*., 2022). Internal mobility is possible by achieving the availability of the necessary conditions – new housing, accessibility of educational institutions or transport to them for children, availability of high-quality telecommunications and consumer goods. Support mechanisms would be needed not only to promote housing, but also to support businesses serving the population (Braslina *et al*., 2021).

Indirect benefits for local government from a more active real estate market are also beneficial (Lagendijk & Cornford, 2000). Construction projects improve local infrastructure and contribute to the overall increase in the value of real estate, as well as provide a common public good. The construction of affordable housing frees up a larger part of the household budget for daily consumption needs, which contributes to turnover in the nearby area (Sloka *et al*., 2017).

The overall situation of the availability of new housing in Latvia indicates a relative 'active circle' of Pierīga – North Vidzeme – territory, which covers mainly Riga and Vidzeme regions and is characterized by more active construction of new apartments (Figure 1).

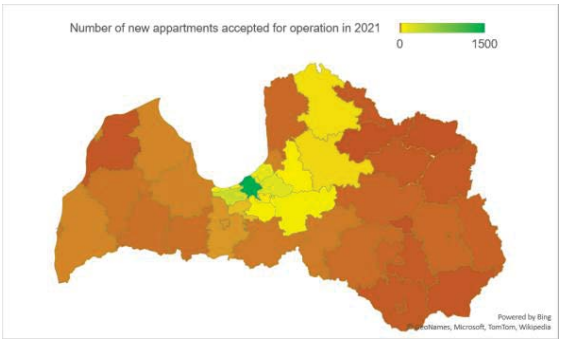
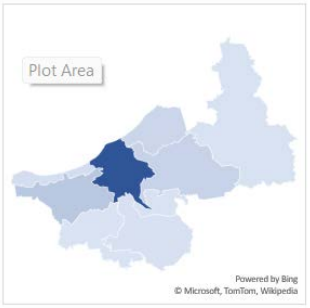


Figure 1. Breakdown of the number of new apartments accepted for operation in Latvian counties and cities of the country.
Source: CSB, authors' calculations.

The most significant number of new construction objects is in Riga and municipalities bordering Riga. A relatively high indicator is observed in a semicircle, which includes Ogre, Sigulda, Cēsis and Valmiera counties. In Riga region, the greatest opportunities for obtaining a new housing are in Riga with 1537 new apartments accepted for operation in 2021 (Figure 2). Of the adjacent territories, the highest indicator

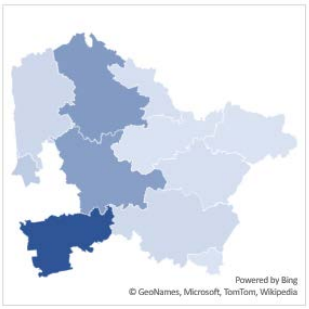
is in Mārupe county with 320 apartments and Ropaži county with 201 apartments. The lowest indicator is Olaine County with 31 new apartments accepted for operation.



Jūrmala	81
Rīga city	1537
Ādaži county	164
Ķekava county	50
Mārupe county	320
Olaine county	31
Ropaži county	201
Salaspils county	44
Sigulda county	45

Figure 2. Breakdown of the number of new apartments accepted for operation in Riga region counties and cities.
Source: CSB, authors' calculations.

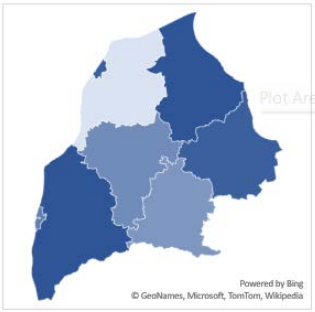
In Vidzeme region, there are prospects for new housing in Ogre County with 79 new apartments in 2021 (Figure 3). There is also a positive situation in Valmiera and Cēsis counties with 40 and 38 new apartments accepted for operation, respectively. In other municipalities, no statistics are available or less than 10 new apartments have been put into operation.



Alūksne county	N/A
Cēsis county	38
Gulbene county	2
Limbaži county	6
Madona county	5
Ogre county	79
Saulkrasti county	13
Smiltene county	N/A
Valka county	2
Valmiera county	40
Varakļāni county	N/A

Figure 3. Distribution of the number of new apartments accepted for operation in Vidzeme region counties and cities.
Source: CSB, authors' calculations.

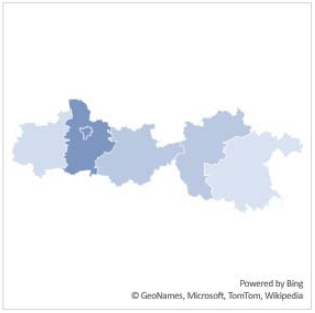
The Kurzeme Planning Region does not offer significant dwelling opportunities in new projects on a national scale; however, there is a certain variation within the region (Figure 4). The largest number of apartments accepted for operation is in Talsi and South Kurzeme counties with 14 apartments each, as well as in Ventspils and Tukums counties with 13 apartments each. Ventspils City provides more opportunities for dwelling, but in Ventspils region only one apartment was accepted for operation.



Liepāja city	10
Ventspils city	13
South-Kurzeme co	14
Kuldīga county	9
Saldus county	8
Talsi county	14
Tukums county	13
Ventspils county	1

Figure 4. Distribution of the number of new apartments accepted for operation in the counties and cities of the Kurzeme region.
Source: CSB, authors' calculations.

In Zemgale planning region, there are higher dwelling possibilities in Jelgava and Jelgava County, where in 2021 29 and 19 apartments were put into operation (Figure 5) In total, it is more than in all other Zemgale counties combined, which provides Jelgava with significant competitive advantages for attracting remigrants who would like to return directly to Jelgava or its county. Aizkraukle and Bauska counties have the same number of new apartments – 11 each.



Jelgava city	29
Aizkraukle county	11
Bauska county	11
Dobele county	8
Jelgava county	19
Jēkabpils county	7

Figure 5. Distribution of the number of new apartments accepted for operation in Zemgale counties and cities.
Source: CSB, authors' calculations.

The Latgale planning region is the least attractive from the context of new housing opportunities, because in this region the best county is equivalent to the worst counties in terms of the number of apartments in other regions (Figure 6). For a potential seeker of a new place of residence, the greatest opportunities are available in Rēzekne municipality and city, where a total of nine new apartments have been accepted for operation. Līvāni municipality also provides small advantages with five new apartments. Other Latgale counties and Daugavpils have even lower activity.

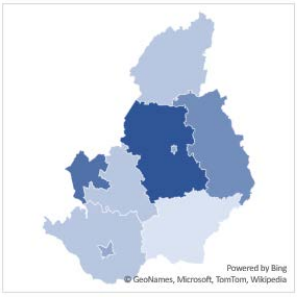


Figure 6. Distribution of the number of new apartments accepted for operation in Latgale region counties and cities.
Source: CSB, authors' calculations.

It can be concluded that outside Riga and Vidzeme region there are relatively few opportunities to acquire new housing. The availability of quality housing in existing buildings, including renovated ones, is not excluded; however, the study of this indicator is not possible based on the public information available in the study on the state of the housing stock by municipality. Taking into account the low availability of new apartments outside the Riga region, it is important to develop state and local government programs to promote the availability of the housing stock. The measures would include not only the creation of a municipal housing stock, but also the provision of support and advice for obtaining financial support for housing construction.

In order to address market failures and ensure high-quality and affordable rental housing in regions for households that cannot afford housing at market price due to insufficient income, several public sector activities have been announced in the public sector in Latvia, which are mainly aimed at low-income groups of the population. **The Ministry of Economics has developed a brand new support program, within the framework of which real estate developers will be able to receive support for the construction of low-rent residential rental houses in the regions**. It is planned to build 700 low-rent apartments in the regions with help of this funding. In the programme support to real estate developers for the construction of rental housing, the Development Finance Institution ALTUM intends to issue a long-term loan (up to 30 years) and a capital rebate (up to 30% of the total eligible costs of the project). To receive a capital discount, certain conditions will have to be met, for example, the quality requirements of a residential rental house and a certain amount of rented apartments. ALTUM support programme is intended for real estate developers and is available to commercial companies, cooperative societies and private companies. It will be possible to acquire rental rights for housing for any household that meets the established household income thresholds (net) and has entered the queue administered by the municipality. The aim of the support programme is to provide affordable housing, so it is stipulated that the rent initially does not exceed 5 EUR m^{-2} and that rents can be indexed annually to the annual average national inflation rate.

It is planned to achieve a similar goal by the Housing Fund provided by the Ministry of Environment and Regional Development, one of the tasks of which is the attraction of financial resources and investments in housing development. At the same time, the creation of this fund is intended not to have an impact on the general budget. It is planned to create public sector rental apartments and lease them to immobility managers. The plan foresees that managers, in turn, will manage and rent out housing, making regular payments to the fund. It is also intended to use the inverse proportionality and to provide for more allocated funding for planning regions with lower gross domestic product.

The activities carried out and planned are aimed at supporting low-income social groups, currently not focusing on support mechanisms for the construction of private sector and private equity housing in the regions.

The study evaluated changes in construction volume and cost, which have an immediate impact on the region's construction growth prospects. 83 experts from the field of public administration, civic initiatives (NGOs), academia, and businesses in the construction industry participated in this evaluation and provided their opinions.

Construction cost forecasts indicated that in 2022 construction costs will increase by 20.5 (actual increase by 19.7% (CSB, 2023)), which directly affects the decrease in construction volume. According to the researchers' forecasts, a large increase in construction costs is expected also in 2023, mainly in the field of the cost of building materials and the maintenance and operation of machinery and equipment. Total construction costs in 2023 are expected to increase between 9.9% (combined forecast) and 9.4% (expert forecast). Annual cost growth in 2024–2026 is forecast at an average of 8.7% for the combined forecast and 4.5% according to the experts' forecast (Table 1).

Table 1

Yearly construction cost changes in Latvia

2020	2021	2022	2023	2024-2026
+1.3%	+6.7%	+19.7%	Study forecast	
Combined forecast →			+9.9%	Annual average +8.7%
Expert forecasts →			+9.4%	Annual average +4.5%

Source: CSB data, expert opinions gathered for the study, authors' calculations.

In 2022, the most notable increase was recorded in construction products for building materials by 24.7%, followed by maintenance and operational costs of machinery and equipment – by 17.5%, but labour wages of workers rose by 10.3% (CSB, 2023). Timber, bituminous and metal products have the highest expected growth. In these groups of materials in 2023, increasing costs could reach annual growth closer to the 20–25% mark.

Contrary to the rise in construction costs, in 2022 the total volume of construction production decreased for the second year in a row by 11.3% (CSB, 2023). According to the projections of the study, growth in construction volume between -1.4% and -0.2% is also forecast in 2023 (Table 2).

Table 2

Yearly construction cost changes Latvia

2020	2021	2022	2023	2024-2026
+2.7%	-6.2%	-11.3%	Study forecast	
Combined forecast →			-0.2%	Average +2.0% per annum
Expert forecasts →			-1.4%	Average +2.0% per annum

Source: CSB data, expert opinions gathered for the study, authors' calculations.

Increasing construction prices and decreasing trends in construction volumes point to a trend of stagnation and recession in the construction sector, which can have a direct impact on the further development of housing construction and restoration in rural areas.

According to the study's estimates, residential building construction prices are predicted to rise by 14.3% in 2023. Experts predict an increase in the cost of building materials that is slowing, but still increasing annually with an increase in costs of 8.6% in 2023 and an average of 4.0% annually in 2024–2026 (Figure 7).

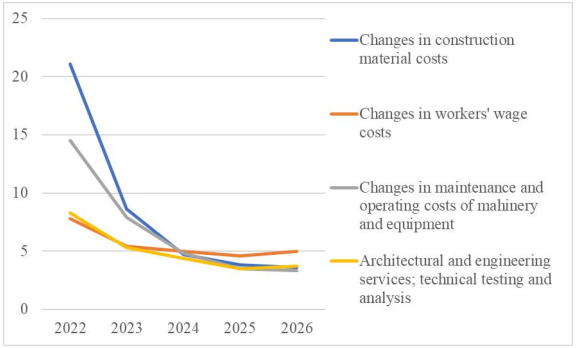


Figure 7. Forecasted construction resources costs for 2022–2026, percentage of the previous year.
Source: expert opinions gathered for the study, authors' calculations.

For the first time in projected observations following expert assessments, the expenses associated with maintaining and operating machinery and equipment were greater than the growth in worker pay. The growth of this resource group has typically been within a few percent every year, but in 2022, expert projections will finally approach double digits and a 14.5% cost increase is expected. In further years, this growth is projected to be lower, with 7.9% in 2023 approaching the 3% annual growth level in the following years. The large increase in fuel prices, which is immediately reflected in the operating expenses of machinery and equipment, is to blame for the rise in the price of this type of resource. The lack of competition in Latvia's machinery and equipment market, which is evident in the analysis of factors affecting the cost of machinery and equipment, may be a secondary issue.

The cost of building materials is anticipated to be higher in the construction of residential buildings than in the general ranking; experts predict that in 2022 as a whole, they might increase by 30.0%, while in 2023 they could continue within the bounds of 16% growth. (Figure 8).

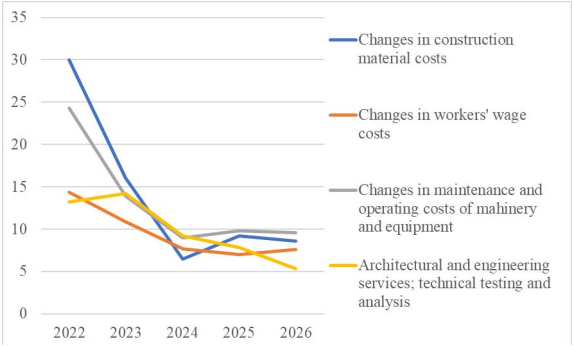


Figure 8. Forecasted residential buildings cost changes by resource types for 2022–2026, percentage of the previous year.
Source: expert opinions gathered for the study, authors' calculations.

Analyzing the factors that determine prices reveals that the prices of building materials have the biggest influence on the prices of metal, wood, and energy resources. The present increasing prices of fuel and energy resources, as well as the lack of competition in Latvia's machinery and equipment market, have a particularly negative impact on the maintenance and operating expenses of machinery and equipment used in the construction industry. It has been determined that the issue is related to the availability of spare parts and machines from specific brands. When assessing the causes of this increase in costs, the Russian-Ukrainian war and the associated changes in international relations, as well as the supply chain disruptions caused by COVID-19 and not yet fully restored, are considered to be the main ones.

On the other hand, Latvian labor expenses are mostly influenced by the pace of building. Additionally significant pressure comes from other EU construction sectors, where both salaries and labor demand have an effect.

Representatives of local governments surveyed in the study during in-depth interviews and focus groups indicate that the **increase in the prevalence of remote work has opened up new opportunities to maintain quality housing in small towns and rural areas**, as long as there is a sufficiently good internet connection, and the distance to cities is not so great as to be an obstacle to access to work or various necessary services. The most remote rural areas, where there is no infrastructure for transport, telecommunications and urban health and education infrastructure, the preservation of the place of residence and the creation of new quality housing do not take place. At the same time, experts have observed a trend towards the expansion of the ranges of economic centres-cities, people build houses outside the city. **The ideal option that many strive for is a house in the suburbs with a small plot of land.**

Municipalities experts emphasize that the difference in housing affordability between regions and Riga remains very large, and it is necessary to reduce it – Latvia differs significantly negatively in terms of regional differences against the background of other countries, experts point out. The large regional differences mean that there are the regions outside Riga that are entering a negative development spiral - lack of access to housing, the labour force is draining and the economic development of the region is regressing.

Experts also point out that the regions of Latvia are currently affected by new challenges related to the current energy crisis and large tax payments. Many entrepreneurs find it difficult to pay wages, not to mention bonuses, which is another obstacle to investing in improving the living environment. Increasing uncertainty about future remuneration increases the risks for starting construction – uncertainty increases whether the intended idea will succeed, whether the desired income will be guaranteed. Although the energy crisis undoubtedly affects the whole of Latvia, in an **unstable environment, entrepreneurs tend to postpone investments or invest only in the economically strongest points**, which in the case of Latvia is the Riga region, which further aggravates the gap between urban and rural zones in Latvia. The challenge for cities further away from Riga is also caused by the high transportation costs, which have increased significantly due to the increase in fuel prices. Latgale is currently more affected than other regions by geopolitical challenges, which also directly affect local construction companies. In the interviews of the study, it is highlighted that a sense of periphery and abandonment has developed among entrepreneurs in Latgale, which negatively affects plans for investments in housing improvement.

Conclusions

1. In regions outside Riga, the number of new apartments put into operation is very low, which is disproportionate to the population structure. With the exception of Riga, where in 2021 1537 new apartments were put into operation, only in Ādaži, Mārupe and Ropaži counties there are more than a hundred new apartments. In all other counties and cities of the country, this indicator is measured only in tens or even less. This creates significant obstacles to the economic development of rural areas.
2. In all regions of Latvia, one of the main problems is the lack of new and high-quality housing. The housing stock of municipalities is insufficient, no new residential facilities are being built, although in many municipalities such plans are mentioned. There are challenges related to the increase in construction costs, labour outflow, unavailability of financial loans outside the Pierīga zoning.
3. Experts point to the problem of rural depopulation, but how to act in this situation, the opinions of experts differ. While some stress the need for comprehensive rural revitalisation, others point to the need to think about **development centres** – where people want to live, where there is infrastructure that can be provided.
4. Taking into account the low availability of new apartments outside the Riga region and the high increase in construction costs, it is important to continue to develop not only state and local government programs for promoting the availability of housing stock for low-income

groups, but also to promote private capital investments.

5. It is stipulated that support measures should not only cover the creation of a municipal housing stock, but also provide support and advice for obtaining financial support for housing construction in the private sector.
6. It is necessary to strengthen state and local government programs for facilitating the availability of housing stock, using both fiscal and monetary support approaches.
7. It is desirable to consider the possibilities of directing municipal land to the construction of the economic segment (including row houses) for the needs of entrepreneurs and municipalities. In the case of entrepreneurs, preference should be given to companies in smart specialisation sectors.
8. It is necessary to provide for guarantees or other support mechanisms for credit institutions for the construction of houses of the economic segment outside the Pierīga region.
9. Municipal development plans need to take into account a balanced territorial plan for the availability of places of residence, educational institutions, transport hubs and other essential elements in order to promote territorial attractiveness and support mobility.
10. It is desirable to strengthen the co-financing of the municipality for the construction or renovation and reconstruction of residential buildings.
11. In order to reduce housing shortages, it is desirable to develop better transport infrastructure – a link between cities and smaller places where free housing might be available.
12. It is desirable to develop motivational mechanisms for entrepreneurs who are ready to renovate houses and build dormitories for their employees in the regions.
13. It is advised that municipalities create residential structures and provide accommodation for rent with a right of redemption to priority groups of the population (families with children, priority specialists specified by local governments, etc.).

Acknowledgements

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STATE FUNDED PENSION SCHEMES IN THE BALTIC STATES: ASSETS AND RETURN ANALYSIS

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Abstract
The Baltic States have a three-tier pension system. Pillar II is the state funded pension scheme in which contributions are made automatically from an employee's gross salary as part of social contributions. The contributions to Pillar II state funded pension schemes may be invested in several pension plans with different risk ratios of which three types are the most common: active, balanced and conservative ones. The accumulation of funds and consequently a partial amount of an old-age pension depends on the chosen pension plan and the manager of funds. The research aim is to assess the operation efficiency of the state funded pension schemes in the Baltic States. The research mainly employs and provides the analysis on the statistical data on the value and return of assets and number of Pillar II scheme participants. Theoretical discussion is built upon the use of scientific publications by means of monographic descriptive method, correlation and regression analyses as well as the methods of analysis and synthesis. In Latvia, 25.62% on average of all state funded pension plans participants have chosen conservative strategy, while only 8.36% on average have chosen this strategy in Lithuania. In Estonia (75.49%) and Lithuania (69.13%), the majority of assets are accumulated in the balanced strategy pension plans. The research results show that pension plans have positive return in long-term; though, sharp fluctuations and negative return might be demonstrated in short-term. Both in Lithuania and Latvia exists a negative correlation between Pillar II pension schemes and inflation, i.e. the return of a pension scheme decreases with the increase of inflation meaning that inflation alongside with other economic and political factors might be considered as a factor affecting the return of pension schemes.
Key words: pension schemes, state-funded, pension plans strategies, Baltic States.

Introduction

The origins of state retirement pensions date back to the end of the 19th century when countries initiated the development of state mandatory social insurance against such social risks as old age and work incapability. Several researchers studying the development of pension systems have come to the conclusion that countries may use one of the two basic pension models: the Anglo-Saxon or Beveridge system, or the continental or Bismarck system (Kolmar, 2007). The continental model is characteristic to Western European countries, and it is based on the solidarity principle of generations with the aim to reduce poverty. The principle of the Anglo-Saxon model envisages a uniform rate depending on the years a person has worked in a particular country, and it is aimed at the maintenance of status. Jefremova (2016) studying the significance of the state funded pension schemes assures that a three-tier pension system is one of the most efficient and progressive pension systems worldwide. Estonian researchers have provided a profound analysis of social protection systems in the Baltic States and indicate that pension systems there with the chosen three-tier system differ from the pension schemes in other European countries (Paas *et al*., 2004). Funded pension schemes are broadly studied by Lithuanian and Estonian researchers (Meckovski *et al*., 2022; Medaiskis & Gudaitis, 2017; Pivoriene & Ambrazeviciute, 2020; Novickyte & Rabikauskaite, 2017; Piirits & Vork, 2019). Volskis E. (2012, 2014) is one of Latvia's researchers who has made valuable contributions to the analysis of pension system in Latvia. One of the aims of Pillar II pension schemes is to accumulate financial resources and receive part of them as an old-age pension. Therefore, it is necessary to choose the most appropriate pension plan and the manager of pension funds. The research aim is to assess the operation efficiency of the state funded pension schemes in the Baltic States. Research tasks: 1) to overview the pension systems and retirement requirements in the Baltic States; 2) to analyse assets value and number of participants in Pillar II scheme; 3) to evaluate the return of assets invested in Pillar II scheme.

Materials and Methods

The research mainly employs and provides the analysis on the statistical data on the value and return of assets and number of Pillar II participants compiled by the following authorities of the Baltic States: the State Social Insurance Agency of the Republic of Latvia**,** the Bank of Lithuania and Pensionikeskus AS of the Republic of Estonia. Theoretical discussion is built upon the use of scientific publications by means of monographic descriptive method, as well as the methods of analysis and synthesis. Correlation and regression analyses were applied to determine the relationship between two variables: pension scheme and inflation.

Results and Discussion

Three-tier pension system

The Baltic States have a three-tier pension system, which includes Pillar I (National Mandatory

Bonded Pension Scheme), Pillar II (State-funded Pension Scheme) and Pillar III (Private Voluntary Pension Scheme). Pillar I is a non-accumulating pension scheme, which means the participation of all residents who pay or whom social contributions are paid for. This scheme is also known as PAYG or pay-as-you-go pension system in which pensions are financed by the contributions collected from the current employees. Pillar I is based on gender and generation solidarity (Manapensija, s.a). Pillar II is a state funded or accumulative pension scheme which allows to make additional savings for the pension. Contributions to Pillar II pension funds are made automatically from an employee's gross salary as part of made social contributions. These contributions are invested in financial instruments consistent with a person's selected pension strategy. Pillar III is a private voluntary pension scheme ensuring additional savings for a person's pension through private pension funds. Figure 1 reflects the historical development of the pension systems in the Baltic States.

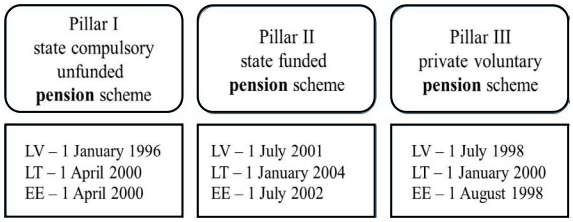

Figure 1. Three-tier pension systems in the Baltic States.

Source: author's construction based on Paas *et al*., 2004.

The pension system of Latvia is the oldest pension system in the Baltic States as its Pillar I started the operation in 1996, while Lithuania has initiated the pension schemes only from 2000. However, in 2004 all three Baltic States had Pillar II pension schemes. Estonian researchers Paas et al. (2004) have mentioned that Pillar II scheme is compulsory for younger and voluntary for older employees. In Latvia, residents born after 1 July 1971 are mandatory participants of the state funded pension scheme, while voluntary participants may be persons born between 2 July 1951 and 1 July 1971 (Manapensija, s.a). In Estonia, the mandatory date for participation in the scheme is 1 January of the year after the person has reached the age of 18 (Pensionikeskus.ee, s.a.). Strumskis and Balkevicius (2016) analysing the pension system in Lithuania have pointed that Pillar II is voluntary and an employee may freely choose the contributions and pension fund manager. Yet, the situation has changed after the Pension Reform in Lithuania and participation in Pillar II pension scheme is mandatory from 2019 (Pivoriene & Ambrazeviciute, 2020). The rights to receive a state funded pension depend on several factors (Table 1).

Pension reforms in the Baltic States envisage a gradual increase of retirement age up to 65 years. In 2023, persons (both men and women) having reached the age of 64 years and 6 months and having at least 15 years of the insurance service have the right to an old-age pension in Latvia. In Estonia, the retirement age is 64 years and 3 months, while Lithuania has different retirement age requirements for men and women, i.e. 64 years and 6 months for men and 64 years for women. The pension system prescribes also the right to early retirement or delay of retirement.

Table 1

Comparison of retirement requirements in the Baltic States

Indicator	Latvia	Lithuania	Estonia
Retirement age in 2023	64 years and 6 months	64 years and 6 months (for men) 64 years (for women)	64 years and 3 months
Planned retirement age	65 (from 2025)	65 (from 2026)	65 (from 2026)
Insurance period (length of service)	at least 15 years (20 years from 2025)	at least 15 years	at least 15 years
Early retirement	2 years before the retirement age if insurance period is at least 30 years	maximum 5 years before the retirement age	2 years before the retirement age

Source: author's construction based on Valsts sociālās apdrošināšanas…, s.a.; Pensionikeskus, s.a; Lietuvos Bankas, s.a.

The most favourable situation is reported in Lithuania, where persons may retire even five years before the retirement age, while Latvia has the strictest terms stating that early retirement is possible two years before the retirement age and only in the case a person has an insurance period for at least 30 years. In Estonia, these are two years before the retirement age. However, according to Riigiportal Eesti.ee (s.a.), in Estonia, the retirement age from 2027 will depend on the average life expectancy and it would be possible to retire even five years before the retirement age.

Pillar II state funded pension strategies

The contributions to Pillar II state funded pension schemes may be invested in several pension plans with different risk ratios of which three types are the most common: active, balanced and conservative ones (Table 2).

Table 2

Comparison of Pillar II state funded pension strategies in the Baltic States

Indicator		Active plans			Balanced plans	Conservative plans
		Type 1	Type 2	Type 3		
Risk		high	high	moderate	low	low
Return rate		high	moderately high	moderate	moderately low	low
Investment sources	LV	up to 100% in investment funds and shares	up to 25% in fixed income securities up to 75% in investment funds and shares	50% in fixed income securities 50% in investment funds and shares	up to 75% in fixed income securities up to 25% in investment funds and shares	100% in fixed income securities
	LT	up to 98% in shares	up to 85% in shares	up to 50% in shares	35–85% in shares	10–19% in shares
	EE	up to 100% in investment funds and shares	various depending on the fund		up to 60–70% in shares	at least 80-90% are invested in government bonds
Target audience: age		around 20–30	up to 45	from 46 to 55	from 56 to 60	more than 60

Source: author's construction based on Valsts sociālās apdrošināšanas…, s.a.; Pensionikeskus, s.a; Lietuvos Bankas, s.a.

Consistent with Article 12 of the Law on State Funded Pensions (the Republic of Latvia), Pillar II funds may be invested in securities or money market instruments issued by the state, local governments and international financial institutions, shares and other debt securities of commercial companies, deposits in credit institutions, investment funds, derivatives and venture capital market instruments. In addition, the law prescribes restrictions for the investments and prohibits investing funds in real estate, virtual (crypto) currencies, financial instruments issued by the fund manager and granting or using them as loans (Valsts fondēto pensiju …, 2000). The law allows to invest up to 100% of total funds in shares and up to 20% of total funds may be invested in other currencies.

In general, *active plans* mean that funds are invested in shares of various companies; thus, ensuring the highest long-term returns. In Latvia, additional two kinds of active plans are introduced from 2018, i.e. Active 75% and Active 100% pension schemes. *Balanced plans* ensure a dynamic and stable increase of invested resources and protect the accrued funds from large fluctuations. *Conservative plans* ensure a low profitability, since they mainly preserve the accrued pension capital at the same time ensuring a steady increase in the capital value. In 2023, there are six conservative plans, three balanced plans and twenty active plans of which seven plans are under Active 50% strategy, two – Active 75% and eleven – Active 100%. In Lithuania, the pension strategies are divided into conservative, small equity share, medium equity and equity plans. Two pension funds fall under the category of conservative plans, one under small equity share, one – medium equity share and four – equity share funds. For the purpose of analysis, small equity share and medium equity plans are considered

as balanced pension plans, while equity ones as active pension plans. In Estonia, pension plans are divided consistent with the risk level: low (conservative), medium (balanced) and high (active). The degree of risk is determined by the structure and proportion of investments.

The value of Pension II pillar scheme assets consists of contributions made by the scheme participants and profit from investment generated by the pension plans. Figure 2 discloses the data on total assets value and number of participants in Pillar II pension schemes in the Baltic States.

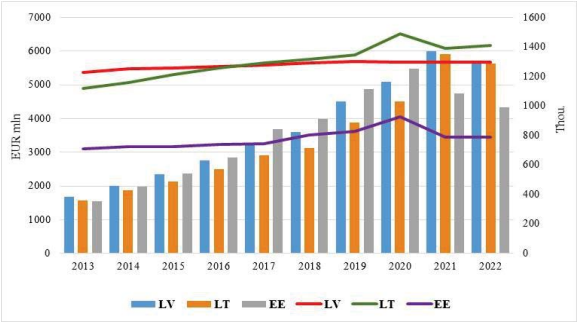

Figure 2. Total value of assets and number of Pillar II scheme participants in the Baltic States for 2013–2022, at the end of the year.

Note: bars – assets, EUR mln, lines – participants, thou.

Source: author's construction based on Valsts sociālās apdrošināšanas…, s.a.; Pensionikeskus, s.a; Lietuvos Bankas, s.a.

Total value of assets of the state funded pension scheme has steadily increased in Latvia and Lithuania up to the end of 2021 reaching almost EUR 6 bln in each country with the following decrease in 2022, while Estonia reports a decrease already in 2021. However, in Latvia, the largest increase in the value of total assets was reported in 2019 when assets grew by EUR 915.41 mln or 25.46% compared with the previous period. Such an increase was reached thanks to net contributions made by the scheme participants (EUR 516.70 mln) and profitable investment of the scheme's funds (EUR 398.80 mln). In Lithuania, the largest increase of assets value was observed in 2021 – by EUR 1.41 bln or 31.43% compared with 2020. The annual rate of return was 21% and such a growth was experienced due to fast rising equity markets (Invalda INVL, 2022). In Estonia, the fastest increase was seen in 2014 and 2017, i.e. by EUR 450.52 mln (29.32%) and EUR 828.78 mln (29.13%). In 2022, the value of assets decreased in all Baltic States mainly due to the sharp rise of inflation, the war in Ukraine and increase of energy resources prices. The decrease was around 5.32% in Latvia and 4.9% in Lithuania. In Estonia, the decline was larger, i.e. 8.82%. However, the decrease in total assets value in Estonia started already in 2021 (13.07% vs 2020).

Changes in the number of scheme participants have a minor impact on the value of assets. Hence, in Latvia, the changes in the number of scheme participants have been very steady, i.e. 0.59% on average within the period analysed (the largest changes in 2014 (increase by 1.77%) and 2020 (decrease by 0.34%). Lithuania demonstrates bigger fluctuations: 2.69% on average with a sharp growth in 2020 (10.35%) followed by a quite rapid decrease in 2021 (6.64%). Such changes are due to the changes in the number of participants of conservative pension plans. In 2020, the number of participants in conservative Pillar II plans increased by 103% or a bit more than twice; yet, this number decreased by 59.42% in the following year. In Estonia, the number of scheme participants is 1.65 times smaller than in other Baltic States on average. Changes are similar to those reported by Lithuania: the largest increase in 2020 (12.26%) with a very rapid decline in 2021 (15.23%). Basic reasons here might be the Pension Reform of Estonia initiated in 2021.

The value of assets per scheme participant is also a significant aspect for the analysis (Figure 3). In general, the size of the accumulated capital in Pillar II scheme per participant depends on several factors: amount of contributions, duration of participation in Pillar II scheme and performance results of the selected investment plan.

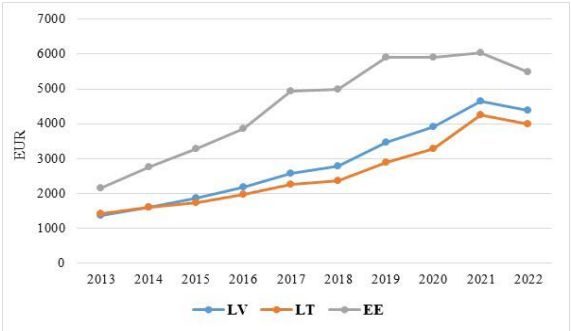

Figure 3. Value of assets per scheme participant in the Baltic States for 2013–2022, EUR, at the end of the year.

Source: author's construction based on Valsts sociālās apdrošināšanas…, s.a.; Pensionikeskus, s.a; Lietuvos Bankas, s.a.

The largest amount of contributions made per scheme participant is reported by Estonia which exceeds the amount of contributions made in other Baltic States 1.66 times on average. The explanation lies in smaller number of participants and approximately the same amount of contributions made. The average increase in the value of assets per participant in Estonia has been more moderate (11.60%) in contrast to Lithuania and Latvia (12.66%

and 14.08% respectively). The analysed indicator has grown in all Baltic States till the end of 2021 with a bit more expressed fluctuations in Estonia which demonstrated also the sharpest decrease in the value of assets per participant in 2022 (9.07%). Latvia and Lithuania reported decrease by 5.32% and 6.27%, respectively.

Total assets of Pillar II state funded pension scheme are broken down by three main strategies: conservative, balanced and active to analyse the assets value in the Baltic States (Figures 4, 5, 6).

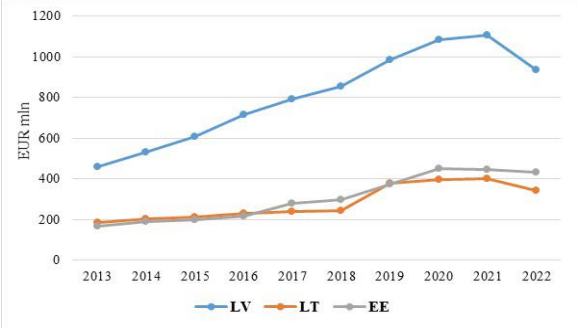

Figure 4. Total value of assets of conservative strategy plans in the Baltic States for 2013–2022, EUR mln, at the end of the year.
Source: author's construction based on Valsts sociālās apdrošināšanas…, s.a.; Pensionikeskus, s.a; Lietuvos Bankas, s.a.

According to Figure 4, the assets value of conservative strategy plans in Latvia is approximately 2.7 times higher than in Lithuania and Estonia on average. The value of assets has increased at an average rate of 13.68% till 2019, then the rate has slowed down to 9.78% in 2020 and 2.34% in 2021. The maximum value was reached in 2021 amounting to EUR 11.08 bln. In 2022, the value of assets decreased to EUR 935.34 mln or by 15.61%. In Lithuania, the value of assets in conservative strategy plans demonstrated the highest rate of increase by 55.28% in 2019. However, the maximum value of EUR 403.34 mln was reached in 2021 mainly due to the growth of assets in two pension funds: Life-cycle pension fund 1975-1981 and Life-cycle pension fund 1968-1974. In Estonia, the largest value of assets observed was also in 2021 (EUR 445.75 mln). The value of assets has started to decrease already in 2021 which might be associated with the Pension Reform in Estonia.

The number of strategy participants in Latvia is on average three times larger than in Lithuania (Figure 5).

In Latvia, 25.62% on average of all state funded pension scheme participants have chosen conservative strategy, while only 8.36% on average have chosen this strategy in Lithuania. Unfortunately, no publicly available data broken down by pension scheme strategies are available for Estonia.

Different data and situation are demonstrated by assets accumulated in the balanced strategy pension plans (Figure 6).

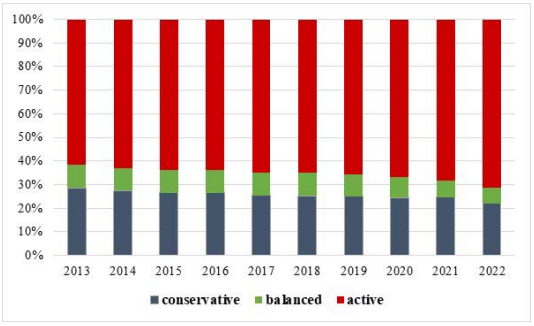

Figure 5. Proportion of Pillar II pension strategies participants in Latvia for 2013–2022, at the end of the year, %.
Source: author's construction based on Valsts sociālās apdrošināšanas…, s.a.

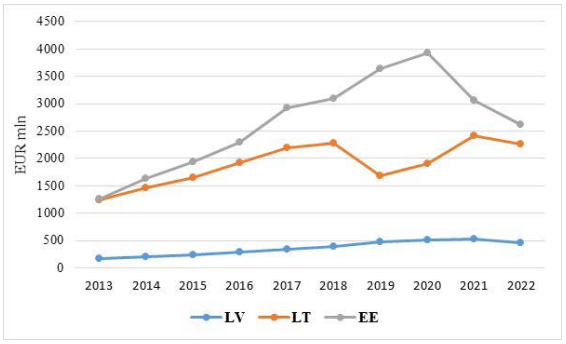

Figure 6. Total value of assets of balanced strategy plans in the Baltic States for 2013–2022, EUR mln, at the end of the year.
Source: author's construction based on Valsts sociālās apdrošināšanas…, s.a.; Pensionikeskus, s.a; Lietuvos Bankas, s.a.

In contrast to conservative strategy plans, in Estonia (75.49%) and Lithuania (69.13%) the majority of assets are accumulated in the balanced strategy pension plans. The value of assets demonstrated a growing trend till 2018 in the two countries. In Lithuania, the value of assets decreased by 25.69% in 2019 compared with the previous year due to a 32.73% decline in the number of scheme participants. However, the value of assets per participant grew by 55.54% from EUR 2465.56 to EUR 3834.82. In 2021, the largest rate of increase (25.90%) was reached followed by a 6.42% decrease in the following year. Estonia has reported a growing trend at an average rate of 17.93% reaching EUR 3.93 bln in 2020. The sharp decrease in 2021 (22%) might be associated with the

Pension Reform and more extensive transition of participants to active pension strategies.

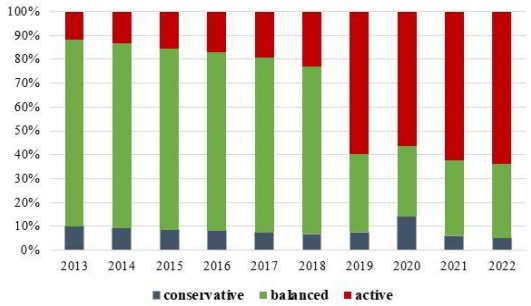

Figure 7. Proportion of Pillar II pension strategies participants in Lithuania for 2013–2022, at the end of the year, %.
Source: author's construction based on Lietuvos Bankas, s.a.

Within the period analysed the proportion of scheme participants in balanced pension plans accounts for 57.43% on average, reaching the largest number of participants (942 451) in 2017. The number and consequently the proportion of active scheme participants significantly started to increase from 2019. The increase accounted for 59.61% compared with the previous year and the number of active scheme participants continued to grow with every year reaching 898 210 participants in 2022. The changes follow from the new pension model which was introduced in Lithuania from 2019. This means that Life cycle pension funds were obliged to offer participants to join those pension funds which were most appropriate for them to accumulate more funds for pension capital and their age (Ministry of Social…, 2023). Therefore, pension scheme participant had an opportunity to choose those plans which ensure higher return on investment.

The growth of accumulated assets in active plans also evidences the transition from balanced pension schemes to active ones that is expressively true for Lithuania (Figure 8).

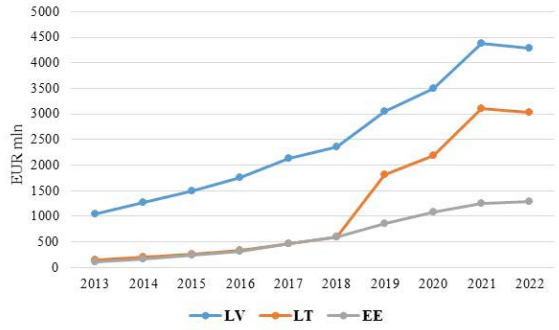

Figure 8. Total value of assets of active strategy plans in the Baltic States for 2013-2022, EUR mln, at the end of the year.
Source: author's construction based on Valsts sociālās apdrošināšanas…, s.a.; Pensionikeskus, s.a; Lietuvos Bankas, s.a.

In Lithuania, assets of active strategy plans have sharply grown from 2018; thus, reaching EUR 1.82 bln in 2019 or increasing by 203.46% compared with the previous year. The value of assets moderately increased also in the following two years (by 31% on average) up to 2022. The value of assets per participant has increased throughout the entire period analysed reaching the largest value in 2021 when it amounted to EUR 3584.40 per participant or growing by 37.07% compared with the year before. Estonia demonstrates moderate fluctuations in the value of assets, and it is the only country which reports an increase in the assets value also in 2022. In Latvia, the increase of assets value has been the lowest, i.e. annually 17.21% on average.

The comparison of average annual return of three pension strategies and annual inflation rates might provide an insight in return of contributions made by the scheme participants (Figures 9 and 10).

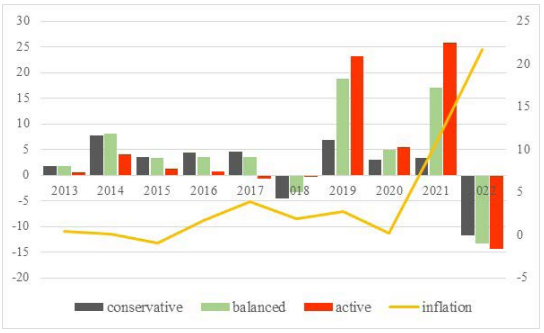

Figure 9. Average annual short-term return of Pillar II pension scheme and inflation rate at the end of the year in Lithuania between 2013 and 2022, %.
Source: author's construction based on Lietuvos Bankas, s.a; Official statistics portal, s.a.

In general, returns from investments in pension plans are higher than inflation, especially in 2019, when the average return of pension schemes exceeded the inflation rate by 13.57 percentage points. Rabikauskaitė and Novickytė (2015) also have concluded that pension funds preserve the assets value despite financial slowdowns. However, this is true till 2022, when the return of pension funds' assets was 35% below the inflation rate. Such a tremendous gap is due to the emergence of various political and economic circumstances. In 2022, the average return of assets was -13.20%, while the inflation rate was 21.70%. It shall be considered that the data show the average figures and the assessment of them require precaution as any individual pension plan may demonstrate different return rates. So, for example, in 2019, when the average annual inflation rate was 2.70%, the highest average return over a year was demonstrated by active plans (23.10%) of which Life-cycle pension funds, 1975–1981 were the most profitable (23.71%) followed by Life-cycle pension funds, 1989–1995 and Life-cycle pension funds, 1996-2002 (22.91% and 22.90%, respectively). In

Lithuania, the calculated correlation shows that there exists a negative correlation between Pillar II pension schemes and inflation, i.e. the return of a pension scheme decreases with the increase of inflation. The strongest negative correlation is observed between a conservative pension scheme and inflation (r=-0.7281). The coefficient of determination (R^2=0.53) means that only 53% of the variability observed in the target variable are explained by the regression model. Considerably lower results are obtained analysing correlation between a balanced pension scheme and inflation (r=-0.4048 and R^2=0.16) and an active pension scheme and inflation (r=-0.2320 and R^2=0.05). Hence, the correlation and regression analyses prove that inflation is only one of the factors affecting the return of pension schemes.

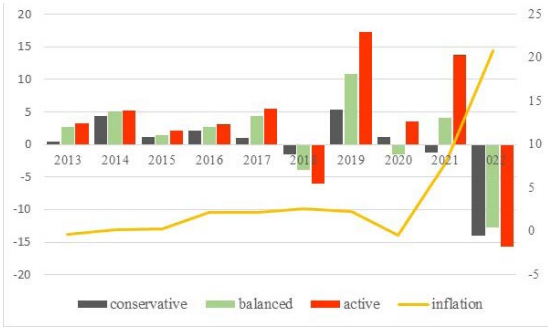

Figure 10. Average annual short-term return of Pillar II pension schemes and inflation rate at the end of the year in Latvia between 2013 and 2022, %.
Source: author's construction based on Valsts sociālās apdrošināšanas…, s.a.; Official statistics portal, s.a.

In Latvia, active pension schemes in short-term have reported higher return throughout the entire period analysed with the exception of 2018 and 2022. The year 2018 was unfavourable for the financial instrument market due to losses at the global stock and bonds market. The downturn had the hardest hit on the return of active plans (-5.96%), though a negative return was experienced also by balanced and conservative pension plans. In general, negative return results are due to the cyclical nature of financial markets.

In Latvia, the correlation trend is similar showing a negative correlation between Pillar II pension schemes and inflation. However, the correlation is stronger. Similar to Lithuania, also in Latvia, the strongest negative correlation is observed between a conservative pension scheme and inflation (r=-0.9072). The coefficient of determination (R^2=0.82) means that 82% of the variability observed in the target variable are explained by the regression model. Weaker but still significant correlation is observed between a balanced pension scheme and inflation (r=-0.6827 and R^2=0.47) and active pension schemes and inflation (r=-0.5546 and R^2=0.31). This means that inflation has been one of essential factors affecting the return of pension schemes in Latvia.

In a long-term (over 10 years), pension plans in Latvia have reported a positive annual return around 3% on average. The highest average annual return was achieved by Active 50% pension plan (3.60%), conservative pension schemes were the only ones who demonstrated a negative long-term return in 2022.

Conclusions

1. The Baltic States have a three-tier pension system. Pillar II is the state funded pension scheme in which contributions are made automatically from an employee's gross salary as part of social contributions.
2. Total value of assets of the state funded pension scheme has steadily increased in Latvia and Lithuania up to the end of 2021 reaching almost EUR 6 bln in each country with the following decrease in 2022, while Estonia reports a decrease already in 2021. Changes in the number of scheme participants have a minor impact on the value of assets.
3. In Latvia, 25.62% on average of all state funded pension plans participants have chosen conservative strategy, while only 8.36% on average have chosen this strategy in Lithuania. In Estonia (75.49%) and Lithuania (69.13%), the majority of assets are accumulated in the balanced strategy pension plans.
4. Within the entire period analysed, the assets value of conservative strategy plans in Latvia is approximately 2.7 times higher than in Lithuania and Estonia on average. The number of strategy participants in Latvia is three times on average larger than in Lithuania.
5. In Lithuania, the highest average short-term return of pension plans exceeding the inflation rate by 13.57 percentage points on average was observed in 2019.
6. In Latvia, active pension plans compared with other plans in short-term have reported higher return throughout the entire period analysed with the exception of 2018 and 2022, when the return of active plans decreased by 5.96%. However, a negative return was experienced also by balanced and conservative pension plans.
7. In a long-term (over 10 years), pension plans in Latvia have reported a positive annual return around 3% on average. The highest average annual return was achieved by Active 50% pension plan (3.60%) and conservative pension plans were the only ones who demonstrated a negative long-term return in 2022.

8. Both in Lithuania and Latvia exists a negative correlation between Pillar II pension schemes and inflation, i.e. the return of a pension scheme decreases with the increase of inflation. The strongest negative correlation is observed between a conservative pension scheme and inflation (r=-0.7281 in Lithuania and r=-0.9072 in Latvia), while the weakest correlation was reported between an active pension scheme and inflation (r=-0.2320 and r=-0.5546, respectively). This means that inflation alongside with other economic and political factors might be considered as a factor affecting the return of pension schemes.

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ASSESSMENT OF SOCIAL BENEFITS FOR FAMILIES WITH CHILDREN IN LATVIA

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Abstract
Social benefits are essential in providing support to families with children, especially in the first years of the child's life as well as to families at risk of poverty (large families, parents raising a child alone). Social insurance benefits ensure parents with income while taking care of a child. Latvia's strategic planning documents have defined social protection for families with children as one of the priority areas for several planning periods simultaneously emphasising the need to increase social security and promote the birth rate in the country. The research aim is to assess the social benefits system for families with children in Latvia. The research results allow concluding that the expenditure for social support for families with children as percentage of GDP in Latvia is lower than the average EU Member States indicator as well as it is the lowest one among the Baltic States. Support for families with children in Latvia is gradually growing; however, it is necessary to regularly increase the childbirth allowance taking into account inflation in order not to worsen the financial situation of these families as well as to allocate a larger proportion of GDP to support families with children in Latvia.
Key words: social benefits, support for families with children, birth promotion.

Introduction

Researchers and the society regularly hold discussions about the low birth rate and factors impacting it. The government may contribute to the increase in the birth rate by providing support to families with children. Social protection for families with children is implemented in the form of financial support, services (education, care) and parental leave. Financial support is basically provided through social benefits and tax incentives. Abolina (2016) in her PhD thesis 'Family and Development of Family Support Policy in Latvia (1990–2015)' has indicated that such classification of support measures is based on Math&Thevenon's theoretical framework, and it is used in all EU Member States when developing policy for family support.

Social protection for families with children has been defined as one of the priority areas in Latvia's strategic planning documents for several planning periods. The documents particularly emphasise the necessity to increase social security and promote the birth rate in the country (Latvijas iltgspējīgas attīstības ..., 2010). According to the National Development Plan of Latvia 2021–2027, one of the directions of action is 'Strong families across generations', which is aimed at improvement of the support system for families with children, so that the child birth does not significantly reduce the level of income per family member (Latvijas Nacionālais attīstības ..., 2020).

Abolina (2016) in her PhD thesis concludes that the state support for families is vital, especially on conditions when the birth of each subsequent child increases the probability of the family to fall below the poverty risk threshold.

Kristapsone and Kantane (2019) indicate that the surveyed population of Latvia specify the necessity to increase social benefits and improve the availability of kindergartens to improve the situation of families. Social benefits for raising a child are most frequently introduced with the aim to reduce the risk of poverty in families with children, to cover the costs of raising children as well as to promote birth. Most often the countries of the Baltic Sea region choose to increase the existing amounts of benefits or expand the range of their recipients; thus, compensating for the effects of inflation and improving social protection (Pabalstu par bērnu ..., 2022).

Grinevica, Bite, Broka (2022) have revealed that childcare benefits are an essential support for families with children. Although the amounts of parental benefits increase in Latvia, the birth rate is decreasing from 2016, and it will affect the national economy and welfare in the long-term. Therefore, it is necessary to continue the improvement of the support system for families with children. Also, according to the OECD Report 2022, demography is the main factor affecting long-term growth prospects in Latvia. The low birth rate and migration are the most important factors.

Pezer (2022) points that state policies supporting families with children differ among countries; though, they have a common goal – to improve the welfare of children. A combination of universal and targeted support (family or social assistance benefits) is most effective in reducing poverty and compensating costs. High and even not so high social support for families with children significantly reduces poverty in families.

Research hypothesis – social benefits for families with children are increasing in Latvia; however, they are still essentially smaller compared with the majority of the EU Member States. The research aim is to assess the social benefits system for families with children in Latvia.

The following research tasks are subject to the aim:

1) to study types and amounts of social benefits in Latvia;
2) to compare social protection expenditure in Latvia and other EU Member States.

The research covers the period from 2011 to 2022, in some cases, the scope of research is wider, which is related to significant changes in the regulatory framework.

Materials and Methods

Research methods: the monographic and descriptive methods, analysis and synthesis, the graphic method, statistical method (analysis of the chain increase, correlation).

The present research is based on various scientific publications, publicly available documents, information available in databases and other sources.

Results and Discussion

Social benefits in Latvia

Various social benefits are one of the most significant forms of social protection for families with children. The system of benefits may be divided into three large groups. Group 1 includes social insurance benefits (sickness, maternity, paternity, parental), Group 2 – state social benefits and allowances (state family allowance, childcare benefit, childbirth allowance etc.) and Group 3 – social security benefits. The system of state social benefits encompasses both benefits that are paid regularly and lump-sum allowances. Furthermore, there are benefits the amount of which depend on the average salary subject to social contributions made by a child's parent. Yet, there are also benefits the amount of which is a constant sum or it depends on the number of children in the family (Table 1).

Maternity benefit consists of two parts – prenatal maternity leave and postnatal maternity leave. In addition, if a woman has started to receive a medical care in a preventive medical institution up to the 12th week of pregnancy and continued it throughout the pregnancy, an additional leave (14 days) is granted, which is added to the prenatal maternity leave. The number of granted and paid days of maternity benefit have not been changed since 1997. However, the amount of maternity benefit has not been changed since 2010, and it is granted in the amount of 80% of the average salary subject to social insurance contributions made (previously 100%).

Paternity benefit is granted and paid for 10 working days of the granted leave (for 10 calendar days until 1 August 2022) to the father of a newborn baby or one of the parents in case of adoption, another person who takes care of the child at the request of the child's mother if the child's paternity has not been recognised (established), the child's father is dead or the child's father has had his rights of custody terminated.

The extension of the paternity leave is positive, since it encourages the involvement of fathers in the childcare. The range of paternity benefit recipients was also expanded and from 1 August 2022 it is possible to receive this benefit by a person who takes care of a child if the child's paternity has not been established or the child's father is dead, or the child's father has had his rights of custody terminated (Darba likums, 2001). However, it should be admitted that the amount of the paternity benefit (80% of the benefit recipient's average salary subject to social insurance contributions made) has not been changed since 2010 (Par maternitates un..., 1995).

Parental benefit was introduced from 2008, which partially replaced the childcare benefit for employed persons. From 2014 the parental benefit is granted and paid to a socially insured person who takes care of a child or several children born in the same birth if the person is an employee or self-employed on the day the benefit is granted. When determining the amount of parental benefit, the calculated average salary subject to insurance contributions and the chosen duration of receiving the benefit are taken into account. The fact that the benefit recipient has an opportunity to choose the duration of the benefit payment should be evaluated positively; thus, individualising the needs and financial situation of each family. The benefit is higher (60%) if it is received for a shorter period, while choosing a longer period, it is lower – 43.75%.

Until 30 September 2014 the parental benefit was granted in the amount of 70% from the benefit recipient's average salary subject to insurance contributions. However, regulatory enactments prescribed the minimum amount, stating that the benefit could not be less than 70% of the double amount of the state social security benefit valid on the day of requesting the parental benefit.

Limits for the amount of unemployment, maternity, paternity, parental and sickness benefits were set from 2010 to 2014 in order to maintain a sustainable social security system in Latvia in the situation of economic crisis. The limit was EUR 16.38 per calendar day and 50% were calculated from the sum exceeding the day limit. The limit of maternity, paternity and parental benefits was increased to EUR 32.75 per day from 2013 (Par valsts pabalstu ..., 2009).

Table 1

Social benefits for families with children in Latvia between 2011 and 2022

Type of benefit	Length of payment	Amount of benefit, date of changes
Benefit depends on the average salary subject to social contributions (%)		
Maternity benefit	112–126 days (of which 56–70 days before the birth of a child and 56 days after the birth of a child)	80%
Paternity benefit	10 calendar days, 10 working days from 1 August 2022	80%
Parental benefit	until the child is 1 year old (without earning income)	from 1 January 2011 – 70% but not less than the state social security allowance from 1 October 2014 – 60%
	until the child is 1.5 years old (without earning income)	from 1 October 2014 – 43.75%
	until the child is 1 or 1.5 years old (earning income)	from 1 October 2014 – 30%
Sickness benefit	from the 1st to the 14th day of work incapability (child is taken care of at home) from the 1st to the 21st day of work incapability (child is taken care of in hospital) from the 1st to the 30th day of work incapability (bone fracture)	80%
Benefit or allowance is a constant sum depending on the number and age of children in the family		
State family allowance	• 1–15 years • 15–19 years if a child continues to study in a general or vocational education institution and is not married (from 2018 until the age of 20)	from 1 January 2011 for each child – EUR 11.38
		from 1 January 2017 for the 1st child – EUR 11.38; for the 2nd child – EUR 32.76 (11.38x2+ suppl. 10); for the 3rd child – EUR 100.14 (11.38x3+ suppl. 66); for the 4th child – EUR 196.07 (11.38x4.4+ suppl. 116)
	from 2022 • 1–16 years • 17–20 years if a child continues to study in a general or vocational education institution and is not married	from 1 January 2022 for 1 child – EUR 25; for 2 children – EUR 100; for 3 children – EUR 225; for 4 children and more – EUR 100 for each subsequent child
Childcare benefit	until the child is 1 year old 1–2 years old	EUR 71.14 (unemployed) EUR 42.69
	until the child is 1 year old 1–1.5 years old 1.5-2 years old	from 1 January 2013 – EUR 142.29 (unemployed) EUR 142.29 EUR 42.69
	until the child is 1.5 years old 1.5–2 years old	from 1 January 2014 – EUR 171 EUR 42.69
Childbirth allowance	lump-sum payment	EUR 421.17

Source: authors' construction based on Par maternitātes un ... (1995), Valsts sociālo pabalstu ... (2002), *Noteikumi par ģimenes ...* (2009), *Noteikumi par bērna ...* (2009).

The minimum amount is no longer set for the parental benefit from 1 October 2014 and the childcare benefit to socially insured persons is also paid together with the parental benefit. Starting from 1 October 2014, the parental benefit is granted also to working parents who continue to work and were not on the childcare leave – the benefit was paid in the amount of 30% of the granted benefit amount.

Significant changes have been made from 2023 to take over the conditions stipulated by the Directive 2019/1158 of the European Parliament and of the Council of 20 June 2019 on the work-life balance

for parents and carers. The changes relate to the determination of the non-transferable part of the parental benefit – two months that have to be used by the other parent until the child reaches the age of eight. In addition, the benefit payment period is extended by one month. Also, the amount of parental benefit for working people has been increased to 50% of the amount of the granted benefit (Par maternitātes un ..., 1995). Changes to the regulatory framework will promote greater involvement of fathers in the childcare and, hence, increase the support for families with children.

As indicated in the annotation of the amendments to the law "On Maternity and Sickness Insurance", the number of men who take leave in connection with the birth of a child and simultaneously receive the paternity benefit has been gradually increasing since 2013. If 42% of fathers received the paternity benefit in 2013, then the proportion of fathers receiving the paternity benefit increased to 56% or by 14 percentage points in 2020. The society generally recognises the importance of a father in the process of the child's personality formation.

The **sickness benefit** is also a significant form of support for families with children. The benefit is granted to an insured person if there is a need to take care for a sick child who has not reached the age of 14. In certain cases, if the child has a serious illness requiring long-term inpatient treatment, the benefit is granted until the child turns 18.

The sickness benefit for the care of a sick child under the age of 14 is granted until the 14th day of work incapacity if the child is taken care of at home (until the 21st day if hospitalised). The norm introduced from 2021 stipulates that the sickness benefit is granted until the 30th day of work incapacity if the child is taken care of due to an injury related to a bone fracture. The sickness benefit is granted in the amount of 80% of the benefit recipient's average salary subject to insurance contributions.

The next group relates to the **state social benefits and allowances.** The following benefits shall be noted in connection with the support for families with children: state family allowance, childcare benefit, childbirth allowance and benefits for children with disabilities – of which benefits for children with disabilities are not studied in the present research as they have a separate target audience with its own specifics.

The right to receive state social benefits does not depend on the person's social insurance contributions made. The state family allowance is granted to a person who is raising a child. The allowance is aimed at provision of regular support to families which have incurred additional expenditure due to the necessity to raise children. In Latvia, the state family allowance is universal, since it is granted for each child regardless of the parents' level of income as it is traditionally in the majority of European countries (e.g. Estonia, Lithuania, Ireland, France, Sweden, Finland and others – in total, in 80% of the EU Member States). In Latvia, the universal state family allowance system for families with children was introduced in 1992 (Koncepcija par ģimenes…, 2011).

In Latvia, the procedure for granting and disbursing the state family allowance has been changed and improved several times within the period analysed. Between 2011 and 2016 the amount of the state family allowance was EUR 11.38, for the 2nd child the allowance was increased two times and for the 3rd child and subsequent children – it was three times higher than for the 1st child in the family.

The regulatory framework was significantly amended from 2017 improving support for families with four children as well as determining payment supplement for families raising more than one child. Supplement to the state family allowance was EUR 10 per month for two children and EUR 66 per month for three children. For each subsequent child the supplement was by EUR 50 per month larger than it was previously for the total number of children in the family (Valsts sociālo pabalstu ..., 2003, Noteikumi par ģimenes …, 2009).

The amount of state family allowance was essentially increased from 2022 continuing to improve the financial support for families with children. The amount of allowance depends on the number of actually raised and received allowance for children aged between 1 and 20 years in the family. Although the new calculation procedure does not provide for a supplement to the state family allowance, the budget of every family is increased thanks to the amendments to the regulatory framework.

It should be emphasised that the state family allowance payment period has been extended until the child reaches the age of 16 (previously the age of 15) regardless of the status of education (whether the child continues studies at school or not). In addition, the new calculation procedure is simpler and fairer, as it does not consist of two parts (allowance and supplements), neither the sequence of children nor the total number of children in the family is evaluated anymore. Therefore, the amendments to the regulatory framework significantly increase support for families which raise two or more children; thus, reducing the risks of poverty for families with children as well as promoting a birth increase.

Childcare benefit is granted to a person who cares for a child until the child turns two years

old (Valsts sociālo pabalstu..., 2002). Until 2008, the benefit until the child turned one year old was granted under a mixed system, i.e. the benefit was paid both to employed and unemployed persons. The improvement of benefit system envisaged the consideration of employment fact from 2008. Parental benefit was started to be paid to employed persons, while unemployed persons continued to receive the childcare benefit.

The amount of childcare benefit has increased during the period analysed thanks to the amendments to the regulatory framework; though, there have been changes made regarding the duration of benefit payment. The amount of benefit is differentiated depending on the child's age. The amount of childcare benefit and the breakdown of payment period was changed from 2014; yet preserving the total duration for benefit payment until the child turns two years old. The amount of benefit for a person who takes care of a child under the age of one and a half years was increased by EUR 28.71 per month reaching EUR 171 per month. In addition, both employed and unemployed persons may receive the benefit; hence, greater support is ensured for families with children up to the age of one and a half years. Nevertheless, it should be admitted that the amount of benefit for children between one and a half and two years has not been changed since 2008 (EUR 42.69 per month).

Until 2013 the amount and period for payment of the childcare benefit depended on the employment status of a benefit recipient. The amount of benefit for an unemployed person who cared for a child up to the age of one year was EUR 142.29 per month and EUR 142 per month for a person who cared for a child between one and one and a half years of age. The amount of benefit was EUR 42.69 per month for a person who cared for a child between one and a half and two years of age. If the childcare benefit is granted for twins or several children born in the same birth, a supplement is granted for each subsequent child in addition to the benefit.

The amount of childcare benefit and its supplement is being reviewed by the Cabinet at the suggestion of the Minister for Welfare considering the possibilities of the state budget, the economic situation in the country and the increase in the monthly average gross salary of employees determined by the Central Statistical Bureau. However, it should be noted that neither the amount of benefit nor supplement has been changed since 2014 (Noteikumi par bērna ..., 2009).

Childbirth allowance is a lump-sum payment aimed at provision of material support to ensure the needs of a new-born baby. The allowance is paid to one of the parents permanently living in Latvia for each child who has been assigned an identification number. The allowance is also granted to the guardian if the child has been taken under guardianship until the age of one year (Valsts sociālo pabalstu ..., 2002).

From 1 October 2004, the amount of childbirth allowance was increased consistent with the value of an infant's dowry calculated by the Central Statistical Bureau (CSB) in current prices expressed in terms of money – from EUR 139.44 to EUR 421.17, and this amount of allowance has been maintained until now (Noteikumi par bērna ..., 2009).

The childbirth allowance is applied consistently, its amount has grown and the conducted studies recognise it as an essential support allowing to cover the first needs of the child (Tautas ataudzi ietekmējošo ..., 2013).

According to the CSB statistics, consumer prices increased by 7.9% in 2021 and the annual inflation rate reached 3.3% (Latvijas makroekonomiskais apskats, 2022). The prices continued to grow also in 2022; thus, the authors recommend reviewing the amount of childbirth allowance consistent with the current economic situation and considering the sharp growth of prices and the average current consumer price index calculated by the CSB as stipulated by the regulatory framework.

It should be admitted that families with children may receive two types of state benefits in Latvia: state social benefits and state security benefits. Moreover, financial support is mainly envisaged during the first year of the child's life without provisioning opportunities for the childcare in the following years of childhood and covering additional expenses of the family during the school years. Only the state family allowance provides support to the family almost throughout the child's upbringing and schooling period. It does not encourage parents to take care of and expenses for raising several children as well as it does not provide opportunities for sufficient care of own and children's health (Koncepcija par ģimenes..., 2011, Tautas ataudzi ietekmējošo …, 2013).

In Latvia, the increase of birth effectiveness is affected by mass emigration and the large number of premature deaths. The advancement of situation requires solutions for the improvement of children and youngsters' health, education and good working opportunities. Frequent changes in the regulatory framework in connection with the procedure of granting childcare and parental benefits and state family allowance causes distrust to the system. Although the amount of benefits is increasing, the birth rate in Latvia continues to decrease. It is essential to achieve public trust to the system and when developing a long-term demographic policy,

policy instruments should be applied consistently in order the support in the form of benefits could become one of the aspects for planning children (Tautas ataudzi ietekmējošo…, 2013).

Social protection expenses in the EU context

The amount of maternity and paternity benefits demonstrate an increasing trend within the period of 2013–2022, while the parental benefit is an exception. It is related to the amendments to the regulatory framework regarding the changes in the period for receipt of the benefit. From 1 October 2014 the recipients of the parental benefit were granted the opportunity to choose the period for benefit receipt: until a child becomes one year or one and a half years old. The benefit is higher (60% of salary subject to insurance contributions) if it is received for a shorter period but choosing a longer period, it is lower – 43.75%. The data evidence an increase in the amount of parental benefit from 2017.

Table 2

Average amounts of the state social security benefits in Latvia between 2011 and 2022, EUR

Year	Maternity benefit		Paternity benefit		Parental benefit	
	EUR	Chain increase rate, %	EUR	Chain increase rate, %	EUR per month	Chain increase rate, %
2011	992.25	-	173.28	-	474.63	-
2012	979.60	*-1.28*	173.63	*0.20*	409.80	*-13.66*
2013	1 111.88	*13.50*	207.52	*19.52*	469.87	*14.66*
2014	1 205.75	*8.44*	222.10	*7.03*	498.24	*6.04*
2015	1 350.52	*12.01*	259.32	*16.76*	383.72	*-22.99*
2016	1 445.13	*7.01*	268.93	*3.70*	344.86	*-10.13*
2017	1 548.80	*7.17*	286.78	*6.64*	362.70	*5.17*
2018	1 687.19	*8.94*	312.26	*8.88*	390.18	*7.58*
2019	1 821.36	*7.95*	337.73	*8.16*	426.52	*9.31*
2020	1 946.09	*6.85*	365.12	*8.11*	467.67	*9.65*
2021	2 125.44	*9.22*	392.17	*7.41*	498.06	*6.50*
2022	2 366.56	*11.34*	427.68	*9.05*	551.04	*10.64*
2022/2011	*1374.31*	*138.50*	*254.4*	*146.81*	*76.41*	*16.10*

Source: authors' calculations based on VSAA data, 2022.

The comparison of the data of 2022 and 2011 demonstrates that the average amounts of maternity and paternity benefits have significantly increased (by 138.5% and 146.81%, respectively). The increase was stipulated by the growth of the average salary in the country. In contrast, the average salary was impacted by the increase in the minimum monthly wage (Official Statistics Portal, 2022), and this is also confirmed by the calculated correlation coefficient (r=0.976) which shows a close linear relationship between these indicators.

The analysis of the data in the context of the EU Member States allows to conclude that in 2020, the largest proportion of expenditure as percentage GDP on social support for families with children was in Poland, Luxembourg, Germany, Denmark, Finland, Austria and Sweden (the proportion ranges between 2.9–3.74%), while in Latvia it is only 1.69%. Moreover, it has significantly increased in Poland and Germany, while in Latvia the proportion has even slightly decreased comparing 2020 with 2011 (Figure 1). In 2020, the EU Member States have invested 2.2% on average of their GDP in the support policy measures for families and children.

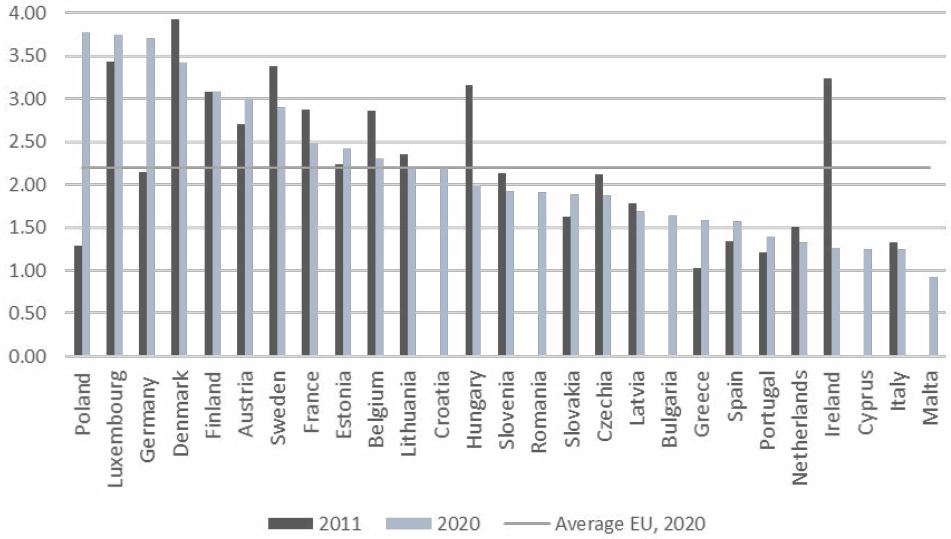

Figure 1. Social protection expenditure as percentage of GDP for families with children in the EU Member States in 2011 and 2020, %.
Source: authors' construction based on Eurostat and OECD data, 2020 and 2021.

The comparison of the data in the context of the Baltic States reveals that the expenditure on social protection for families with children as percentage of GDP in Estonia and Lithuania is higher than in Latvia both in 2011 and 2020.

Although it is recognised that national expenditure indicators do not provide a sufficient picture of the generosity of family policy, it is possible to roughly assess the action policy at the national level and to evaluate the changes in the support for families and their impact on reduction of the risks of poverty among children (Pabalstu par bernu ..., 2022).

In Latvia, the calculated correlation coefficient demonstrates a moderately close relationship (r=0.77) between the birth rate and expenditure for social protection as percentage of GDP. Mezs (2013), when analysing the demographic policy differences in the EU Member States, also indicates on a strongly expressed relationship – the more favourable is the family and children support policy and the more resources are invested in it, the higher the birth rate and vice versa. Latvia should increase support for families with children, since this is the only way to ensure a positive natural growth (Mezs, 2013).

In general, researchers have no single opinion on the impact of financial support on the birth rates. Several studies conclude that financial support for families with children promotes the birth in the country, while others reveal no significant impact of financial support on the birth rate (Demogrāfiskas politikas un ..., 2019).

In 2020, the highest total birth rates among the EU Member States were reported by France (1.8), Czechia (1.7), Denmark (1.7) and Sweden (1.7), while the lowest ones in Italy (1.2), Cyprus (1.3) and Greece (1.3) (The World Bank, 2020).

The family policy of Finland is considered successful because much attention is paid to the reconciliation of work and family life. The family policy is aimed at supporting families with small children, the childcare is ensured until the child becomes seven years old, a generous childcare benefit is available as well as leave for parents; thus, allowing to balance a childcare and job retention (Tautas ataudzi ietekmējošo …, 2013). In 2013, the birth rate in Finland was one of the highest in the EU (1.8), yet, nevertheless social support as percentage of GDP is one of the highest in the EU Member States the figure is only 1.4 in 2020. The research of this trend requires more profound studies (The World Bank, 2020). Lindberg etc. (2018) admit that Finland's family policy is aimed at high employment of parents and low level of poverty.

Sweden implements various mutually coordinated birth-promoting measures and support for family formation. The population of Sweden considers the existence of two or three children in a family to be the norm, and this number of members of the ideal family is one of the largest in the European Union (Demogrāfiskas politikas un ..., 2019). As stated by Pezer (2022) the social policy for families with children is generous, universal and promotes gender equality in Sweden as a country of social democratic welfare. In Sweden, payments for each additional child are increasing the most compared with other EU Member States.

According to Mezs (2013), Estonia also implements a successful demographic support policy

for the financing of which Estonia invests more state funds than Latvia and thus reduces negative natural growth to a minimum.

Conclusions

1. In Latvia, financial support in the form of social benefits for families with children up to the age of two is more diverse and greater compared with later periods.
2. The amounts of maternity, paternity and parental benefits as well as the state family allowance have increased during the period analysed, while the childcare benefit and the childbirth allowance have not been changed since 2014 and 2004 respectively.
3. The analysis of the data in the context of the EU Member States allows to conclude that in 2020, the largest proportion of expenditure on social support for families with children as percentage of GDP was in Poland, Luxembourg, Germany, Denmark, Finland, Austria and Sweden (the proportion ranges between 2.9–3.74%), while in Latvia it was only 1.69%; thus, being considerably less than in the EU Member States on average. The most rapid increase of expenditure has been reported by Poland and Germany; yet Latvia has even experienced a slight decrease in expenditure.
4. The calculated correlation coefficient demonstrates a moderately close relationship (r=0.77) between the birth rate and expenditure for social protection as percentage of GDP.
5. A regular increase of the amount of childbirth allowance considering the inflation rate is required in order not to deteriorate financial situation for families with children as well as a larger proportion of expenditure of GDP should be allocated for the support of families with children.

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THE NATURE OF STARTUPS: THEORETICAL ASPECTS AND AN ANALYSIS OF A SURVEY OF POPULATION IN LATVIA

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Abstract
A review of the available literature revealed that there was no information about public opinions on startups; therefore, the authors set the main aim to theoretically examine the nature of startups and identify the opinions of residents on startups in Latvia. The specific research tasks were defined as follows: 1) to conduct a theoretical review of literature on startups and the ecosystem thereof in Latvia; 2) to identify the knowledge and opinions of residents aged 18 to 75 about startups in Latvia. As part of the present research, the authors conducted a survey in Latvia to identify the population's knowledge of startups, differences between startups and other kinds of enterprises as well as the role of startups in entrepreneurship. The research employed the monographic and descriptive methods, the descriptive statistics method and a sociological method – an Internet survey using quota sampling. The survey was conducted in January 2023 and involved 1005 respondents throughout Latvia. The survey found that most of the respondents (73%) generally knew or had heard about startups and, according to the respondents, the main features that distinguished startups from other kinds of enterprises were innovation (54%), use of modern technologies (48%) and fast growth (41%). 63% of the respondents who had heard about startups noted that the startups, compared with other kinds of enterprises, were generally important for further development of the business environment in Latvia.
Key words: startups, Latvia, ecosystem, entrepreneurship, company, development.

Introduction

A startup is a new enterprise that has been operating for up to 10 years and whose business model supplies goods and/or services, solves customer problems, implements innovations and fosters overall growth (Vonoga & Zvaigzne, 2022). Latvia legislation defines a start-up company – a capital company with a high growth potential, the main activity of which is related to the development, production or development of scalable business models and innovative products (Likumi.lv, 2016). In Lithuania, the new legislation defines a start-up as a very small or small enterprise with a large and innovation-based business development potential, operating for less than 5 years (Startuplithuania, 2019). Start-up is a very small nascent enterprise that is expected to discover or create a new need, an attractive and unusual product, a scalable business model, and rapid significant growth. It creates new jobs, brings solutions to current problems in the economy, technology, ecology, communication, leisure, and entertainment. Start-up is a relatively new and attractive business form that has been explored in a broader economic and industry context (Winden *et al*., 2020). Start-up is a young and very small enterprise whose staffing and human relationships are different from the internal environment of larger enterprises (Slavik *et al*., 2020). Startups play an important role both in increasing competition and in fostering the growth of the national economy. The operation and development of startups provide high-paid jobs, as well as contributes to the inflow of innovative business ideas, the development of high value-added goods and services, the attraction of investments and a transition of the national economy to a modern and innovative economy (Ministry of Economics, 2020; 2023). Startups are associated with the potential for development of a modern, high value-added economy. The Law on Aid for the Activities of Start-up Companies has been in force in Latvia since 2017, and one of the national startups – the global printing, sewing and delivery outsourcing giant Printful – managed to achieve the so-called unicorn status, as the value of the startup exceeded one billion USD (Barons, 2022).

Overall, the development of the field of startups in the period 2018–2021 could be characterized by a steady growth and fast increase in investments in the information and technology sector, as a large part of the economic, financial and legal activity moves to the global market outside Latvia, as well as by a relatively large number of startups that have uncertain global-scale potential for growth (Cross-Sectoral Coordination Centre, 2022).

Despite their uncertain business prospects, startups play an important role in fostering economic growth (Acs & Mueller, 2008; Acs & Audretsch, 2010) and providing new job opportunities (Henrekson & Johansson, 2010). Startups, including high-tech ones, are often expected to foster innovation (Lynskey, 2004; Kato & Zhou, 2018).

Startups have become one of the main factors in growth in the country, as the number of startups has increased significantly in recent years, while promoting regional development and innovation, accelerating institutional and structural changes, increasing productivity and launching new goods and services on the market. Today in view of the impact of the recent economic crisis, fostering and encouraging entrepreneurship is even more important (Ziakis *et al*., 2022).

The research aims to theoretically examine the nature of startups and identify the opinions of residents on startups in Latvia. The following specific research tasks were set: 1) to conduct a theoretical review of literature on startups and the ecosystem thereof in Latvia; 2) to identify the knowledge and opinions of residents aged 18 to 75 about startups in Latvia. As part of the research, a survey was conducted in Latvia to identify the knowledge of residents aged 18–75 about startups, differences between startups and other kinds of enterprises as well as the role of startups in entrepreneurship.

The research employed the monographic and descriptive methods, the descriptive statistics method and a sociological method – an Internet survey using quota sampling.

Startup ecosystem

Latvia was ranked 42nd among 150 countries in the Global Startup Ecosystem Index 2021 designed by the international startup ecosystem map and research centre StartupBlink. The index indicates that the startup ecosystem in Latvia has the potential to become a technological centre with access to the European market and relatively low costs. In Latvia, the potential of startups is also supported by economic indicators, e.g. the number of startups that have attracted investments has grown from 42 in 2018 to 71 in 2021 (Ministry of Economics, 2020; 2023). A medium-term strategy for developing an ecosystem for startups is also included in the National Industrial Policy Guidelines for 2021–2027, which envisage creating a new economic pattern based on knowledge and innovation, focusing on both increasing the capacity for innovation and improving the quality of the institutional environment and increasing the dynamism of entrepreneurship (Ministry of Economics, 2020; 2023). The startup ecosystem is the driver of exports from Latvia. It is important for national enterprises to identify prospects for exports and consider their business broadly. It is no secret that national entrepreneurs often focus on the domestic market. In this respect, startups are the driver of exports, as the Latvian and Baltic markets are not capacious enough for the technologies and products they develop (Karika, 2022).

The ecosystem in Latvia is small but dynamic, and it is made up of highly motivated and talented multilingual individuals (often fluent in at least three or more languages) of different ages and experience. The startup environment is dynamic and growing fast. All the key stakeholders have joined their efforts to facilitate this growth. In Latvia, the startup infrastructure consists of more than four hundred registered startups, a group of institutional investors and business angels, a diverse range of modern office spaces for co-working, dozens of government incubators, the academic community and private persons, as well as many interesting meetings, productive conferences and hackathons. Several annual Tech & Innovation conferences are held in Riga: iNovuss, Deep Tech Atelier, Riga Tech Girls, TechChill and others. In addition, a unique law on startups was adopted and a startup visa, which formally is a temporary residence permit, was designed in order to make the national startup ecosystem even more dynamic and productive (Investment and Development Agency of Latvia, 2020). Open data hackathons or digital innovation contests are events where individuals from different fields of activity cooperate to create platforms that will benefit society, thereby creating a win-win situation for all the participants. Hoping to promote digital services that could be a key element in the development of startups, government agencies coordinate such events. It is an excellent way of fostering business growth (Komssi *et al*., 2014). In this way, software developers could extend their applications to startups, as they can cooperate effectively with the help of the organizers and have access to the necessary infrastructure to grow an enterprise, and hackathons could provide great experience for would-be entrepreneurs to cooperate with external partners in order to create new ideas (Zhao *et al*., 2016).

In 2022, the European startup list included 97 most important startups. The technology sector is booming in Latvia. This year, the list of 97 best Latvian technology startups is an eclectic mix of hyper-growth scale enterprises, small creative startups and others (Seedtable, 2023). The capital Riga is undoubtedly the centre of startup activity, where events such as Tech Chill are held, while other cities, such as Jurmala and Daugavpils, are also involved. More than 400 startups are currently registered in the national ecosystem of startups, and in 2021 it was considered one of the most startup-friendly countries in the world (Allen, 2022).

Overall, the review of the available literature on startups in Latvia allows us to conclude that there is little or almost no scientific literature on the topic, and this makes the present research important for the overall development of startups.

Materials and Methods

The main research question aimed to identify the relevance of startups in Latvia. To find out the opinions of residents about startups in Latvia, the research employed a data collection method – a survey of participants of an Internet panel of the research centre SKDS. It is a database of respondents maintained by the research centre, the purpose of which is to give the panellists the opportunity to participate in various social and marketing studies via the Internet. The survey participants registered in the panel receive invitations to participate in surveys by electronic mail

(e-mail) along with a hyperlink to the beginning of a survey questionnaire, which is placed on the WEB survey server of the research centre. Surveys are distributed by means of Internet resources, as this is the fastest and most effective way of data collection. Group members reported that online surveys were easier to complete when they spent most of their working time online (Nixon *et al*., 2022).

The survey was conducted as an interactive dialogue – after the respondent answered the question/ questions on the screen, s/he pressed the confirmation button, and the data recorded on the screen were sent to the server. The respondent then received the next survey question or questions on the screen. In this way, the entire questionnaire was completed online (SKDS, 2023). The survey was conducted as part of the present research in January 2023. The residents of Latvia aged between 18 and 75 were surveyed using random sampling. The sample size achieved was 1005 respondents. A detailed socio-demographic profile of the respondents is presented in Table 1.

Table 1

Socio-demographic profile of the respondents, n=1005

Indicator		Number	%
TOTAL:		1005	100
GENDER	Man	486	48.4
	Woman	519	51.6
AGE	18–24 years	72	8.5
	25–34 years	162	17.7
	35–44 years	208	20
	45–54 years	204	19.1
	55–63 years	189	17.3
	64–75 years	170	17.4
FAMILY STATUS	Married or living with a partner	639	62.8
	Divorced or not living with the husband/wife	89	8.7
	Not married	216	22.5
	Widow/widower	61	5.9
LANGUAGE SPOKEN IN THE FAMILY	Latvian	618	61.7
	Russian	376	37.2
	Other	11	1.1
EDUCATION	Primary	45	4.6
	General or professional secondary	598	58.9
	Higher	362	36.5

Indicator		Number	%
MAIN OCCUPATION	Senior or middle-level manager	77	7.3
	White-collar worker	334	33.3
	Blue-collar worker	228	22.3
	Business owner, sole proprietor	80	7.8
	Pensioner	155	15.6
	Schoolchild, student	36	4.2
	Housekeeper, on parental leave	46	4.7
	Unemployed	49	4.8
AVERAGE MONTHLY INCOME PER FAMILY MEMBER (QUINTILES)	Low (EUR 400 and less)	168	16.7
	Medium low (401-555 EUR)	143	14.3
	Medium (556-750 EUR)	154	15.2
	Medium high (EUR 751-1000)	133	13.2
	High (EUR 1001 and more)	121	12.2
	No opinion	286	28.6
CHILDREN AGED UNDER 18	Yes	330	33.1
	No	669	66.3
	No opinion	6	0.6
NUMBER OF INDIVIDUALS IN THE HOUSEHOLD	One	179	17.7
	Two	361	35.7
	Three	228	22.8
	Four and more	237	23.7
REGION	Riga	340	33.1
	Vidzeme	279	27.3
	Kurzeme	113	12.3
	Zemgale	135	13.7
	Latgale	138	13.6
TYPE OF RESIDENCE PLACE	Riga	340	33.1
	Another city or town	430	43.8

Source: authors' calculations based on the results of a survey of participants of a WEB panel of the research centre SKDS.

The demographic profile of the respondents indicated that 48.4% men and 51.6% women participated in the survey. Of the respondents, 33.1% indicated Riga as their place of residence, while 27.3% represented Vidzeme, 12.3% Kurzeme, 13.7% Zemgale and 13.6% Latgale. 61.7% of the respondents spoke Latvian in their families.

As shown in Table 1, 35.7% respondents' households consisted of 2 people, 23.7% had four people and more, 22% had three people and 17.7% were single-person households. At the same time, 66.3% respondents stated that they did not have children. This means that the respondents from several generations lived together.

In addition, the demographic profile of the respondents indicated that 58.9% respondents had general or professional secondary education, and 36.5% had higher education.

The survey was structured in four question blocks; the first identified the respondents by demographic characteristic, while the next three question blocks established the respondents' level of knowledge about startups, the role of startups, as well as differences between startups and other kinds of enterprises. All the respondents (n=1005) had to answer the questions of the first block, and only those who indicated some knowledge about startups gave answers to the second and third question blocks (*n*=790).

As mentioned above, the target group for the survey was the entire population of Latvia, and the geographical coverage included whole Latvia. However, to make the data more representative, the data were weighted according to the following characteristics: a region, nationality, age and gender.

Results and Discussion

To identify the respondents' knowledge of startups, the first block of questions was as follows: 'When recently talking about companies in society, they often mention the so-called startups. How well do you know what such enterprises are and how they differ from other or 'normal' enterprises? The answer options were as follows: I am aware of the issue, but not in detail; I have only heard about it; I know it very well; no opinion; I have not heard about it'. The survey question base included all the respondents, *n*=1005.

The answers of the respondents in detail are presented in Table 2.

Table 2

Respondents' knowledge about startups, n=1005

Indicator		Distribution of respondent answers										Total	
		…very good awareness		…general awareness, but not in detail		Awareness of the existence of such enterprises, yet no knowledge about anything more regarding them		No awareness of such enterprises		No opinion		Number	%
		Number	%	Number	%	Number	%	Number	%	Number	%		
TOTAL RESPONDENTS		47	4.8	256	25.8	431	42.5	215	21.4	56	5.6	1005	100.0
Gender	Man	30	6.3	145	30.2	201	40.7	81	16.8	29	6.0	486	100.0
	Woman	17	3.3	111	21.6	230	44.3	134	25.7	27	5.1	519	100.0
Age	18–24 years	7	9.4	32	44.5	23	32.0	10	14.2			72	100.0
	25–34 years	14	8.7	64	39.2	54	33.1	23	14.6	7	4.4	162	100.0
	35–44 years	19	8.9	57	27.0	82	39.6	41	20.0	9	4.5	208	100.0
	45–54 years	3	1.5	51	24.5	94	46.2	44	21.8	12	6.0	204	100.0
	55–63 years	3	1.6	29	15.4	89	47.0	55	29.2	13	6.9	189	100.0
	64–75 years	1	0.6	23	13.3	89	52.2	42	25.1	15	8.9	170	100.0

		Distribution of respondent answers											Total
Education	Primary	2	4.5	8	19.1	13	27.0	16	36.2	6	13.2	45	100.0
	General or professional secondary	16	2.7	124	21.0	268	44.7	155	25.8	35	5.8	598	100.0
	Higher	29	8.1	124	34.3	150	41.0	44	12.4	15	4.2	362	100.0
Main occupation	Senior or middle-level manager	15	19.2	26	33.9	22	29.0	9	11.4	5	6.5	77	100.0
	White-collar worker	18	5.7	118	35.7	144	42.5	47	13.9	7	2.1	334	100.0
	Blue-collar worker	3	1.3	31	13.8	108	46.9	69	30.4	17	7.6	228	100.0
	Business owner, sole proprietor	3	3.8	24	29.9	35	43.8	14	17.5	4	5.1	80	100.0
	Pensioner	1	0.6	24	15.0	74	47.7	41	26.9	15	9.8	155	100.0
	Schoolchild, student	4	10.9	18	51.1	12	32.5	2	5.5			36	100.0
	Housekeeper, on parental leave	1	2.1	5	10.4	20	43.2	18	40.4	2	4.0	46	100.0
	Unemployed	2	4.4	10	21.1	16	32.2	15	30.0	6	12.2	49	100.0
Average monthly income per family member (quintiles)	Low	2	1.2	32	19.6	65	38.4	52	30.8	17	10.0	168	100.0
	Medium low	5	3.4	24	16.8	73	50.5	37	26.4	4	2.9	143	100.0
	Medium	4	2.6	35	22.9	77	49.7	30	19.5	8	5.3	154	100.0
	Medium high	7	5.5	44	33.5	61	45.9	18	12.8	3	2.2	133	100.0
	High	20	16.9	47	38.6	35	28.6	17	14.1	2	1.7	121	100.0
	No opinion	9	3.2	74	26.3	120	41.6	61	21.4	22	7.5	286	100.0
Number of individuals in the household	One	8	4.5	40	22.5	76	42.3	41	22.5	14	8.2	179	100.0
	Two	16	4.6	89	25.0	159	43.7	78	21.5	19	5.2	361	100.0
	Three	12	5.1	59	26.4	100	43.5	44	19.5	13	5.4	228	100.0
	Four and more	11	4.8	68	28.8	96	40.1	52	22.1	10	4.2	237	100.0
Region	Riga	27	8.2	111	33.5	139	40.2	47	13.5	16	4.6	340	100.0
	Vidzeme	13	4.7	78	28.3	116	41.1	55	19.8	17	6.1	279	100.0
	Kurzeme	2	2.0	15	13.1	52	46.1	36	31.6	8	7.2	113	100.0
	Zemgale	4	3.0	32	24.4	52	38.1	40	29.3	7	5.2	135	100.0
	Latgale	1	0.7	20	14.8	72	52.3	37	26.4	8	5.8	138	100.0

Source: authors' calculations based on the results of a survey of participants of a WEB panel of the research centre SKDS.

Most of the respondents (73%) generally knew or had heard about startups (5% knew about the issue very well, 26% were aware of the issue but not in detail, 42% had only heard about the existence of such enterprises). 21% of the respondents had not heard about startups, which was a significant proportion.

The survey found that mostly men and younger respondents had heard about startups. A trend could be observed that as the level of education and income increased, the proportion of respondents who had heard about startups increased as well. It could also be observed that as the level of urbanization decreased, the proportion of respondents who had heard about startups decreased as well. It means that the residents in less populated areas did not receive information about startups.

The second block of questions was formulated as follows: 'What do you think are the features that make startups different from other or 'normal' enterprises?' The following answer options were given: ability to achieve the main goals of the enterprise, interest in solving customer problems, duration of the enterprise up to 7 years, fast

growth, use of modern technologies, innovations, no opinion, none of the above. The survey question base was the respondents who had heard about startups, *n*=790.

According to the respondents, the main feature that differentiated startups from other or "ordinary" enterprises was innovation (slightly more than half of the respondents or 54%) marked this option. The use of modern technologies (48%) and fast growth (41%) were also noted relatively often. The following features were noted relatively less often: duration of the enterprise up to 7 years (15%), interest in solving customer problems (10%) and ability to achieve the main goals of the enterprise (8%).

The third block of questions was formulated as follows: 'How important, in your opinion, are startups for further development of the business environment in Latvia against the background of other kinds of enterprises?'

The survey showed that almost two-thirds or 63% of the respondents who had heard about startups noted that startups, compared with kinds of enterprises, were generally important for further development of the business environment in Latvia (very important – 19%, rather important – 44%). 9% of the respondents noted that startups were generally not important for further development of the business environment in Latvia against the background of other kinds of enterprises (not important at all – 2%, rather not important – 7%). It could be observed that younger respondents, the residents of Riga and Latvian-speaking respondents more often noted that startups were generally important for further development of the business environment in Latvia against the background of other kinds of enterprises. A trend could also be observed that as the level of education and income increased, the proportion of respondents who had noted that startups, compared with kinds of enterprises, were generally important for further development of the business environment in Latvia increased as well.

Conclusions

1. A startup is a capital company with high growth potential, whose core economic activity relates to the implementation of a scalable business model and the design, development or production of innovative products. In academia, fast-growing enterprises or those with the potential for fast growth, including those having a scalable business model, are distinguished and emphasized. Besides, in the context of startups, the enterprises that are technology-based are also considered to be new enterprises. In the European Union, uniform criteria for defining a startup are still not adopted, and an understanding of the startup can differ significantly across various European countries.
2. The survey revealed that most of the respondents generally knew or had heard about startups, and it could be concluded that the respondents were informed about the issue and that startups were a current topic in society. 21% of the respondents had not heard about startups, which was a significant proportion. It follows that publicity needs to be increased through holding seminars and events, so that would-be entrepreneurs can establish an enterprise more easily, as well as get more information about support programmes and measures for starting a business.
3. According to the respondents, the main feature that distinguished startups from other kinds of or 'ordinary' enterprises was innovation, slightly more than half of the respondents or 54% noted this option. The use of modern technologies (48%) and fast growth (41%) were also noted relatively often. The answers provided by the respondents showed that the residents of Latvia were aware of the characteristics of a startup.
4. 63% of the respondents noted that startups, compared with other kinds of enterprises, were generally important for further development of the business environment in Latvia. A trend was also observed that as the level of education and income increased, the proportion of respondents who had given such an answer also increased, which indicated that the residents were aware of the essential role of startups in entrepreneurship development.

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LATE-LIFE SUICIDE IN NORWAY AND LATVIA: UNDERSTANDING THE REGIONAL DIFFERENCES AND COMPLEXITIES OF LATE-LIFE SUICIDE

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Abstract
Late-life suicide is a significant public health concern that has been associated with a range of social and individual factors. Social factors, such as social isolation, lack of social support, and financial stress, regional differences can contribute to the risk of suicide in older adults. Individual factors, such as depression, anxiety, and other mental health disorders, as well as physical health problems and chronic pain, have also been associated with an increased risk of suicide in older adults. Understanding the social and individual factors that contribute to late-life suicide in both Latvia and Norway is essential for developing effective prevention and intervention strategies to address this issue. The novelty and aim of research on social and individual factors of suicide among older people lie in understanding the unique risk factors that contribute to late-life suicide both in urban and rural areas. While there is existing research on suicide in general, there are various factors that contribute to suicide risk in older adults. Regional differences are often different from those that affect younger populations. Therefore, research on social and individual factors of suicide among the older persons aims to identify these unique risk factors and develop tailored prevention and intervention strategies that address the needs of older adults. There is still a need for further research to understand the specific social and individual factors that contribute to this issue in rural and urban areas.
Key words: older people, late-life suicide, social isolation.

Introduction

It is estimated that globally there are over 800,000 deaths by suicide every year (about 1 per 40 seconds), a number that is likely to be an underestimate of the real situation. Suicide is a very complex problem, with a range of reasons both at the individual and contextual level (Hawton, 2017). Suicide has become a bigger part of the public conversation in recent years, particularly due to the COVID-19 pandemic, but there is still quite a silence about older people taking their own lives. Suicide among the older people in rural areas has received little public attention and relatively little notice from researchers. This neglect stems in part from the myth that 'little can be done to treat older people who are suicidal, an assumption that reflects a general neglect of the mental health of older people' (Simon, 1989).

The aim of study is to find out possible regional differences in social and individual factors of suicide among the older people in Latvia and Norway. The tasks are:

1) to identify social and individual risk factors of suicide among older persons;
2) to find out statistical data about late-life suicide in Latvia and Norway.
3) to focus attention on how it is possible to analyze regional differences in late-life suicide.

The research questions are: what is known about regional differences of late-life suicides in statistics and previous research? In what direction should further research be carried out about late-life suicide?

Materials and Methods

The article primarily uses a literature review approach to discuss the concept of suicide among older people and the associated risk factors, focusing attention on urban/rural differences. It cites research studies and statistical data from sources such as the Norwegian Institute of Public Health and the World Health Organization to support its arguments. The article also references the theories of Emile Durkheim to explain the social factors that contribute to suicidal behavior. Overall, used methods involve gathering information and synthesizing it to provide a comparative approach to the overview of the topic.

Results and Discussion

Emile Durkheim, a French sociologist, developed a theory of suicide in which he argued that suicide is a social phenomenon that is influenced by the level of integration and regulation within a society. According to Durkheim, there are four types of suicide: egoistic, altruistic, anomic, and fatalistic. Egoistic suicide occurs when individuals lack a sense of belonging and social integration. According to Durkheim, this type of suicide is common among older adults who may experience feelings of isolation and loneliness. The lack of social support and connections can make them more susceptible to suicide. Anomic suicide occurs when individuals experience a disruption in their sense of social regulation. This type of suicide is common among older adults who may experience financial or social upheaval, such as the loss of a spouse or a change in their living situation. Anomic

suicide occurs when individuals have an excessive sense of integration and regulation, for example, religious or military groups. Durkheim did not believe that altruistic and fatalistic suicide is relevant to older adults (Mueller *et al*., 2021). Overall, Durkheim's theory of suicide highlights the importance of social integration and regulation in understanding the risk of suicide among older adults. It suggests that older adults who lack social support and connections, or who experience disruptions in their sense of social regulation, are at an increased risk for suicide. According to Durkheim's theory, there is background for rural/urban differences.

Late-life suicide, defined as suicide among individuals aged 60 and older, is a significant social concern in Norway. According to statistical data from the Norwegian Institute of Public Health (FHI, 2021), suicide is the second leading cause of death among individuals aged 70 and older in Norway, with a rate of approximately 25 deaths per 100,000 individuals. The suicide rate among older adults in Norway is also higher than that of the general population, with a rate of 16 deaths per 100,000 individuals for those aged 60 and older compared to a rate of 12 deaths per 100,000 individuals for the overall population. In 2020, the first year of the COVID-19 pandemic, we observed an increase in the age group 70 to 79 years (Figure 1), (FHI, 2021). In examining the suicide rate disparity between older adults and the general population in Norway, it is crucial to explore potential rural vs. urban differences. Factors such as accessibility to mental health services, social isolation, and economic conditions may vary between rural and urban areas, influencing suicide risk differently. Additionally, the observed increase in suicides among the 70 to 79 age group during the pandemic might have distinct implications in rural regions, where older adults might face unique challenges accessing healthcare and support services.

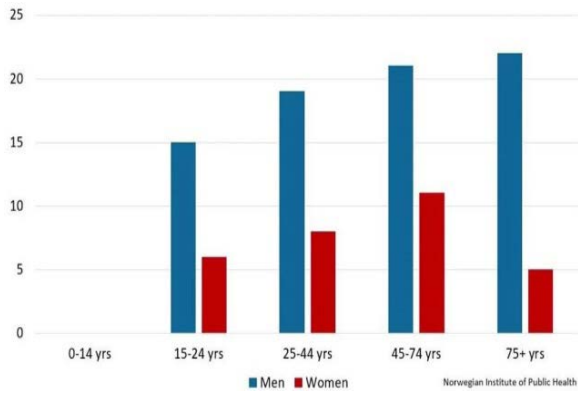

Figure 1. Number of suicides per 100 000 inhabitants for men and women in different age groups, based on suicide rates for 2014–2020.

Even though the increase in suicide in the older population was within the expected random variation, we cannot exclude that factors related to the pandemic have had an impact. This can be because the pandemic has led to increased levels of stress, anxiety, and depression, which can contribute to an increased risk of suicide, especially among older adults in both urban and rural areas. Furthermore, the pandemic has led to increased social isolation and loneliness, which can exacerbate existing mental health issues and contribute to an increased risk of suicide, especially in older adults (FHI, 2021).

Urban Aspects

In urban areas, the pandemic's impact on mental health might be magnified due to factors such as population density, limited green spaces, and higher levels of social and economic inequalities. Urban older adults may face increased stress and anxiety from disruptions to their daily routines, isolation from family and friends, and difficulties accessing healthcare services.

Rural Aspects

In rural areas, the pandemic's effects on mental health may be compounded by existing challenges such as limited access to healthcare, social isolation, and a shortage of mental health resources. The pandemic's disruption of rural support networks and communal activities may exacerbate feelings of loneliness and hopelessness among older adults in these areas.

Unique Challenges

Both urban and rural settings may experience unique challenges. For example, older adults in rural areas may have limited access to telehealth services, which are critical during the pandemic, while older adults in urban areas might face increased stress from overcrowded living conditions or social disconnection in highly populated neighborhoods. Research has shown that older adults, in both rural and urban areas, are at an increased risk for suicide due to several factors, including physical health problems, social isolation, and loss of autonomy (FHI, 2021). This bitter phenomenon is more common among older men, for the most part those over 80 years old, especially when they face chronic pain and dependence on others, as well as loneliness, feeling of abandonment and a loss of meaning for life. All these conditions are risk factors for suicide; 'some of these factors can be controlled and their influence is limited but some others may simply be too much of a burden for individuals and their families' (De Leo, 2022). Urban/rural differences could play a significant role in how these risk factors impact older men's suicide risk. If we choose Latvia as an example, both Latvia and Norway have different rates of suicide, with Latvia having a higher rate compared to Norway. According to data from the World Health Organization, the suicide rate in Latvia

was 29.5 per 100,000 people in 2018, while in Norway, the suicide rate was 14.8 per 100,000 people in the same year. In Latvia, previous research has shown that late-life suicide is often associated with a history of alcohol abuse and financial difficulties. Additionally, the impact of the Soviet occupation on mental health of Latvians may be a factor in the high suicide rates in the country. Availability of health care and social services in remote rural areas can be an important influencing factor in Latvia. Recent studies of Latvian researchers have paid attention only to representation of motives of suicide as urban/rural differences (SVA, 2009; Kozlovs & Skulte, 2022).

In Norway, previous research has shown that late-life suicide is often associated with a history of depression and previous suicide attempts. Additionally, social isolation and a lack of social support have been identified as risk factors for suicide in older adults in Norway. In rural areas the risks of social isolation and lack of social support are higher than in urban areas.

Norway and Latvia have some differences when it comes to geographical factors that may influence suicidal behavior. Norway is a relatively wealthy country with a high standard of living and a comprehensive welfare system. Access to healthcare and mental health services is generally good, and there are resources available for those at risk of suicide. However, rural areas of Norway may have more limited access to healthcare and mental health services, which could contribute to higher rates of suicidal behavior in these regions. Latvia, on the other hand, is a country that has been historically exposed to socioeconomic challenges and has had a hard time recovering from the economic crisis of 2008. It has a higher poverty rate compared to Norway and access to healthcare and mental health services may be more limited, particularly in rural areas. Regional disparities in availability of health care and social services are risk factors for older people in rural areas in Latvia (Holma, 2017). Additionally, cultural attitudes towards mental health and seeking help for suicidal thoughts may be different in Latvia, which could also contribute to higher rates of suicidal behavior.

The Survey of Health, Ageing and Retirement in Europe, (SHARE, 2022) and the ESS (European Social Survey) provide data on suicidal behavior in different European countries. According to the data, there are geographical differences in suicidal behavior in Europe. Northern and Western European countries tend to have lower rates of suicide compared to Eastern and Southern European countries. Literature provides consistent evidence that older adults from southern and eastern European countries demonstrate higher level of loneliness than their peers from the west and north (Lee, 2020). Factors that may contribute to these differences include cultural attitudes towards mental health, access to mental health resources, and socioeconomic factors such as poverty and unemployment more common in rural areas. It is important to note that data from surveys may not be fully representative of the entire population and should be interpreted with caution.

Discussion and Challenges

One of the important research projects that has been done in Norway so far in opinion of authors is 'Elderly and suicide' by I. Kjølseth. The project describes the complex causal relationships behind suicidal acts, which signals should we look at, and moreover what we can do to prevent it from happening. Kjølseth discusses if it is easier to understand older people taking their own lives than younger ones and assumes that suicide rates among the elderly confirm that Norwegians have a reason to fear old age. One reason for this may be a societal attitude that it is 'normal' to have suicidal thoughts in old age. However, older adults who have survived suicide attempts speak of deep despair, feeling invisible or disconnected from others, and the struggle to maintain control over their own lives. Suicidal behavior in the elderly is different from what we see in younger and middle-aged individuals. Elderly people are less likely to talk about their suicidal thoughts, and even if they do, it is less likely that anyone will intervene. This was clear in a recent Norwegian study: in more than half of the cases studied, the older adult had attempted to alert someone about their suicidal thoughts, but nothing was done to prevent suicide (Waern, 2013). A fatalistic attitude toward the problem of suicide in late life conveys a materialistic and dismissive message to younger members of society, who instead need examples of courage and determination to live a meaningful life and nurture an authentic sense of belonging to the community (De Leo, 2019).

Regional differences. Geographic variations in suicide mortality differ not only between but also within countries, with differences between urban and rural areas standing out. Suicide rates in rural areas have been shown to be higher than those in urban areas, and this disparity is particularly pronounced in older adults, which is a significant public health concern. (Casant, 2022). In Baltic countries (including Latvia), studies have shown that rural areas have higher rates of late-life suicide compared to urban areas (Stumbrys, 2022). Factors contributing to this include a lack of access to mental health resources, a lack of social support, and poverty. Additionally, rural areas in Latvia may also be more likely to experience social and economic disruption, which can further increase the risk of suicide among older adults.

Since 1971, excess male suicide mortality has, without exception, been higher in the rural than the

urban population, even though excess male suicide mortality has increased for both (Pray, 2013). A study conducted in Latvia found that alcohol use is a significant risk factor for suicide, both in rural and urban areas, meaning that individuals who had a history of alcohol use were at a higher risk of suicide, regardless of whether they lived in a rural or urban area. The study also found that the pattern of alcohol use was different between rural and urban populations in Latvia, with higher rates of heavy drinking in remote areas. The findings suggest that addressing alcohol use and abuse could be an important strategy for reducing suicide rates in both rural and urban areas of Latvia.

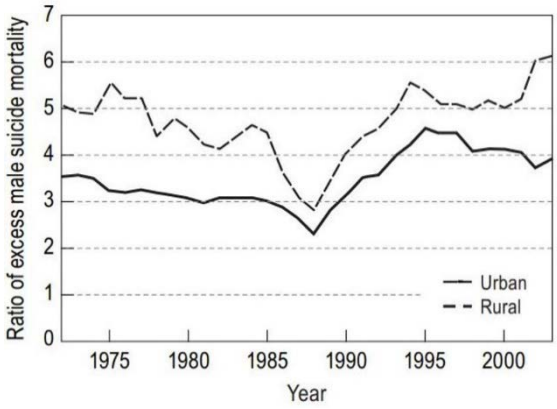

Figure 2. Male excess suicide mortality in rural vs urban populations across Latvia. Calculations based on a 3-year moving average. Source: Demographic Bulletins and Demographic Yearbooks. Riga.

In Norway, the issue of late-life suicide in rural areas is similarly concerning. Studies have shown that older adults in rural areas may be more isolated and have less access to mental health resources, which can contribute to an increased risk of suicide. Additionally, poverty and a lack of economic opportunities in rural areas of Norway have been identified as risk factors for suicide in older adults. One study conducted in Norway (Kleppestø, 2020) found that older adults living in remote areas were more likely to experience social isolation and had less access to mental health resources compared to those living in urban areas. This study also found that rural areas in Norway were characterized by lack of economic opportunities, which can contribute to an increased risk of suicide among older adults. Another study conducted in Norway (Dahl, 2019) found that older adults in rural areas were more likely to experience depression, social disconnection and anxiety compared to those living in urban areas. This study also found that older adults in rural areas were less likely to receive treatment for mental health issues, which can contribute to an increased risk of suicide.

Late-life suicide is a significant public health concern in rural areas not only in Latvia or Norway. The study by Ding and Kennedy (2020) did not compare suicide rates between rural and urban areas specifically. Instead, the study aimed to understand the factors that contribute to vulnerability to late-life suicide in the USA. The study found that several factors can increase the risk of suicide among the elderly, including social isolation, depression, and physical health problems. The authors also noted that cultural attitudes towards suicide and mental health, access to mental health resources, and the availability of lethal means can all play a role in the risk of suicide in later life. While the study did not compare suicide rates in rural and urban areas, it highlights the importance of addressing risk factors in both settings in order to reduce the incidence of suicide among the elderly. The study by Niu et al. found that the risk for late-life suicide was higher in rural areas of China, with gender being a factor in the increased risk. Research explains that elderly men in rural areas had a higher risk of suicide compared to elderly women in the same area. The risk of suicide in older adults is increased in rural areas due to factors such as poverty, lack of access to mental health resources, and social isolation. Further research is needed to better understand the specific needs of older adults in rural areas and to develop effective interventions to prevent suicide in this population.

It is complicated to know the exact number of suicides among the elderly. This is because the elderly often encounters preconceived attitudes even after their death. This means that the cause of death is not always investigated or confirmed. Additionally, serious illnesses may cause the cause of death to be attributed to the severity of the older person's illness (Farberow, 1999).

Why do we look at suicide among the elderly differently? Perhaps it is because the fear of old age with functional decline and dependence is frightening for most people, and it leads to a sort of acceptance of the action taken by the elderly. Research shows that the elderly had underlying anxiety before suicide. This anxiety was characterized by fear of losing self-care ability and autonomy (Kjølseth, Ekeberg, & Steihaug, 2010). They felt a loss of identity and that hope for a better life was gone. They were at 'the turning point' in a process where life had to end in death and its release (Crocker & Evans, 2006).

From a sociological perspective, suicide can be related to the society the older person lives in, the status of the elderly in society, and the degree of respect they are given (Kjølseth, 2014). Being a part of a society and experiencing a strong and secure identity is important for a person, whether they are young or old. When the elderly begin to feel that they are a

burden to their family and society, there is something wrong with our view of old age. The elderly can also have loss of close relatives and lose their social role, and they can get diseases that hinder the expression of life (Rasnaca *et al*., 2022). Older adults who reported feeling lonely were nearly three times more likely to die by suicide than those who did not report feeling lonely (Shiovitz-Ezra, 2018).

From a psychological perspective, ageing changes can contribute to increased suicide risk. Research shows that with increasing age, there is a decline in cognitive functions. This is especially related to memory and forms of problem-solving. A paradox in this is that emotional regulation can also improve over time, and negative feelings decrease, and positive feelings increase. This contributes to the fact that memory related to positive memories becomes better and better. This is called the 'positivity effect'. However, the older suicide-prone individuals had difficulty regulating positive thoughts and utilizing them. They did not have many good memories from childhood and adolescence and could not think in a positive future-oriented way (Kjølseth, 2014). Somatic illness with resulting functional decline, depression, isolation, loneliness, and life stressors are other factors that constitute a suicide risk among people over 65 (Kjølseth, 2014).

There are several risk factors that have been identified as associated with late-life suicide in Norway. Some of the most reported risk factors include:

1. Mental health conditions: Depression, anxiety, and bipolar disorder are linked to increased suicide risk in older adults, both in rural and urban settings.
2. Physical health conditions: Chronic illnesses like cancer, heart disease, and chronic pain also elevate the risk of suicide in older adults, regardless of their location.
3. Social isolation: Social isolation, whether living alone or lacking social support, contributes to higher suicide risk in older adults, including those in rural areas.
4. Financial stress: Older adults facing financial strain, such as insecurity or debt, may experience an elevated risk of suicide, irrespective of rural or urban contexts.
5. Access to lethal means: Availability of lethal means like firearms or medications can raise suicide risk in older adults, regardless of where they reside.
6. Recent loss or significant life event: Older adults coping with recent losses (e.g., spouse or friend's death) or significant life events (e.g., retirement or relocation) may face an increased risk of suicide in both rural and urban environments.

According to Kjølseth, the key to understanding the suicides of the elderly is their experience of not being worth anything which is related to functional loss and helplessness. But is that an individual experience or does it reflect society's attitude? Is it true that we don't really care about the oldest and most fragile?

To answer these questions, we need to research three independent factors which relate to each other in terms of suicidal behavior: **individual, network and society**. Individual factors refer to the characteristics and attributes of a single person, such as their personality, values, and beliefs. Network factors refer to the connections and interactions between people, such as their social networks and relationships. Society factors refer to the larger cultural and societal context in which individuals and networks exist, such as laws, norms, and institutions. In rural areas, understanding the interplay of these factors becomes crucial in comprehending the unique challenges and risk factors that may contribute to suicidal behavior among older adults. Factors like limited access to mental health services, tight-knit community networks, and cultural attitudes toward mental health play a significant role in shaping the suicide landscape in rural settings. Comprehensive research on these interconnected aspects is vital for developing effective suicide prevention strategies tailored to rural communities' specific needs. As already stated, these three factors are interconnected and can influence each other. For example, an individual's personality can influence the types of networks they form, and their networks can in turn influence their personality. Society factors can also shape the networks that form and the behavior of individuals within those networks. Additionally, the behavior and actions of individuals and networks can also shape the broader societal context.

All three factors can influence suicidal behavior in different ways. Individual factors that may increase the risk of suicidal behavior include mental health conditions, a lack of social support, exposure to trauma or abuse, feelings of hopelessness or helplessness, state of mind, finances, and occupation. Network factors that may increase the risk of suicidal behavior are social isolation or lack of social support, exposure to suicidal behavior in one's social network, a history of bullying or harassment, conflict or stress within one's relationships or family, local environment, or participation in social life. Often networks will have changed to such an extent that there are hardly any networks at all in old age. Public transport availability for older people is crucial in remote rural areas. Societal factors that may increase the risk of suicidal behavior include lack of access to mental health care, economic stress or inequality, exposure to media portrayals of suicide, societal changes that increase stress, such as war, violence, and disasters, societal norms that discourage seeking help or expressing emotions. It's worth noting that it is not always

possible to predict who will attempt suicide and that many people who die by suicide do not have a known mental disorder. Also, suicidal behavior is not caused by any single factor, and many factors can contribute to the risk of suicide.

Suicide prevention. There are several interventions that have been shown to be effective in reducing the risk of suicide among older adults. These include increasing access to mental health services, providing social support and companionship, and reducing access to means of suicide. In Norway, there are a few initiatives in place aimed at reducing the rate of late-life suicide. These include the 'Senior Alert' program, which aims to identify and provide support to older adults at risk of suicide, and the 'Life-Saving Conversations' campaign, which encourages individuals to have open and honest conversations about mental health and suicide with their loved ones. Additionally, the Norwegian government has set a goal to reduce the suicide rate among older adults by 20% by 2020, through the implementation of a few targeted intervention and prevention programs (regjeringen.no 2020).

It's worth mentioning that despite the efforts, the suicide rate in Norway has not decreased in the last years.

Reducing the rate of suicide among older adults is a complex issue that requires a multifaceted approach. Some strategies that have been shown to be effective in reducing the risk of suicide among older adults include:

Enhancing mental health services: Improve access to counseling and medication management in both rural and urban areas to prevent older adult suicides.

Addressing social isolation: Combat loneliness in rural regions by offering support programs like volunteer visiting initiatives, equally vital in urban areas.

Limiting access to lethal means: Restrict access to firearms and prescription drugs for suicide prevention among older adults, applicable to both rural and urban settings.

Tackling economic disparities: Addressing economic and social inequalities is crucial, particularly in rural areas with higher poverty rates, to reduce suicide risk among older adults.

Promoting positive aging: Encourage social engagement and a sense of purpose for both rural and urban older adults to decrease suicide risk.

Public awareness campaigns: Raise awareness about suicide risk and encourage help-seeking behaviors, equally important in both rural and urban communities.

Training healthcare professionals: Ensure proper training for identifying and responding to older adults at risk of suicide, regardless of location.

Considering regional nuances enhances the effectiveness of suicide prevention efforts among older adults. It's important to keep in mind that suicide prevention is a complex and multifaceted issue, and no single strategy will be effective in addressing it. It is important to implement a comprehensive, integrated, and multidisciplinary approach that addresses the different factors that contribute to suicide.

Conclusions

Europe is seeing unprecedented growth in the ageing population. The World Health Organization projects that from 2000 to 2050, the ageing population over 60 years will triple in size from 600 million to two billion (World Health Organization, 2015). As this trend progresses, governments are faced with the ethical and moral imperative to ensure that older persons maintain a high quality of life as they age (Shiovitz-Ezra, 2018).

Based on the stated tasks and purpose of the article, the following conclusions can be drawn:

1. Social and individual risk factors of suicide among older persons have been identified through the study. These factors may include individual (loneliness, depression, physical illness, substance abuse, and financial difficulties), network (social isolation, lack of links with peer groups, relatives), society (attention to older person problems).
2. Statistical data on late-life suicide in Latvia and Norway has been collected and analyzed. The findings may suggest differences in suicide rates among older persons in different regions, as well as differences between two countries.
3. The study has highlighted the need for further research on late-life suicide, particularly in terms of exploring the regional differences and specific risk factors that may be contributing to the issue. This may involve conducting more in-depth qualitative studies and developing targeted interventions to address the identified risk factors.
4. There is a need for more research to better understand the factors contributing to late-life suicide in both Latvia, Norway, and the whole Europe as well as to develop effective interventions to prevent suicide in older adults. One area of research that could be useful is to investigate the role of cultural and societal factors in late-life suicide in these countries. Another area of research that would be beneficial is to study the effectiveness of interventions aimed at reducing social isolation and increasing access to mental health resources for older adults.
5. In conclusion, late-life suicide is a significant public health concern in both Norway and Latvia. While the overall suicide rates differ, the rates of late-life suicide in both countries are rising. Previous

research has identified several risk factors for suicide in older adults, such as physical illness, depression, and social isolation. Social factors and suicide among older persons are the area where more research is needed to find out trends in regional differences.

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SOCIAL ENTREPRENEURSHIP IN LATVIA AND ITS CHALLENGES

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Abstract
Social enterprises, as an interdisciplinary form of business, often face problems that traditional enterprises and civil society organizations have already overcome: lack of legal framework, complex business models, business identity problems, lack of public awareness, lack of visibility and difficulty in accessing investment markets. The name 'social entrepreneurship' makes it clear that it is not easy to have a business oriented towards a social goal, because 'social' implies that the business is directed to the goal of reducing social problems and enhancing the quality of life, which, besides being expensive, is also a complex process. The purpose of the article is to reflect the challenges faced by representatives of social entrepreneurship in Latvia: before April 1, 2018, when this type of business was non-profit, and after, when the opportunity was given to establish a profit-making social enterprise. In order to achieve the goal, following tasks are set – to provide a theoretical explanation of social entrepreneurship, as well as, with the help of empirically obtained information, to reveal the challenges faced by representatives of social entrepreneurship in Latvia. According to interviewed informants, the main challenges for social entrepreneurs in Latvia are the lack of qualified employees, institutional cooperation and funding, which would allow organizations to effectively carry out their business; in addition, difficulties are caused by situations when financing is too complex or difficult to access, and social entrepreneurship lacks public support. Rather often, social entrepreneurs lack knowledge about business risks and how to plan their business in the long term.
Key words: social enterprise, social entrepreneurship.

Introduction

Social entrepreneurship involves producing goods or services to solve a social problem or benefit society, rather than to increase profits for business owners. Types of social entrepreneurship, business models, goods and services can vary significantly – social enterprises can be large or small, international or local, but all are united by the desire to create great social added value using business methods (Ulande & Licite, 2018). Starting from the 80s and 90s of the 20th century, social entrepreneurship experienced rapid development. It is characterized by practical aspects – the increase in the number of social enterprises around the world, by subordinate theoretical aspects – efforts to define and study social entrepreneurship, and by legal aspects – in many countries, social entrepreneurship is already thought of as a specific form of business. An important role in the development of social entrepreneurship is played by the British sociologist and politician M. Young (Michael Young), who, starting from 1997, opens several schools of social entrepreneurs in Great Britain. However, the initial stage of the rapid development of social entrepreneurship is associated with the name of the Nobel Peace Prize laureate, the Bangladeshi economist M. Yunus (Muhammad Yunus), who since 1983 has been issuing microcredit to poor people and investing the earned money in solving social problems. He has formulated the basic postulates of social entrepreneurship, which are often used today as the basis for many definitions of social entrepreneurship:

1) the goal of a social enterprise is not to make the most money, but to prevent poverty or solve a social problem; 2) financial and economic sustainability is important for a social enterprise; 3) investors get back only their investment without interest; 4) when the investment is repaid, the company's profit is invested in the development of the company; 5) responsibility towards the environment must be observed in social entrepreneurship; 6) the workforce is provided with wages appropriate to the labour market and good working conditions; 7) those involved must do their work with joy (Seven Principles of Social Business, 2009).

From the mentioned basic postulates of social entrepreneurship, it can be concluded that the achievement of social goals requires investment and institutional support, which offers entrepreneurs the opportunity not only to see their opportunities to help and support specific social groups in the field of social problem prevention, but also to do it realistically and legally. Thus, social entrepreneurship can be seen as similar to social policy, where both have the same goal – to provide the necessary support to those members of society who need it most, thus improving the welfare of these people. However, social entrepreneurship is distinguished from social policy by an important nuance – a social entrepreneur must be able to 'produce' the necessary resources with the available means to realize their social goals. The state, by creating a social entrepreneurship support mechanism, has foreseen specific activities to promote the development of social entrepreneurship. However, as the practice of social entrepreneurship reveals, entrepreneurs face not only a lack of

financial resources, but also a lack of institutional cooperation, which in turn significantly limits the effective implementation of social entrepreneurship. Therefore, the purpose of the article is to reflect the challenges faced by representatives of social entrepreneurship in Latvia: before April 1, 2018, when this type of business was non-profit, and after, when the opportunity was given to establish a profit-making social enterprise. To achieve the goal, the following tasks are set – to provide a theoretical explanation of social entrepreneurship, as well as, with the help of empirically obtained information, to recount the challenges faced by representatives of social entrepreneurship in Latvia.

Materials and Methods

Various methods were used to achieve the purpose of the article and to complete the tasks. The article was composed using a systematic review of scientific literature, as well as an analysis of empirically obtained information. The analysis of empirical information is based on an expert interview that was carried out on November 23, 2022 with Head of the Latvian Social Entrepreneurship Association Regita Zeila, as well as a semi-structured interview with the representatives of the social enterprise 'Mājas TUVU' on February 17, 2023. Social enterprise 'Mājas TUVU' was chosen for the interview, using the principle of availability. The interview took place in Jelgava, and it was 40 minutes long. Monographic and descriptive methods were used to conduct theoretical debates and evaluate research findings based on scientific theories and insights on social entrepreneurship.

Theoretical Findings

Although it seems that it is conceptually clear what social entrepreneurship is and what a social entrepreneur does, there is no generally accepted and universal definition of social entrepreneurship; almost every personality, researcher, expert, entrepreneur in the field of social entrepreneurship, and even every country has its own insights on how to define social entrepreneurship, which essentially consists of attempts to include both the purpose of social entrepreneurship in the definition, to describe the basic features of a social enterprise, and to highlight the phenomenon of a social entrepreneur. Therefore, the definitions of social entrepreneurship and social enterprise are often multifaceted and include various parameters.

Until April 1, 2018, in Latvia, the so-called non-profit social entrepreneurship was carried out by public benefit organizations – associations and foundations whose activities are regulated by the Public Benefit Organizations Law (Public Benefit Organisation Law, 2004). However, starting from April 1, 2018, social entrepreneurship has been possible to be carried out by commercial companies that have a social purpose. The biggest difference between public benefit organizations, which are NGOs by nature, and social enterprises is that social enterprises have a commercial status (Ltd), which, on the one hand, opens up opportunities for the entrepreneur to obtain the necessary financial resources for the implementation of his social goals, but, on the other hand, – imposes additional duties related to the bureaucratic burden, for example, the preparation of reports, which includes measuring and assessing one's own social activity. Since 2018, a social enterprise in Latvia has been defined within the framework of the Social Enterprise Law, including in the definition mainly the legal status and goals of a social enterprise: 'a social enterprise is a limited liability company that has been granted the status of a social enterprise in accordance with the procedures set out in this law and which carries out economic activities that creates a beneficial and significant social impact by employing target groups or improving the quality of life for groups of society whose lives are affected by significant problems for society, or by performing other socially significant activities that create a lasting positive social impact' (Social Enterprise Law, 2018). On the other hand, the information reflected in the scientific literature shows that the basic element and driving force of social entrepreneurship is the individual – the personality – the social entrepreneur, who is usually defined as a highly motivated person with a clear social mission and enthusiasm to turn their mission into social value: 'the social entrepreneur is the heart of social business. Personal leadership in this context is related to the social entrepreneur's ability to advance the social goal, to defend this goal' (Velden *et al*., 2014). 'Social entrepreneurs are individuals with innovative solutions to society's most pressing social problems' (Abu-Saifan, 2012).

It is relatively difficult to fully analyze social entrepreneurship in Latvia, because there is little historical data on social enterprises, their formation and development, and in general the history of the development of social entrepreneurship in Latvia is relatively short. For example, in Lithuania, the Law on Social Entrepreneurship has been in force since 2004, but in Latvia it came into force only on April 1, 2018; it provides that the social enterprise's own goal is not to make money, but to be able to finance its social impact with profit – 'the social enterprise does not distribute the profit obtained, but invests in achieving the goals defined in the statutes' (Social Enterprise Law, 2018) In the fall of 2015, the Latvian Social Entrepreneurship Association was founded; the purpose of which is to promote the development of social entrepreneurship in Latvia. As reflected in the information contained in the Register of Social Enterprises, 212 out of 268 registered social enterprises were active as of July 20,

2023 (Register of Social Enterprises on 20.07.2023). Social enterprises operate in various sectors, including but not limited to: provision of social and health services, work integration, production of various goods, charity shops, online platforms, environmental and nature protection, promotion of cultural diversity and protection of cultural heritage, community and cultural space management, promotion of improvement and availability of education, provision of consultations and information, provision of communication services, promotion and strengthening of civil society (Ulande & Licite, 2018).

According to the information provided by Ministry of Welfare of Republic of Latvia, the most active social enterprises represent the field of work integration (23%) and education – 21% of all social enterprises. On the other hand, a small number of social enterprises represents the field of environmental protection (4%) and social services (6%) (Figure 1).

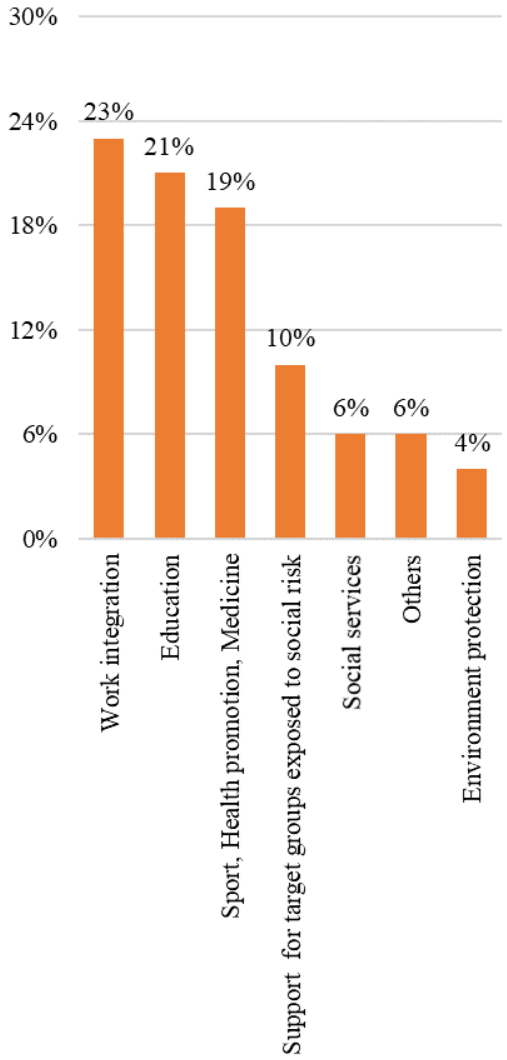

Figure 1. Fields of Active Social Enterprises in Latvia, n=212.
Source: Authors' construction based on the Statistical data on Social Enterprises (Statistical data on Social Enterprises, 2023).

According to the situation in Latvia, it is very important to provide support to population groups exposed to social risk. Social enterprises provide invaluable support to target groups exposed to social risk in a wide variety of life situations in terms of meeting basic needs, for example, housing repairs or food and clothing. Unfortunately, only 10% (21 enterprises) of all social enterprises are oriented towards providing support to population at social risk.

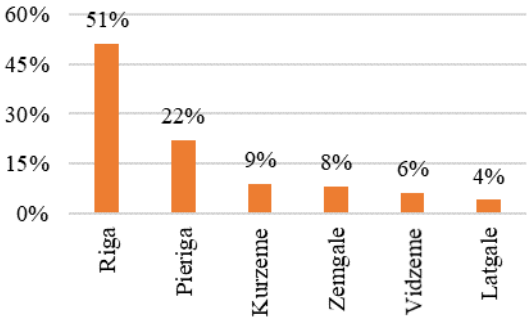

Figure 2. Statistics about active social enterprises by regions, n=212.
Source: Authors' construction based on the Statistical data on Social Enterprises (Statistical data on Social Enterprises, 2023).

As statistical data shows, most of social enterprises (51%) are located in Riga that is the capital city of Latvia and in Pieriga (22%) that is the area close to Riga. As reflected in the statistical data on the population at risk of poverty in Latvia (Figure 3), it can be concluded that the most of the population at risk of poverty is located in the regions of Latgale (34.6%), Vidzeme (36.3%), Kurzeme (27.8%) and Zemgale (21%), where there are the fewest social enterprises. Riga and Pieriga have the most social enterprises, but there are the least number of people at risk of poverty (15.6% in Riga and 16.6% in Pieriga), which can be explained by the proximity of the capital and greater opportunities for employment. From the above, it can be concluded that the activity of social enterprises, oriented towards reducing social risks for Latvian citizens, is very unevenly distributed among the regions of Latvia. However, this type of activity, which would be oriented towards providing support to various types of at risk population, is a great need in the regions.

According to the Social Enterprise Law, social enterprise status can be obtained by both existing companies and newly established ones. In order to be evaluated for the possibility of receiving the status of a social enterprise, the company needs to define: a social, important problem for the society, which the company solves or plans to solve; the social goals defined in the statutes; social, society-relevant

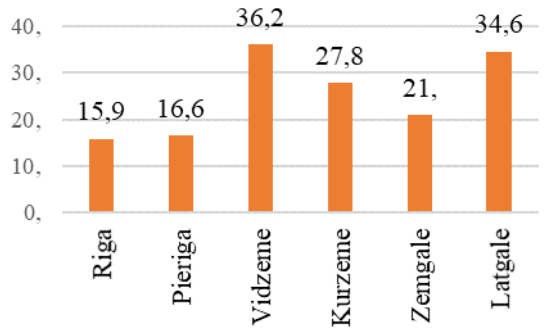

Figure 3. Proportion of population (%) who are at risk of poverty in the regions of Latvia.
Source: Authors' construction based on the Statistical data on at risk of poverty rate in regions, (At risk of poverty ..., 2023).

problems that affect the above-mentioned groups of society; other socially significant activities that create a long-term positive social impact, and at least one measurable indicator must be specified, with which the results of the activity will be measured in the following years (Social Enterprise Law, 2018). From the above, it can be concluded that the process and procedure for granting the status of a social enterprise includes not only specific requirements for companies that want to obtain the status of a social enterprise, but also provides a specific set of knowledge and skills for identifying and evaluating social impact. This could partly be explained by the fact that the granting of the status of a social enterprise must be justified, as the social enterprise is offered the opportunity to use state and local government support for the development of social business, which is also defined in the Social Enterprise Law:
1) special reliefs, such as a reduction of the corporate income tax base for certain groups of expenses not related to economic activity;
2) the municipality is entitled to grant real estate tax benefits to the social enterprise;
3) a public person may transfer movable property to the ownership of a social enterprise free of charge;
4) a public person, a capital company of a public person, a capital company has the right to transfer its property to a social enterprise for use free of charge;
5) a social enterprise has the right to engage volunteers for activities that are not related to the administration and accounting of the enterprise, as well as the basic functions of the enterprise (Social Enterprise Law, 2018).

Several other instruments are also available in Latvia for starting and supporting social entrepreneurship: the most important of them is JSC 'Development Financial Institution Altum', which, within the framework of the European Social Fund project 'Support for social entrepreneurship', has been providing information and consulting to social entrepreneurs, as well as financial support for social enterprises since 2017. Support for social entrepreneurs is also provided by the business incubators of the Latvian Investment and Development Agency (Social entrepreneurship, 2020). Social enterprises also have the opportunity to receive support from the municipality, which is provided for by the Social Enterprise Law, but although the Social Enterprise Law stipulates that municipalities have the right to transfer their property to social enterprises for use without compensation, this is not the duty of the municipalities: the social entrepreneur must contact municipalities and ask for their support, showing what the potential benefits of mutual cooperation would be for the municipality and its residents (Zeila & Ulande, 2020).

The Social Enterprise Law provides not only the procedure for obtaining the social status of a company and the range of support measures, but also the obligations of social entrepreneurs related to the identification of the social sphere of their business and the evaluation of the achieved results (social impact).

Latvian social entrepreneurs must submit an annual social enterprise activity report, which includes information on measuring and proving social impact. It is important to add that measuring social impact requires knowledge and skills both in conducting social research and in identifying target groups at risk of social exclusion. Social entrepreneurs need to add evidence that proves the achieved social impact, such as stories of direct beneficiaries, expert evaluations and opinions, individual interviews, etc. Therefore, in the context of measuring social impact, it is essential to understand the difference between the measurable indicators of activities and the results and benefits of a social enterprise. If the measurable indicators of the activities numerically show what and how much was done, then the results and benefits reflect the lasting value of these activities and the positive social changes created (Zeila & Ulande, 2020).

On the one hand, impact measurement is necessary to understand to what extent the company's social goals have been achieved; find out how effective the chosen solutions and tasks are in achieving the goals - whether the activities reach the desired result; understand how to improve activities and offer to increase its social impact, as well as to convince investors and other stakeholders that it is worth investing money and other resources in the company (Mthembu & Barnard, 2019). But on the other hand, impact measurement imposes additional responsibilities on the social entrepreneur, which require not only financial investment, but also time, specific knowledge and energy. Social impact is reflected not by measurable indicators, which are

the easiest to count, but by the fact that a company creates a specific social impact. It is the results, benefits and long-term impact that reveal the changes and social impact of the company's activities. Also, the Ministry of Welfare, explaining the social impact and the specifics of its measurement, emphasizes that the impact of a social enterprise is the performance indicators and long-term changes that have arisen as a result of the entire activity of the social enterprise in a certain period of time (Social impact, 2020). So, a social enterprise must not only have a clear social goal, but also be financially sustainable, combining social and profit-oriented activities, achieving a specific social impact on the target group. The main challenges of social entrepreneurship are directly related to the interaction of the above-mentioned factors and the ability to balance them. The development of social entrepreneurship in Latvia is essential, because it is not only able to unite community members and show how much can be done together, but also to indicate social problems faced by community members and the ways they can be solved. It is also a significant support for local governments, as social entrepreneurs operate in the sphere of improving the quality of community life, which is the main task of local governments. Therefore, it is important to identify the problems faced by social entrepreneurs, so that it would be possible to provide them with the greatest possible support for solving these problems.

Results and Discussion

Analyzing the information available in the sources, the opinions of experts in the social business sector and also the available studies, it can be concluded that the challenges are quite different – depending on the point of view of the evaluator or the analyzed part (Table 1).

Table 1

Challenges in social entrepreneurship in Latvia

Challenges	1. Lack of support instruments including tax incentives and available financing.
	2. Administrative burden, imposed by social enterprise status.
	3. Small Latvian market, low willingness of customers to pay for goods and services appropriately.
	4. Lack of skills and knowledge in business, business management and financial management.
	5. Reliance on grants and other available support for social enterprises.
	6. Focusing on achieving social goals and helping the target groups (as opposed to making a profit and ensuring financial stability).

Source: Authors' construction based on the documents and literature (Kalve, 2012; Ulande & Licite, 2018; Informative report on the operation …, 2020).

Summarizing the opinion of experts in the field of social entrepreneurship and social entrepreneurs from the available research data, it can be concluded that social entrepreneurs see obstacles to development mostly in the lack of available support, including financial support, and the administrative burden imposed by obtaining and maintaining the status of a social enterprise, while experts in the field of social entrepreneurship mention too much concentration of social entrepreneurs on achieving their social goal and helping specific groups of society, not being able to purposefully build the company as a financially stable and competitive entity, possibly due to a lack of management knowledge, skills and abilities as the main challenges for social entrepreneurship in Latvia. Researcher L.Licite-Kurbe also stresses financial challenges for social enterprises in her research in 2022 (Licite-Kurbe, 2022).

Back in 2012, the challenges of social enterprises in Latvia were aptly highlighted by the study 'Latvia on the road to social entrepreneurship' conducted by the association Public Policy Center PROVIDUS and the association 'Civic Alliance Latvia', within the framework of which it was concluded that the biggest development challenges of Latvian social entrepreneurs are related with the observation that social entrepreneurs have an idea, a social problem they want to solve, but have no appropriate business skills and no business mindset (Lesinska *et al*., 2012).

In this period of time, for the successful development of social entrepreneurship, it was very necessary to solve problems in the field of profit opportunities, in order to reduce the dependence on sponsors and financial support, placing greater emphasis on independent economic activity, as pointed out by the

Global Entrepreneurship Research Association in the 2012 Business Monitoring Report (Kalve, 2012).

From the previously conducted studies, which cover the period of time when the Social Enterprise Law did not exist in Latvia yet (therefore, social impact assessment was not required yet), it can be concluded that during this period the main challenges of social entrepreneurs were related to profit making and balancing of social goals. The research reveals that some social enterprises have been able to develop successfully only because of available support, and some of the social enterprises in Latvia were formed because of the availability of financial instruments. On the other hand, the opinion of social entrepreneurs themselves about the factors hindering development is summarized in the Informative report of the Ministry of Welfare in 2020 'On the operation and development of social enterprises' and the main obstacles are mentioned as: lack of support tools, including tax incentives and available funding, administrative burden in the process of the allocation of financial support and monitoring of social enterprises, confusion with the allocation of state support, the application of the requirements of regulatory laws and regulations and the related administrative burden, as well as the relatively small Latvian market, low customer solvency and activity. Therefore, it can be concluded that the social entrepreneurs themselves do not mention the lack of management skills or the lack of knowledge on how to build a social enterprise as a competitive and financially self-sufficient structure being the main challenges for social entrepreneurship.

On the other hand, referring to the analysis of the business project of social enterprises financed by the European Union Structural Funds and the Cohesion Fund carried out in 2022 by 'Altum' as a cooperation partner of the Ministry of Welfare, it can be concluded that only every fourth social enterprise that has received financial support from 'Altum' would be considered a creditworthy company: one that could receive a bank loan as a standard company on market terms. The financial indicators of many grant recipients are not high enough to qualify for a loan, and a large number have not stabilized their economic activity in order to be able to take on credit obligations independently and without additional support; in many cases, the profitability of a social enterprise is completely dependent on grants/subsidies and any credit obligations could lead such enterprises to insolvency (Informative report on the operation…, 2022). The importance of the available grants in the case of the creation and the existence of social enterprises was also confirmed by the latest statistical data, which reflect the fact that as of July 30, 2023, 206 out of 212 active social enterprises have used the Altum financing tool (Statistical data on Social Enterprises, 2023).

From the challenges discussed above, which have affected the sphere of social entrepreneurship, it can be concluded that the opinions of social entrepreneurs themselves and industry experts regarding the challenges are ambiguous: social entrepreneurs believe that the difficulties they face in their business are caused by administrative requirements, in connection with the status of a social enterprise preservation, as well as limited availability of necessary support and lack of finance. On the other hand, industry experts believe that the entrepreneurs themselves lack the necessary knowledge and skills in social entrepreneurship, as well as their insufficient focus on profit, which would allow ensuring the necessary financial sustainability, regardless of the available grants and subsidies.

The discussion on the challenges faced by social enterprises after April 1, 2018, based on empirically obtained information, reflects the trends of the difficulties experienced by social enterprises oriented towards providing support to groups of persons exposed to social risk. In order to find out what challenges social entrepreneurs from this field of business face now, at a time when most companies have already recovered from the effects of the Covid-19 pandemic, and to achieve the goal of the report, interviews were conducted with an expert – the head of the Latvian Association of Social Entrepreneurship – and several representatives of social enterprise 'Mājas TUVU'. The social enterprise 'Mājas TUVU' is located in the Zemgale region and its scope of activity is to provide support to Latvian families and lonely people in difficulties, as well as work with young people, organizing camps and educational events, giving young people the opportunity to spend their free time in a healthy and fulfilling environment. The social enterprise has renovated several homes for families at risk of poverty, and also provides food for residents who have financial difficulties to meet their basic needs.

According to the expert, the main challenges for social enterprises in Latvia are the lack of qualified employees and funding that would allow organizations to start any activity. Also, the more common difficulties can be observed in situations where financing is too complex or difficult to access, and social entrepreneurship lacks public support. As the expert points out: 'Challenges include the inability of social enterprises to realize business risks or to plan their business in the long term – mostly in connection with business participants from the social field, for example, associations or fellowships'. The expert also mentions the difficulties faced by companies from the business environment: 'the challenge is to fully implement the social mission, to achieve and measure the social impact, as well as to be aware of the changes created and to communicate with the

wider society, thus reflecting its divergence from any other company'. On the other hand, representatives of the social enterprise 'Mājas TUVU' believe that social entrepreneurship faces such challenges as bureaucratic burden, as well as measuring social impact: 'how can we measure how a person's life has changed after the support we have provided in less than a year? It is just not possible'!

As reflected in the review of the results of the previous researches, other representatives of social entrepreneurship have similar thoughts, for example, the representative of the Foundation 'Iespēju tilts' believes that sometimes qualitative rather than quantitative indicators are more important indicators of impact, because it is very important for people from social risk groups, that they are given the opportunity to design handicrafts and bring them to sell in the shop: 'They are happy to participate. They have a goal for doing something. Not so much material interest, but moral interest – you feel needed by someone, you can leave the house and bring the product.' The social enterprise 'Iespēju tilts', located in Vidzeme, provides various types of support to people with disabilities. The social enterprise has created a day-center for the residents of this target group and a store where it is possible for people with special needs to sell their hand made products. Other social enterprise 'Visi Var' is located in Vidzeme and the purpose of its activity is to promote the employment of persons with disabilities, their relatives and socially disadvantaged groups. The social enterprise has set up four workshops where people with disabilities are engaged in sewing, knitting, printing and card making. E. Vilkina, head of the social enterprise 'Visi Var', emphasizes the same: 'A person gains self-confidence that someone needs him, that he can do something, that someone appreciates and likes his product. This is a great value that people also recognize themselves. They rejoice. Sometimes the money is not as important as the fact that he is appreciated.' (Final report. Evaluation of intermediate…, 2021). According to the representatives of the social enterprise 'Mājas TUVU', a big challenge is both bureaucracy and receiving support from the state and local governments or their attitude: 'the bureaucratic burden is great, we would also like more support from the local government and the state, especially from the local government; it would be necessary to change and clarify the Social Enterprise Law, clarifying the provision of support to social enterprises, because now the situation is like this – we go, knock, beg, but the municipality simply does not hear us. I don't know, guess we don't know how to talk? I don't know, but we are not heard.' The representatives also mention a specific case when they asked the municipality for premises, but the municipality refused, as a result of which financial resources had to be spent: 'don't they understand that the funds that we were forced to pay for the premises would have been used for people, the residents of this municipality!' The interviewed representatives of social enterprises in previous studies have had a similar experience: 'I would like the state administration to simply love you for what you do. But it doesn't happen. All the messages that come from them are in a formal aggressive tone about the fact that you must have violated something before you prove that you have not. It is the existing emotional background. A lot of my friends feel that way. They just don't complain because that's the nature of entrepreneurs - just go and do it. But the mood that can be felt from the state administration is very negative.' This is also pointed out by another social entrepreneur: 'In Latvia, by nature, entrepreneurs are viewed with terrible suspicion, they are some kind of fraudsters. Elsewhere in the world, it is not considered so. Elsewhere, entrepreneurs are looked at as those who contribute to the state budget, who make up the state budget.' The research also conducted interviews with municipal employees, during these interviews a bureaucratic burden was found in the phase of starting a social business: 'In a conversation with two existing managers of social enterprises, I received the answer that if they knew how bureaucratic/complicated starting a social business is, they would not do it again; it causes worry' (Final report. Evaluation of intermediate …, 2021).

The representatives of the social enterprise also mention the challenges associated with attracting volunteer work: 'it would be good to develop some kind of strategy that motivates people to participate voluntarily to help others. It can be concluded from the above that, although the law provides for the possibility for local governments to supply social enterprises with the necessary support, this does not mean that this support will be received, even if requested. We also see that the opinion of experts on the challenges faced by social entrepreneurs differs from the point of view of the entrepreneurs themselves: social entrepreneurs experience difficulties in their everyday life, which the law is powerless to prevent, for example, the law provides for receiving support from the municipality, but in reality it is not obtainable. On the other hand, the expert sees financial attraction as the main challenges in the field of social entrepreneurship, as well as the skills of social entrepreneurs to do business, emphasizing the fact that entrepreneurs often lack the necessary skills to assess business risks and plan their business in the long term. Both the expert and the representatives of the social enterprise mention the difficulties of social entrepreneurs in evaluating the

social impact; in this matter, the Ministry of Welfare and the Latvian Social Entrepreneurship Association is providing the great support to social entrepreneurs.

Conclusions

1. Social entrepreneurship is not focused on making a profit, but on mitigating the social problems of society, as well as improving the quality of life of citizens exposed to social risk, which reflects the social specificity of entrepreneurship. However, in order for a social enterprise to be able to realize its social goals, financial resources are needed, which can only be obtained if the company focuses not only on achieving its social goals, but also on making a profit.
2. According to the analysis carried out by social entrepreneurs, the main challenges in the field of social entrepreneurship are related to the administrative requirements for maintaining the status of a social enterprise (bureaucratic burden), the limited availability of the necessary support, difficulties in evaluating the social impact, as well as the dysfunctionality of the support mechanism and the lack of finance. It is possible to reduce the bureaucratic burden by developing the electronic reporting system, as well as improving the base of regulatory acts. It would also be necessary to improve and specify the institutional cooperation, as well as the responsibility of the parties involved in the support apparatus.
3. From the experts' point of view, the main challenges in the field of social entrepreneurship are the entrepreneurs' own lack of necessary knowledge and skills in business, insufficient focus on profit, as well as difficulties in evaluating social impact. Since social entrepreneurship is an interdisciplinary field of business, it is necessary to obtain an appropriate education in the context of community development. By using the opportunities for improving knowledge in the field of social entrepreneurship offered by the Latvian Social Entrepreneurship Association, it is possible to promote entrepreneurship by accepting challenges in overcoming difficulties.

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SOCIAL INCLUSION VS SOCIAL EXCLUSION: THE CASE OF THE PREIĻI AND LĪVĀNI DISTRICTS

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Abstract
In August 2021, we carried out a study of the needs of socially isolated people in the Preiļi and Līvāni districts of Latvia. The aim was to identify the real situation of social exclusion in rural areas of Latvia in order to provide a more complete picture of the needs of socially excluded groups and thus contribute to regional development policy, especially from the perspective of social inclusion. The qualitative research approach was chosen to acquire information: interviews with representatives of socially excluded groups and semi-structured interviews with professionals working with different categories of socially excluded people. Social exclusion is a sensitive topic for those who are socially disadvantaged, so the basic principles of research ethics were strictly observed: personal autonomy, non-harm, confidentiality and fairness. The study found that the most pronounced form of social isolation is exclusion from the labour market. People who are unemployed, are trapped in a 'poverty cycle' from which they cannot escape without the help of social institutions. The information obtained does not confirm the long-standing assumption that long-term unemployed are mere 'consumers of the system', nor does it confirm the assumption that socially isolated people have high expectations of a high salary. Sometimes existing attempts to improve the situation of socially isolated people are not in line with their real needs, thus failing to achieve the intended goal. In general, the specificity of the region is such that there are no mass one-size-fits-all solutions, but each situation and problem has to be tailored individually.
Key words: social inclusion, social exclusion, isolation, poverty, social needs.

Introduction

Social inclusion, poverty reduction and economic development in rural areas is one of the six pillars of rural development policy in the European Union. The Common Agricultural Policy of the European Union has as one of its long-term objectives the balanced territorial development of rural economies and communities, including the creation and preservation of jobs. This objective is also relevant to rural development in Latvia, and therefore research on both social inclusion and exclusion is relevant. 2010 was declared the European Year for Combating Poverty and Social Exclusion in the European Union, and for that reason Latvia launched a broad awareness-raising campaign on the availability of resources for people in need. The EU's inclusion policy was echoed in Latvia through NGO and media activity, but not as part of government policy. It was only with the launch of Latvia's national reform programme, EU 2020, that the requirement to reduce the risks of poverty and exclusion was included (Lāce, 2012). According to the current EU Rural development policy, specific focus is turned on vulnerable population. Additionally, it is admitted that in Latvia, the continued trend of depopulation has major consequences for the long-term sustainability and quality of public services to the population in rural and sparsely populated areas (EU Rural, 2021). In 2022, 26% of Latvian population were at risk of poverty and social exclusion which was the 5th highest rate in the EU (EUROSTAT, 2023). According to the report by OECD, the gap in GDP per capita between the richest (Riga) and the poorest (Latgale) Latvian regions has slightly decreased. GDP per capita in Latgale has increased by 5.3% per year between 2000 and 2015, slightly surpassing the growth of GDP per capita in Riga (4.9% per year over the same period). However, Riga has more than twice the GDP per capita of Latgale. As a result, Latvia remains the country with the 3rd highest regional economic disparities among 30 OECD countries with comparable data (OECD, 2019).

The need to develop a regional social inclusion policy is based on information about the actual situation in the regions, which yet is an under-researched field. One of the studies aimed at identifying the real situation of social exclusion in rural areas of Latvia was implemented in 2021 as a field study 'On the needs of the socially isolated population in the Preiļi and Līvāni districts'. It was carried out on the basis of existing perceptions of social isolation. European Union policy planning documents and theoretical literature refer to the so-called social exclusion or simply exclusion. Social exclusion and social inclusion are seen as interlinked phenomena in these documents. The concept of social exclusion offers a way of understanding the cause-effect relationship between complex living conditions and the diverse needs of individuals. Social inclusion is necessary for an individual to live well in the society through which action is taken to ensure equal opportunities for all, whatever their situation or background, and to enable them to reach their full human potential. Social inclusion is the process by which society combats poverty, inequality and social exclusion. The problem in Latvia is with the long-term unemployed as well as those people, who have lost

the courage to look for work. This is the conclusion of experts from the Organisation for Economic Co-operation and Development, or OECD, who presented their scientific study on employment in Latvia in 2019. But employment varies widely from region to region, which is why practical case studies are needed.

It is important to find out the nature of social exclusion and its manifestations in order to reduce it and thus promote social inclusion practices in Latvia, as well as to inform the general public about the situation in the districts.

Materials and Methods

The qualitative sociological research approach was chosen for the field research in Preiļi and Līvāni districts. Given that social exclusion is a sensitive topic for those in a position of social isolation, the basic principles of research ethics were carefully observed: principles of personal autonomy and fairness, principles of non-harming and confidentiality. Participants were provided with detailed information on the objectives of the research, the respect of anonymity and the right to withdraw from the study. Some of the interviewees also exercised this right and did not wish to be interviewed, or were interviewed but did not wish to give their names and precise demographic data about themselves. The reasons for refusal varied, but a typical response was related to concerns about disclosure of personal information. Informed consent was obtained from all participants, thus demonstrating respect for personal autonomy.

Twenty members of socially isolated groups were interviewed and 10 semi-structured interviews with professionals working with different categories of socially isolated populations were conducted.

The socially isolated groups included the long-term unemployed, people without a fixed place of residence, people with disabilities, families with disabled children, people with low income, and various ethnic groups, including the Roma. They were men and women aged 24–70, who spoke both Latvian and Russian. They were asked about their current life situation, the circumstances that led to their current situation, their current needs in different areas, the support they have received, as well as their plans for the future.

The study used a case study design in order to gain as full understanding of the situation as possible to provide a meaningful explanation of the situation under study. In some cases, the so-called snowball method was used, where one interviewee could recommend for interview a person known to him or her who matched the characteristics of the target group of the study. Interpretative techniques typical of qualitative research approaches were used in data processing and analysis. The reliability of the study is enhanced by the so-called triangulation approach to data extraction, by sampling different socially isolated populations and the institutions involved.

Theoretical literature on the social dimensions of social exclusion was used to design the semi-structured interview questions. The definition of social exclusion already outlines the main areas of exclusion, but in a broader explanation they include the following aspects:

1) resources: material and economic resources, access to services and social resources;
2) participation: economic, social, cultural and educational, political and civic;
3) quality of life and well-being (subjective well-being): health, living environment, crime and criminogenic situation (Dobelniece, 2022).

Isolation is the lack of social contact, limited or infrequent contact with other people, as well as the number and quality of activities in social relationships, which is directly related to quality of life and subjective well-being. Isolation is also characterised by alienation as a state of psychological discomfort. It can be both a cause and a consequence of social isolation and exclusion. Self-doubt, low self-esteem, insecurity, mistrust of other people inevitably manifest themselves in communication, thus producing loneliness. While social isolation can be measured as an objective quantity (social contacts can be counted), loneliness is a subjective experience of social isolation. However, socially isolated people do not always experience loneliness and vice versa: people who are not objectively isolated can also feel lonely. The link between unemployment and social exclusion is not straightforward: unemployment may cause social exclusion, but work does not guarantee its absence. Socially isolated people themselves experience and interpret their situation differently from the way it is defined by the responsible institutions, revealed by statistical data, determined by legislation, etc.

For this reason, exclusion researchers have found that in some cases poverty causes social exclusion, while in other cases poverty is a consequence of social exclusion. In some cases, there is no obvious link between poverty and social exclusion (Lāce, 2012)

Since social isolation is a complex and multidimensional phenomenon, where it is difficult to distinguish between causes and consequences, and which affects all areas of a person's life, Ken Wilber's integral theory has also been used as a theoretical framework. Namely, each individual is part of a larger system, so the changes initiated must affect all levels and all areas of life.

Results and Discussion

In August 2021, 880 long-term unemployed (54% of the total number), 857 unemployed aged over 50

(52.6%) and 375 aged over 58 (23%) were registered in the Preiļi district. 24% or 391 of the unemployed were disabled. Thus, the statistics also confirm the most important social problem in the study area, namely, long-term unemployment is predominantly made up of people aged over 50. Not finding a job makes it difficult to break out of poverty, which could widen the possibilities of finding a better job. Often people find themselves in a cycle of poverty which is difficult to break without the help of public institutions. As one of the interviewees sadly pointed out: 'I am a locksmith by profession, I studied, yes, I have a diploma, yes, but no job'.

If the basic needs of individuals for adequate food, warmth, housing, etc. are not met over a long period of time, then all other issues become subordinate. Unemployment makes access to a range of resources difficult, from limited access to nutritious food, health care and eventually to cultural activities.

If the impact of individual and structural factors is assessed, we see structural factors related to known, long-standing problems like illegal employment, addictions, limited mobility opportunities, low wages, lack of suitable housing, lack of leisure opportunities, etc. The presence of structural disadvantages is evident in the stories of virtually all interviewees of this study.

However, there is a general assumption in the society about the reluctance of the long-term unemployed to work, their high expectations in terms of pay and working conditions. Although similar points were made in the context of this study, overall the information gathered does not confirm the entrenched assumptions about the long-term unemployed as mere 'consumers of the system'. The labour market exclusion of the participants in the study was long-lasting although it cannot be said that they were not working at all. Some spoke of informal casual work, referring to it as 'piecemeal'. Some of the unemployed are the so-called long-term unemployed, who dropped out of the labour market 20–30 years ago.

A 2019 study on the long-term unemployed by the State Employment Agency (ESF project 'Support for the long-term unemployed') found that one of the reasons for long-term unemployment is a lack of motivation, a mismatch between work skills and knowledge and the demand in today's labour market. In comparison with this study, the results on the causes of long-term unemployment in the Preiļi and Līvāni districts are identical to those of the SEA, but they are complemented by factors such as lack of Latvian language skills and rapid, unexpected changes in private life that have led to social exclusion. The latter factor dominates women's accounts of their life situation. If people who drop out of the labour market for a long time or only partially are the most vulnerable social group, women are the most vulnerable in this group. For them, the family is an important factor in determining, reducing or increasing the sense of social exclusion.

The professionals interviewed also confirm that women who are co-dependent on male alcoholism suffer from violence, but due to psychological, economic and social reasons they remain largely passive and do not change the situation. Experts recognise that the prevalence of alcohol dependence is enormous and in some cases consider it to be the main social problem in the Preiļi and Līvāni districts. There are cases when people have been treated for alcoholism, but when they return to their usual social environment, they also return to their drinking habits.

One of the most common beliefs is that people who find themselves in social isolation have only themselves to blame. As one of the professionals who works with the socially isolated says: 'The society has excluded these people. They see that drunkard over there, he doesn't want to do anything, but underneath it all there are so many other problems. Society lives in stereotypes of socially isolated people. It's easier for us to assume that they are claiming benefits'.

Paradoxically, the marginalised themselves do not blame anyone for their unenviable life situation: neither the state, nor their circumstances or their peers, not even their fate. It should be noted that the determinism of circumstances is not an absolute. To make a difference in your life, you have to want to make a difference. As the examples from the study show, the social, economic and institutional conditions around us are not so coercive that the individual cannot resist them.

Another finding that emerged from the study is the self-evaluation of the situation of people in social isolation. None of the 20 socially isolated people interviewed considered their situation to be bad or unsatisfactory, no matter how objectively unpleasant the circumstances. The result of the study shows a fairly stable self-assessment. This is contrary to the common view that people who have been unemployed for a long time suffer from a constant low self-esteem. In order not to lose their self-esteem, some of the participants in the study do not want to change anything. In the conversations they showed a certain resistance to any idea that requires some kind of change. As one of the social workers admitted:

'It is often... unrealistic to motivate people to change. Unless something abnormally dramatic happens, like children being removed from their families... Or if they agree to something, it's for a very short period of time' (Study, 2021) People are afraid of possible changes, whether they will have negative consequences, as has sometimes already been the case in their situation. People do not really see themselves as active participants in improving their situation.

Because their life situation has been shaped over a long period of time, it has been transformed into a kind of modus vivendi – a kind of "frozen zone" where it is not very comfortable, but habitual. And that is better than any change. The persistence of a passive modus vivendi is a precondition for the gradual development of a negative identity – a readiness to deny, reject, isolate, ignore, to distance. Against this background, cases in which a client who is in the line of sight of the institutions significantly improves his/her life. Experts tell of cases where 'people are struggling' or 'have got it' to tackle unemployment and poverty. This is more often the case in families with children, where one or both parents are trying to provide a relatively stable environment for their children, for example by trying to fix their alcohol problem. There are a few exceptional cases where people have managed to break the 'cycle of poverty' and regain a good quality of life.

The study also does not support the assumption that socially isolated people have high aspirations for high wages. The interviews revealed that the interviewees consider the national minimum wage (EUR 500 gross per month) to be a good wage. The most frugal are the elderly (pre-retirement and retirement age), who are characterised by a reliance on institutional arrangements, passivity, a certain modesty and resignation to their particular situation. The income is often below the national minimum wage, but subjective satisfaction with it is relatively high. As one of the researchers on exclusion, Graham Room, points out, social exclusion is cumulative: each individual can experience different types of exclusion, as its dimensions do not exist in isolation from each other.

When people need help to overcome difficulties, they are more likely to turn to relatives, friends and acquaintances for help. Informal social networks are more widespread and more stable than institutional help, about which there is sometimes minimal information. The social services themselves admit that the general specificity of the region is that there are no mass one-size-fits-all solutions, but that each situation and problem has to be adapted individually. At the same time, the experience of each individual reflects the social manifestations of poverty, gender inequality, alcoholism and other social problems.

Low-income or single pensioners and disabled people are also socially vulnerable and often do not have enough money to buy medicines or pay for heating. But there is also a segment of socially isolated people who are beyond institutional reach.

Families with children who have special needs also face difficulties. Institutional support for these families is a matter of survival, because there is a whole complex of problems to tackle. These range from the parents' work problems to fit childcare around their working hours, to the education of the children, to the lack of assistants. Assisted living is one of the key support measures to enable people with disabilities to integrate independently into society. The assistant service is relatively new in Latvia, having been introduced in 2013, and has been criticised by beneficiaries, social services and the ombudsman alike regarding its inefficiency.

People in Preiļi and Līvāni have experienced the same problems as similar families elsewhere in Latvia.

Participants of the study admit that in their dealings with various responsible institutions, their representatives are often unresponsive or too much of a 'servant of the letter'. Sometimes they are sought privately, contacts with officials in the hope that parents will then be listened to. Even when the problem is easily solvable, it lacks the will and decision of those responsible. According to parents, education and care play a huge role on the professional and human qualities. A good quality of life is achieved when social institutions are functioning and needs are being met, and subjectively people experience this as their social well-being.

It is questionable how to develop an inclusion policy for the population of a municipality that would cover a certain coherent set of actions and measures, when an existing study has shown that, in general, the specificity of the municipality is such that there are no mass one-size-fits-all solutions, but that each situation and problem has to be adapted individually.

It is also questionable whether the development of such a policy is feasible and sufficient when the presence of adverse structural factors is evident in the stories of virtually all interviewees. In addition, it should be borne in mind that the quality of life of socially isolated people is shaped by a combination of objective and subjective factors.

Conclusions

1. Social inclusion reflects, on the one hand, the individual's experience and social integration, opportunities for self-realisation, and, on the other hand, society's capacity and opportunities to prevent the causes of social exclusion in order to ensure equal opportunities for all.
2. The concept of social exclusion is a more precise description of a person rather than the concept of poverty. The dimensions of social exclusion are also characterised by its domains, in which participation of individuals is limited and manifested disadvantage, as well as activities in which individuals cannot fully participate, not least in social life and level of well-being.
3. The attempts that are sometimes made to improve the lives of socially isolated people are not in

line with their real needs. As a result, they fail to achieve their intended objective.

4. Social exclusion is localised, but the process of inclusion is global for all local forms of exclusion, shaping the globally local discourse of exclusion as it appears also in this particular field study 'On socially isolated needs of the socially isolated population in Preiļi and Līvāni'. The processes taking place there are not specific to a few social rural people in social isolation.
5. Negative individual social experience and the same experience of cooperation with social assistance institutions are an obstacle to be overcome in people's consciousness and practices of cooperation for both parties involved. Only then will we break down stereotypes that are entrenched in social practice at an institutional level.
6. The objective situation or specific circumstances can be interpreted differently by the individuals involved and organisations. In particular, socially isolated people themselves experience and interpret situations differently than they are defined by institutions who are in charge of these issues, revealed by statistical data, determined by legislation, etc.
7. The study showed that the subjective perception of one's own social assessment of the social situation may not correspond to the actual circumstances, nor the persistence of an individual's modus vivendi, which sometimes prevails over objective circumstances.
8. The problems of socially excluded people are much more complex than they may at first appear. They need not only material benefits and any other kind of material assistance, but also psycho-emotional support: psychologists, drug counsellors, etc.
9. There is a need for independent access to forms of support that are provided episodically, such as a family assistant or a physiotherapist and an occupational therapist for children with special needs, etc.
10. The most clearly expressed need in the course of the research, which was not put into words by any of the participants but which permeated their stories, was the need for social contacts (mutual meeting, support, friendship).

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THE PERFORMANCE OF LATVIAN SOCIAL ENTERPRISES: STRENGTHS, CHALLENGES AND THE VISION FOR THE FUTURE

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Abstract
Performance is a concept which is critical to both conventional businesses as well as social enterprises. However, for the latter, performance is closely tied to social impact which social enterprises and governments supporting the social entrepreneurship field are seeking to achieve. Despite the criticality of the topic, in Latvia performance of social enterprises has not been analyzed in detail before; therefore, this study serves as a valuable starting point for discussions and evidence-based policy and also as a benchmark for future development in the field. Research results indicate that the Latvian social enterprises regard their performance across the social dimensions to be stronger, compared to their results in the business/financial dimensions. A greater balance between the social and businesses/financial performance dimensions is desirable, providing ample space for interventions aimed at strengthening the business skills and capacities of social enterprises, paying particular attention to those engaged in work integration.
Key words: social enterprise, Latvia, performance, social entrepreneurship.

Introduction

The times when social entrepreneurship was a novelty have long been gone both in the economically advanced countries where social entrepreneurship initiatives are strongly supported by governments and also in the least developed countries where this movement is propelled by the society reacting to a variety of unmet needs (Tkacz, 2016). In the context of the latter, higher social inequality (Aponte, Alvarez, & Lobato, 2019) has been established as a factor contributing to the speed of development of various social entrepreneurship initiatives. The global movement of social entrepreneurship has earned recognition, among other merits, as a tool for tackling a variety of social and economic problems (Bandyopadhyay &Ray, 2019), driving innovations (Monroe-White & Zook, 2018), and promoting sustainable development (Blagoycheva, 2019). According to the vision of Michael Porter, the world-renowned professor and author of many books and competitiveness theories, social entrepreneurship also serves as a much needed catalyst for transformation of capitalism which will inevitably result in perception of shared value creation, a particular strength of social entrepreneurs, as the new norm (Driver & Porter, 2012). However, despite the wide acknowledgement and numerous attempts to set clear conceptual boundaries to the phenomenon of social entrepreneurship, a number of 'great divides' still exist (Morris, Santos, & Kuratko, 2020), highlighting its complexity. Questions and concerns regarding the performance of social enterprises contribute to the aforementioned intricacies.

The concept of performance, which can be understood as the ability of an organization to achieve the set goals with the available resources, allows evaluation of social enterprises across both the economic and social domains. Therefore, it is better suited to the social entrepreneurship context compared to the concept of competitiveness which pertains largely to the economic goals. While the social and ecological dimensions of performance entered the traditional business world only with the rise of the stakeholder theory (Öncer, 2018), in the social entrepreneurship context these dimensions have been inherent since the very beginnings of the social entrepreneurship field. Nevertheless, social enterprises find performance management and measurement challenging due to lack of expertise, the complex interconnections between social and economic value created by social enterprises, and also due to the large diversity of operational fields where social enterprises are found, as well as due to the differences in organizational forms and size of the enterprises (Costa & Andreaus, 2021). Although due to the aforementioned reasons it would be impossible to invent a universal approach to performance measurement for social enterprises (Costa & Andreaus, 2021), academic researchers have invested considerable effort in developing and summarizing approaches of varying complexity (Lortie *et al*., 2021; Costa & Andreaus, 2021; Öncer, 2018; Behmane, Rutitis, & Batraga, 2021; Braslina *et al*., 2020; Braslina *et al*., 2021, Seimuskane, Vilka, & Brekis, 2017) that would be suitable for social enterprises. However, what truly indicates how well social enterprises perform, is the social

impact (Öncer, 2018) they create. Social impact '…corresponds to a sustainable change in society and mirrors the effect of SEs on changing the root causes that have initiated their creation.' (Salavou & Cohen, 2021). However, as Rangan &Gregg (2019), contend, there are two levels of social impact – the first related to the social enterprise interventions at the level of individuals and households but the second – related to permanent societal changes achieved via addressing the social problem comprehensively and gaining support from external partners (governments, social services, etc.). It is essential to recognize that the direct reach of social enterprises stretches only as far as the interventions at the household level (Rangan & Gregg, 2019). Achievement of permanent societal changes without active involvement and interest of external stakeholders would be close to impossible. While social impact is crucial, Salavou & Cohen (2021) also highlight the importance of the entrepreneurial orientation and the need to strive for balance which allows social enterprises to achieve even better results.

In Latvia, the growth of the social entrepreneurship sector has been rather moderate (Casno & Sloka, 2020) and fluctuating in response to availability of financial grants (Register, 2023). Competitiveness of social enterprises has been evaluated as insufficient (Dobele, 2015), especially for work integration social enterprises (Timofejevs *et al*., 2021). Social enterprises have been able to increase their turnover and increase the number of their employees (Timofejevs *et al*., 2021). However, a significant proportion of social enterprises (43%) operated with losses in 2020 (Ministry, 2022), indicating a need for policy makers to pay attention to this topic. Although employment of employees from various target groups has been steadily increasing since 2018 (Ministry, 2022), there is still left much to be desired, particularly in terms of employment of people with disabilities (Oborenko, 2022). Efforts towards development of the social entrepreneurship field are visible; however, they lack a holistic approach. Financial grants are not strategically targeted towards resolution of the most severe social problems within society. Moreover, there is a lack of a comprehensive strategy for social entrepreneurship development, detailing the targeted outcomes and actions to be taken to support their achievement. Meanwhile, the attention towards social entrepreneurship among researchers in Latvia is continuing to grow.

A significant milestone and achievement for the Latvian social entrepreneurship sector was the opportunity to take part in the European Social Enterprise Monitor survey for the first time in 2021. The results, apart many other interesting aspects, revealed that social enterprises struggled during Covid-19 largely due to decreased sales. However, many were also able to showcase their resilience by developing new offers for existing and new target groups, and digitalizing their offerings, which actually allowed to increase their revenue (Social, 2022). Among the most common barriers indicated by social enterprises were lack of financing options after starting the business, lack of qualified employees, and poor awareness of social enterprises among customers and general public (Social, 2022). Lack of financial resources among social enterprises has been also highlighted by Casno & Sloka (2023b). Furthermore, authors also accentuate the insufficiency of the technical and material base and partner networks and highlight that resource insufficiency is even more pronounced (although not significant statistically) among work integration social enterprises (Casno & Sloka, 2023 b), reflecting the additional operational challenges they face due to the specificity of their work. Among other aspects, recently researchers have also paid attention to the social entrepreneurship ecosystem (Casno & Sloka, 2023a) and the identity (Casno & Sloka, 2022) of Latvian social enterprises. However, social enterprise performance has not been previously analyzed in depth. This research provides valuable insights from the point of view of social enterprises providing practical implications, support for evidence-based policy-making, and also serving as benchmark to monitor future development of the field.

Materials and Methods

For the research purposes several methods were applied. Specifically, analysis of previous research and analysis of a survey (designed and conducted as part of a doctoral research) of Latvian social enterprise managers, applying statistical analysis methods (descriptive statistics (indicators of central tendency or location), indicators of variability (range, variance, standard deviation, standard error of mean), and independent samples t-test). The survey was distributed among Latvian social enterprises with the official status via direct e-mail and among the members (including *de facto* social enterprises) of the Social Entrepreneurship Association of Latvia

via a newsletter. The survey was selected as the best methodological choice for this research since it allows fast and efficient collection of detailed quantitative data, which can serve as a valuable benchmark for future monitoring needs and is particularly important for evidence-based policy-making. Taking into account the time pressure of social enterprise managers, to elicit a higher rate of completed surveys, none of the survey questions were purposefully made mandatory, resulting in a varying number of valid responses but also at the same time increasing the quality of responses to the more detailed performance questions.

Four questions were used to obtain the evaluations of performance from the point of view of social enterprise managers. 1) respondents were asked to select the most appropriate statement regarding their performance within the last two years (or a shorter period of time if the organization was younger), indicating whether their performance had increased, decreased or remained the same. 2) the respondents who had indicated either a decrease or no changes in performance, where further asked to evaluate the importance of listed preventive factors to obtain insights regarding the most significant challenges. 3) and 4) respondents were also requested to evaluate their past and project their future performance across a number of performance dimensions (question adapted from Salavou & Cohen (2021)).

Overall, the survey was viewed by 94 social enterprise managers, 67 social enterprise managers took part in the survey (survey period: 25.04.2022.-21.06.2022). Although the sample is not fully representative (the overall population size of social enterprises was 202 at the time of the survey according to the Social Enterprise Register), its quality is substantially enhanced by the fact that almost half of the respondents (47.22%) were engaged in work integration, yielding valuable insights about this particular respondent group. All respondents were social enterprises with the official status (organizational form of a limited liability company). Majority (69.44%) employed 1–9 employees, operated 1–4 years (61.11%) and were located in Riga (40%) or Pieriga (20%). Respondents mostly operated in education (19.44%), services (16.67%) and health and social care (13.89%) which is an excellent fit to the overall population (Register, 2023).

Results and Discussion

Although the Covid-19 pandemic brought about challenges for many businesses in Latvia, majority of the surveyed Latvian social enterprises (68.2%) indicated that they had actually managed to improve their performance within the past two years (or a shorter period of time if the organization was younger), 25% of respondents indicated a decrease in performance while for 6.8% performance had not changed. These results largely compliment social enterprises and highlight this particular business form not only as beneficial for the wider society but also as particularly resilient and sustainable also during economically turbulent times. Furthermore, among those who had indicated an increase in performance, the proportion of respondents who were engaged in work integration was even slightly higher compared to the respondents who were not (70.6% and 63.2% respectively). Company age-wise, the respondent group in operation from one to four years, which was also most widely represented in the sample, had indicated an increase in performance most often (86.36% of all respondents in operation from one to four years). This indicates that younger social enterprises have possibly been more capable towards adapting to the digital environment and able to more effectively capitalize upon the opportunities it provides, compared to respondents with considerably more experience in the field. However, the proportion of respondents whose performance either did not change or had decreased during the past two years is still considerable (a total of 31.8%). On average, the respondents belonging to this group evaluated the recent Covid-19 pandemic as the most significant factor preventing the development of the performance of their organizations during the past two years, followed by lack of finance, and lack of government support, as reflected in Table 1.

However, a relatively high degree of variance was observed across the responses for all factors except ‘Insufficient recognition of social entrepreneurship within society’, indicating that the particular situations of social enterprises have been rather diverse. Overall, despite the challenges, a significant proportion of respondents were able to capitalize on the various opportunities and quickly adapt. However, from the perspective of respondents, despite the overwhelmingly positive trend in terms of cumulative performance, respondents’ evaluations regarding particular performance dimensions, reveal certain strengths and weaknesses, as reflected in Table 2.

Table 1

Main indicators of descriptive statistics for the evaluations of the question "To what extent these factors have prevented the development of your organization's performance during the past two years (or shorter period of time if your organization is younger)?"

		Covid-19 pandemic	Lack of finance / investment	Shortage of qualified workforce	Insufficient recognition of social entrepreneurship within society	Lack of government support	Shortage of knowledge / skills
N	Valid	13	13	13	13	13	13
	Missing	54	54	54	54	54	54
n/a		0	0	1	1	0	0
Mean		8.31	6.38	6.00	2.83	6.31	3.62
Standard Error of Mean		0.827	1.003	0.921	0.613	1.028	0.859
Median		10	7	6.50	2.50	7	2
Mode		10	10	8	1; 3	10	1
Standard Deviation		2.983	3.618	3.191	2.125	3.706	3.097
Variance		8.897	13.090	10.182	4.515	13.731	9.590
Range		9	9	9	6	9	9
Minimum		1	1	1	1	1	1
Maximum		10	10	10	7	10	10

Source: Author's own construction based on author's designed and conducted survey in 2022, Evaluation scale 1–10, 1 – did not prevent, 10 – prevented significantly, n/a – not applicable, n=67.

The arithmetic means do not fall below 6 (on a 10-point scale) for any of the dimensions confirming a certain level of grit and persistence. Social enterprises are most confident in their performance with respect to such social performance dimensions as ability to resolve the social problem significant for the organization, ability to create social impact, and ability to ensure the satisfaction of the beneficiaries, demonstrating a relatively high appreciation for their investment in and importance of their individual social missions. However, the evaluations across the economic / business-oriented dimensions of performance lag behind rather significantly reflecting the effects of the Covid-19 pandemic to a certain extent. While social enterprises faced the most challenges in terms of increasing revenue from commercial activity (arithmetic mean of 6.21), other business-oriented dimensions such as the ability to create economic impact and increase other sources of revenue as well as the number of products/services, and the number of customers, of which the latter two are especially significant for financial viability, reveal plenty of room for improvement as well.

Although social enterprises who were engaged in work integration revealed even slightly stronger performance across such dimensions as the ability to create social impact and increase the number of beneficiaries, confirming their vital role as an employer of various groups at-risk, their evaluations for the remaining performance dimensions were slightly lower, as reflected in Table 3, pointing towards additional difficulties that work integration social enterprises face to remain financially viable.

Although the aforementioned differences were not found to be statistically significant, they nevertheless confirm particular challenges among work integration social enterprises due to their operational specificity in terms of employing people with various disabilities, mental disorders, etc.

Table 2

The evaluation of the various dimensions of performance within the past 2 years (or a shorter period of time, if the organization is younger) by Latvian social enterprises

		Ability to create environmental impact	Ability to create social impact	Ability to create economic impact	Ability to increase the number of beneficiaries	Ability to increase the number of customers	Ability to increase the number of products / services	Ability to increase revenue from commercial activity	Ability to increase other sources of revenue (grants etc.)	Ability to ensure the satisfaction of the beneficiaries	Ability to resolve the social problem/-s significant for the organization
N	Valid	44	44	43	43	44	44	44	44	43	43
	Missing	23	23	24	24	23	23	23	23	24	24
n/a		7	0	3	1	0	0	1	1	1	1
Mean		7.03	7.89	6.48	7.19	6.98	6.89	6.21	6.56	7.79	8.05
Standard Error of Mean		0.413	0.282	0.332	0.348	0.334	0.346	0.344	0.375	0.357	0.268
Median		7	8	6	8	8	8	6	7	8	8.50
Mode		8; 10	8	6	8	8	8	8	8; 9	8	9
Standard Deviation		2.511	1.870	2.100	2.244	2.215	2.295	2.253	2.462	2.312	1.738
Variance		6.305	3.498	4.410	5.036	4.906	5.266	5.074	6.062	5.343	3.022
Range		10	8	9	9	9	8	9	0	9	6
Minimum		1	2	1	1	1	2	1	1	1	4
Maximum		10	10	10	10	10	10	10	10	10	10

Source: Author's own construction based on author's designed and conducted survey in 2022, Evaluation scale 1–10, 1 – very poor, 10 – excellent, n/a – not applicable, n=67.

Table 3

Comparison of arithmetic means for the evaluations of listed performance dimensions during the past two years (or a shorter period of time if the organization is younger) between social enterprises engaged in work integration and conventional social enterprises

Does your organization employ people from the groups at risk for social exclusion?		Ability to create environmental impact	Ability to create social impact	Ability to create economic impact	Ability to increase the number of beneficiaries	Ability to increase the number of customers	Ability to increase the number of products / services	Ability to increase revenue from commercial activity	Ability to increase other sources of revenue (grants etc.)	Ability to ensure the satisfaction of the beneficiaries	Ability to resolve the social problem/-s significant for the organization
Yes	Mean	7,53	8.29	6.71	7.24	6.88	6.59	6.06	6.18	7.24	7.75
	N	17	17	17	17	17	17	17	17	17	16
	Standard Deviation	2.601	1.896	2.779	2.333	2.315	2.347	2.680	2.942	2.905	1.949
No	Mean	8.16	7.79	7.22	7.11	7.00	6.95	6.42	6.58	7.89	8.21
	N	19	19	18	19	19	19	19	19	18	19
	Standard Deviation	2.814	1.843	2.102	2.470	2.211	2.297	1.924	2.411	1.967	1.686

Source: Author's own construction based on Kristine Casno designed and conducted survey in 2022, Evaluation scale 1–10, 1 – very poor, 10 – excellent, n/a – not applicable, n=67.

Overall, the distinct focus among social enterprises on social rather than business-oriented performance can be explained by the recent Covid-19 context and involvement and contribution of social enterprises in securing the well-being of their beneficiaries and at the same time by their lower capacity to capitalize on the opportunities provided by digitalization. However, this trend should be monitored especially, since the theoretical literature advocates for balanced social and economic missions and highlight the importance of economic aspects in generation of sustained social impacts.

The projections of social enterprises towards their performance for the next two years reveal confidence in their ability to improve the financial/business oriented performance dimensions. As reflected in Figure 1, social enterprises project that they will be able to strengthen their position (especially in terms of ability to increase revenue from commercial activity) across the economic/financial dimensions of performance, allowing also slight improvement in performance across the social performance dimensions in the upcoming two years.

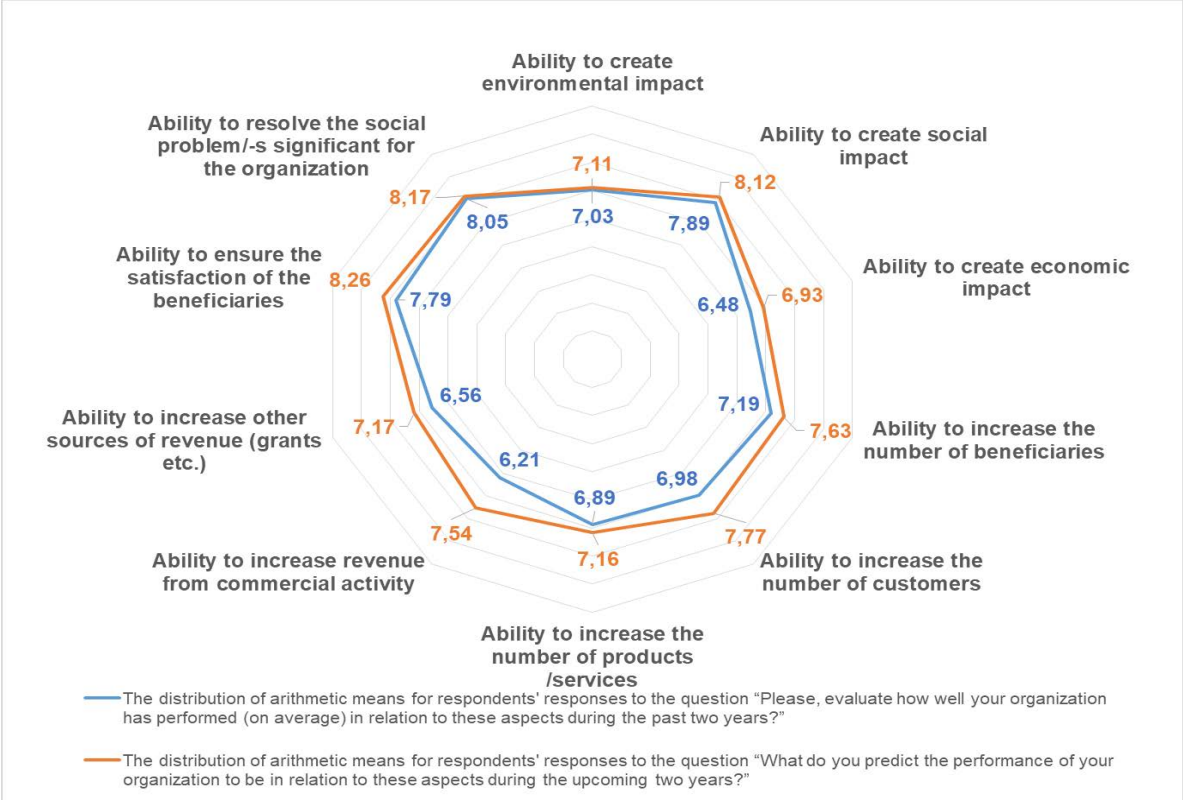

Figure 1. Distribution of the arithmetic means for the respondents' evaluations of their past and future performance across listed performance dimensions.

Source: Author's construction based on Kristine Casno developed survey conducted in 2022, Evaluation scale 1–10, 1 – very poor, 10 – excellent, n/a – not applicable, n=67.

This again highlights the resilience of social enterprises. Although the future projections reveal a greater balance between the social and economic missions, the dominance towards social goals still prevails, accentuating a need for strengthening the revenue generation capacities of social enterprises for enhanced and sustained ability to deliver social impact in the future. Furthermore, the projections for future performance among work integration social enterprises lag behind those of the conventional social enterprises across all performance dimensions, as reflected in Table 4.

Moreover, compared to their evaluations of performance in the past 2 years, their future outlook is more cautious as regards their ability to create environmental and social impact and resolve the social problem significant for the organization. For other dimensions, they project either a slight increase in performance or no changes. None of the arithmetic means for their future performance projections reach the threshold of 8. Although these differences were not found to be statistically significant, they nevertheless confirm a continued cautiousness on behalf of social enterprises regarding their performance potential which

also points towards existence of additional challenges they encounter in their operation compared to those social enterprises who do not employ people from the groups at risk.

Table 4

Comparison of arithmetic means for the evaluations of listed performance dimensions during the next two years between social enterprises engaged in work integration and conventional social enterprises

Does your organization employ people from the groups at risk for social exclusion?		Ability to create environmental impact	Ability to create social impact	Ability to create economic impact	Ability to increase the number of beneficiaries	Ability to increase the number of customers	Ability to increase the number of products / services	Ability to increase revenue from commercial activity	Ability to increase other sources of revenue (grants etc.)	Ability to ensure the satisfaction of the beneficiaries	Ability to resolve the social problem/-s significant for the organization
Yes	Mean	6.88	7.88	6.71	7.65	7.53	6.59	7.24	6.59	7.82	7.65
	N	17	17	17	17	17	17	17	17	17	17
	Standard Deviation	3.080	2.369	2.085	2.090	2.125	1.970	2.195	2.293	2.243	2.262
No	Mean	8.53	8.42	7.47	7.84	8.05	7.47	8.26	7.79	8.58	8.79
	N	19	19	19	19	19	19	19	19	19	19
	Standard Deviation	2.796	1.610	2.318	2.089	1.929	2.366	1.727	2.043	1.835	1.843

Source: Author's own construction based on Kristine Casno designed and conducted survey in 2022, Evaluation scale 1-10, 1 – very poor, 10 – excellent, n/a – not applicable, n=67.

Conclusions

1. Social entrepreneurship has strong potential in improving the social and economic welfare of citizens. However, particularly in Latvia, more strategic management of the field and targeted support grants could contribute to enhanced social impact.
2. Social enterprises have demonstrated a substantial degree of resilience during the Covid-19 pandemic, confirming the sustainability of this business model also during economically turbulent times and highlighting the vital role social enterprises can play in securing the well-being of the wider society.
3. Not all social enterprises were able to capitalize on the opportunities provided by the Covid-19 pandemic, indicating differences in terms of capabilities and specific situations.
4. Past evaluations of the various performance dimensions of respondents reveal particular strengths across the social performance dimensions while the business/financial dimensions lag behind.
5. Future performance projections towards the ability to strengthen the respondents' performance across business/financial performance dimensions are optimistic confirming the resilience of social enterprises; however, the focus on the social aspects of performance prevails, indicating a need for policy-makers to closely monitor the developments.
6. The evaluations of the past as well as projections of the future performance of work integration social enterprises lag behind those of the respondents who are representing conventional social enterprises, confirming the existence of particular challenges characteristic to work integration social enterprises and providing valuable evidence for policy-makers questioning the need for enhanced and specific support measures for this particular social enterprise group.
7. For a sustained development of the social entrepreneurship field, policy makers are recommended to strengthen the businesses development skills and capacities of social entrepreneurs, paying particular attention to work integration social enterprises.

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ENERGY RESOURCES COST-REDUCING ACTIVITIES IN TIMBER INDUSTRY ENTERPRISES IN LATVIA

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Abstract
The energy-intensive timber industry enterprises have a significant role in Latvia's manufacturing sector, contributing to the country's sustainable economic development. They maintain the economic well-being of residents of Latvia's rural regions and represent a substantial proportion of output value and export volume in the manufacturing sector and the state economy. Due to surging energy prices that negatively impact production costs, it is more difficult for enterprises to compete in foreign markets. The study aims to analyse energy consumption trends in timber industry enterprises in Latvia to propose activities for reducing energy costs, thus promoting the international competitiveness of timber industry enterprises. The analysis is based on data from Europe's power market Nord Pool and databases of the Official Statistics Portal of Latvia. Methods used: statistical data analysis using time series analysis and expert interviews. The research results show that a significant threat to the competitiveness of enterprises is the increasing price of electricity, which is the second most consumed energy resource, accounting for nearly 15% of the total annual energy consumption of timber industry enterprises. To address high electricity costs, enterprises have the opportunity to install solar panels. Calculations show that, at an electricity price of 0.198 EUR per kWh, investments could lead to a five-year payback period with an ROI of 7.52%. At a lower electricity price of 0.13 EUR per kWh, the payback period would extend to ten years but still provide a reasonable ROI of 5.2%.
Key words: timber industry, energy consumption, cost-reducing activities, solar panels.

Introduction

Latvia is a country rich in forests, as they cover around 3.4 million hectares or 53% of Latvia's total territory. Among European countries, only Finland (74%), Sweden (69%), Slovenia (62%), and Estonia (57%) have a larger forest area (The World Bank, 2020). The timber industry in Latvia mainly relies on the forestry and logging sector that provides high-quality resources such as pines, birches, and other tree species from local forests. Local resource usage saves on logistics costs incurred by importing from abroad and supports local forestry enterprises. Resources can be used to manufacture a wide range of sustainable products, including pallet boards, furniture, and renewable energy sources such as wood chips, briquettes, and pellets.

The global economic situation has changed rapidly, not only because of the COVID-19 pandemic, which has affected exports of various goods and services to Asia, the United States, and Europe but also due to the Russo-Ukrainian war, which has resulted in very volatile prices of energy resources and other raw materials. Surging energy prices have increased manufacturing costs, making it more difficult for enterprises to compete in foreign markets. As innovative technologies continue to emerge, enterprises must shift to sustainable energy practices, reducing reliance on fossil fuels.

The research examines energy consumption trends and investigates the impact of the price hike on the performance of timber industry enterprises in Latvia. It includes an interview with two industry experts, summary of seven energy cost-reducing activities, approximate costs for implementing each activity, and a calculation of the investments required for installing solar panels with an economic evaluation at different electricity prices. The research had three main tasks: 1) to analyse energy consumption trends in timber industry enterprises in Latvia; 2) to investigate whether the performance of timber industry enterprises in Latvia has been affected by the increase in energy resource prices; 3) to summarise different energy resources cost-reducing activities, compare their advantages and disadvantages.

Materials and Methods

It was specified that timber industry enterprises are enterprises whose type of activity corresponds to NACE 16 (manufacture of wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials) and NACE 31 (manufacture of furniture) according to the statistical classification of economic activities in the European Community, Revision 2. Quantitative and qualitative research methods were used to achieve the goal and perform the tasks. To investigate the energy price hike impact on timber industry enterprises, interviews with industry experts were conducted. To identify energy resource cost-reducing activities that would promote the international competitiveness of timber industry enterprises, seven energy resources cost-reducing activities were summarized, and a calculation of the investments required for installing the solar panels with an economic evaluation at different electricity prices was done.

Results and Discussion

Timber industry enterprises in Latvia export at least 70% of their production annually. In 2020 and 2021, they contributed approximately 3.5% to the country's gross domestic product. In 2020, the export volume amounted to 1.8 billion EUR or 13.3% of the country's total exports, while in 2021, it increased to 2.5 billion EUR or 14.9% of total exports (Official Statistics Portal, 2022). One of the reasons for the rise in export volume in monetary terms is the significant increase in energy prices. Higher energy costs have prompted enterprises to increase manufacturing expenses, resulting in higher prices for final products and leading to lower demand, which negatively impacts the industry's actual export volume. Therefore, monitoring consumption trends and energy prices is essential for assessing their impact on the industry's operations.

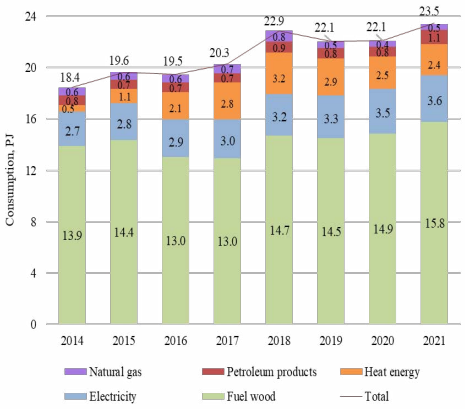

Figure 1. Energy resource consumption in timber industry enterprises in Latvia 2014.–2021., PJ.

From 2014 to 2021, the average annual growth rate of energy consumption in timber industry enterprises in Latvia was 3.5%. In 2021, the total consumption reached 23.5 petajoules (PJ) (Figure 1). The consumption of petroleum products, especially diesel fuel, was relatively insignificant, averaging only 0.8 PJ or 3.9% per year. Natural gas was consumed at an average of 0.6 PJ per year, but dynamic fluctuations in heat energy consumption were observed. In 2014, it accounted for approximately 0.5 PJ or 2.6% of the total energy consumption, but in 2018 increased to 3.2 PJ or 14.1%. Meanwhile, in 2021, the heat energy consumption decreased to 2.4 PJ, leading to a reduced share of the total energy resource consumption of 10.4%. While renewable energy resources, mainly fuel wood, accounted for the largest share of energy consumption, with an average of 14.27 PJ or 68% per year, the second most consumed energy resource was electricity, with an average consumption of 3.14 PJ or 14.9% of the total consumption (Official Statistics Portal, 2022). Despite the dominance of renewable energy resources, electricity still accounts for a significant portion of energy consumption. The cost of this resource has become a concern in recent years. If the average electricity price on the Nord Pool exchange moderately fluctuated with seasonal ups and downs between 2014 and 2020, then in 2021, it experienced a sharp increase, reaching almost 468 EUR per megawatt-hour (MWh) by August 2022. (Nord Pool, 2022). The increasing electricity prices have had a significant impact on various industries, including the timber industry.

Timber industry generated 4.2 billion EUR in total turnover in 2021 (Official Statistics Portal, 2022). Yet over 55% of revenue was produced by only twenty-six enterprises, representing less than 1% of the industry (Lursoft, 2022). That indicates a small number of competitive enterprises, emphasizing the need for prompt solutions. To investigate the effects of the price hike on the performance of timber industry enterprises and to find out how they are tackling it, a quality specialist of pallets and pallet collars manufacturing enterprise LLC 'KRONUS' and a member of the board of furniture production enterprise LLC 'RAUKO' were interviewed.

When asked about the impact of rising energy costs on the enterprise's financial standing and exports, 'RAUKO' explained that projects are planned at least 6–12 months before the sale, with minimal scope for modifying the contracts. As a result, the increase in energy costs, particularly electricity, directly and indirectly affects manufacturing costs. Moreover, raw material suppliers and business partners include the energy price increase in their product and service costs, which 'RAUKO' currently covers from its anticipated profits. For heating, firewood is purchased, and the cheapest available transport is used for exporting goods. In contrast, 'KRONUS' reported that the main impact on its operations is not primarily due to higher energy prices but rather the shortage of timber on the market resulting from the Russo-Ukrainian war. The enterprise has taken measures to secure itself against potential cost increases. It invested in a boiler house that utilizes timber residues from manufacturing and allows to generate heat energy. In addition, an electricity contract signed in 2020 with favourable tariffs remains valid until the end of 2023, reducing concerns about rising electricity prices. 'KRONUS' has not faced any rise in fuel costs, as it relies on an outsourcing service that provides a fixed price for exporting goods.

During a discussion regarding measures aimed at saving electricity and improving energy efficiency, both implemented and planned, 'RAUKO' stated that they are shifting to LED lighting in production and office buildings. Additionally, the enterprise

is gradually replacing outdated manufacturing equipment with energy-efficient alternatives. 'RAUKO' highlighted its efforts to reorganize manufacturing areas, to prevent unnecessary electricity consumption. That includes prohibiting individual employees from working in these areas, illuminating the entire building, and using the centralized ventilation system – the largest electricity consumer. In future, 'RAUKO' intends to undertake two projects – installing solar panels and securing a stable electricity supply for production building. At the same time, 'KRONUS' has installed light sensors in areas with infrequent employee presence to save electricity and implemented an international standard for Energy Management systems ISO50001 to increase energy efficiency. That includes installing thermostats in manufacturing areas to regulate heat and attaching energy meters to each manufacturing equipment to identify the equipment that consumes the most energy and optimize its operating time. 'KRONUS' has also reviewed its manufacturing process and rearranged equipment according to the production cycle, reducing the movement of loading equipment, saving time and resources. In the future, 'KRONUS' is considering the installation of solar panels to increase the proportion of green energy and is developing a project to replace diesel forklifts with electric ones. Also, as 'KRONUS' recycles the residual wood material from manufacturing into briquettes, it plans to expand production and invest in equipment to manufacture pellets from the residuals.

Analyzing the responses, it is evident that 'KRONUS' is more committed to sustainable manufacturing practices and has timely implemented several activities to reduce energy costs. However, for 'RAUKO', the rising electricity prices have emerged as a significant threat that will reduce turnover, profit margins and the ability to compete in the global market. To reduce the impact of external factors, an enterprise must plan how to efficiently use its available resources. The following section summarizes seven cost-reducing activities for energy resources, comparing their advantages and disadvantages.

1) Employee training can play a significant role in promoting energy literacy and reducing energy consumption. By reminding employees to use artificial lighting only when necessary, turning off electrical devices when not in use, and rearranging premises for better airflow, the enterprise can reduce daily energy consumption and save money without significant financial investments. There are at least three ways to provide practical knowledge to employees on how to change their behaviour concerning energy consumption.

The first is interactive e-learning in energy efficiency prepared by JSC 'Latvenergo' trade brand Elektrum (Elektrum, 2022). The necessary resources for learning are any device with an Internet connection (smartphone/tablet/computer) and up to half an hour of the employee's time. The cost of implementing the activity is zero euros. However, considering employees working in production buildings may not have access to a device with an Internet connection during working hours; another alternative is to organize joint employee training events at least twice a year with an energy specialist providing practical recommendations for reducing energy costs. Per price list of Riga Energy Agency, an in-person consultation on energy efficiency costs 30 EUR per hour, excluding value-added tax (VAT). Price includes the specialist's preparation time for the training and the time required for providing the training (Riga City Council, 2021). Assuming the specialist requires two full working days (16 hours) to prepare for the training, and one part-time working day (6 hours) to provide the training, the total cost of the service, including VAT, would amount to 798.60 EUR per consultation, with twice-yearly consultations costing 1,597.20 EUR. Although the expenses are not high, there remains uncertainty about whether employees will implement the specialist's recommendations in their daily practices. In such a scenario, an alternative worth considering is hiring an energy manager or a quality assurance specialist.

Business managers often undertake numerous responsibilities, including energy resource management, which may not always yield successful results. Therefore, it is worth considering creating a new position by hiring an employee with relevant knowledge in energy management. The employee's duties would include regular monitoring and analysis of energy consumption data, organising measures to improve energy efficiency, controlling the performance of heating, ventilation, and air conditioning systems, developing preventive measures to reduce risks and ongoing employee training in energy management practices. According to Baltic online recruitment company cv.lv, the average gross salary of an energy manager in the private sector is 1,900 EUR, and of a quality assurance specialist – 1,700 EUR for full-time working hours. Adding social tax (employer's share of 23.59%) and business risk state fee of 0.36 EUR, the total cost of an energy manager position would be 2,348.57 EUR per month or 28,182.84 EUR per year, but the employment of a quality assurance specialist would cost 2,101.39 EUR per month or EUR 25,216.68 per year. This alternative could be the most beneficial for the enterprise, offering advantages with costs offset by expected energy savings. Although to ensure the success of an energy manager or quality assurance specialist, the enterprise must install data monitoring devices for energy consumption monitoring and provide a management system, such as a mobile app

or an online platform, for processing and analysing the obtained data.

2) Data monitoring enables management to understand where they can reduce energy consumption by optimizing the operating time of production equipment and where they need to implement more complex solutions. Typically, those responsible for paying energy bills have the most detailed knowledge of the enterprise's energy consumption. However, to identify areas for improvement and encourage employee engagement in reducing consumption, enterprises should monitor energy consumption and present the data in a simple, understandable way to all employees.

Prudently made investments in the building's engineering system can pay off in the short term. Several companies offer complex data monitoring solutions for energy management, including monitoring devices, data analysis platforms, and other services. The more expensive the subscription, the more technology and services are included. If the enterprise does not have an energy manager or quality assurance specialist, the service provider can handle data collection and analysis, reducing the enterprise's need for involvement. Yet, while subscriptions for complex data monitoring solutions are available, individual data monitoring devices can also be a cost-effective alternative. Data monitoring devices can track building temperature, air humidity, and CO2 levels. They come in stationary or portable versions, and the costs based on the online store of Scientific Technical Company 'LĀSMA' range from 160 EUR to 1,100 EUR without VAT for a stationary data logger and from 20 EUR to 1,500 EUR without VAT for a portable one. The price mainly depends on the device application possibilities. Software for recording and analysing data can be obtained free of charge or purchased, but paid software will be much more advanced, and its license costs around 350 EUR without VAT. Like the previous activity, the expenses in this case can also be covered by potential energy cost savings.

3) An energy audit provides a comprehensive evaluation of an enterprise's premises and equipment and offers an independent analysis of its energy consumption. Referring to Article 10 of the Energy Efficiency Law (Saeima, 2016), an energy audit is mandatory for all large enterprises. According to the State Construction Control Office, an energy audit for production enterprises cost from EUR 2,000 to EUR 8,500 once every four years, excluding VAT, i.e., 500 – 2,125 EUR per year (Jansone, 2022). While the costs relative to the benefits of an energy audit are not high, considering the market's dynamic demand and fluctuating production volumes influenced by ever-changing factors in the enterprise's external and internal environment, conducting an energy audit once every four years may not be enough. It raises awareness of the current situation for enterprises but offers only general recommendations to promote energy efficiency without focusing on an immediate reduction in energy resource consumption.

4) Switching to energy-efficient light bulbs is a long-term investment in a safe work environment. While it's feasible to fulfil the occupational safety requirements with fluorescent or halogen light bulbs, their shorter lifespan can make them less efficient and more expensive to maintain than LED luminaires. One fluorescent daylight tube costs approximately 30 – 60 EUR without VAT and can operate from 7,000 to 15,000 hours. The cost of a LED tube ranges from 15 EUR to 400 EUR without VAT, and its average lifespan ranges from 25,000 to 50,000 hours. The price of luminaires depends on their intended use – those required for the factory will differ from those installed in the office building. Even though the initial investment in LED luminaires may be higher, their longer lifespan and adaptability to lighting requirements make them a more sustainable and efficient choice. They can also provide better quality lighting than traditional bulbs, which leads to improved visibility, productivity, and overall comfort in a workspace. Integrating sensors or relays to adjust lighting brightness and duration can further enhance energy efficiency resulting in lower energy bills and a more sustainable environment.

5) Solar panels are not a novelty in Latvia, but they have faced limited demand due to the lack of targeted financial support. However, the significant surge in energy resource costs during the first half of 2021 has increased interest in solar panel installations among households and entrepreneurs.

Various companies in Latvia offer solar panel installation services to legal entities. To assess the installation expenses from project development to full implementation and the cost differences between roof and ground installations, six companies were contacted via email, but only one responded. A representative of LLC 'Enefit' indicated that it is necessary to consider the type of roof when installing solar panels on a building - the cost per kilowatt (kW) of solar panel power can vary significantly between a sloping roof and a flat roof ranging from 50 EUR to 250 EUR. During ground installations, additional costs for panel mounting brackets, ranging from 100 EUR to 120 EUR per kW, must be considered. The installation expenses may also fluctuate based on the number of panels used. Suppose for the annual electricity usage of 240 MWh, a 240 kW solar panel system would be necessary to achieve maximum capacity, costing around 1,100 EUR to 1,300 EUR per kW for roof installation and 900 EUR to 1,000

EUR per kW for ground installation. For an annual electricity usage of 840 MWh, an 840 kW solar panel system must be set up, which would incur an initial expense of EUR 900 to EUR 1,200 per kW for roof installation and EUR 800 to EUR 950 per kW for ground installation, meaning that the larger the solar panel system installed, the lower the cost per kW.

To determine the economic viability of solar panels, a sample of random numerical values representing the electricity consumption of a small timber enterprise was generated and the annual electricity consumption was calculated to be 271.61 MWh, assuming a change in consumption from 21 to 24 thousand kilowatt hours (kWh) within a year. The manufacturing costs of products sold by the enterprise in the previous financial year were estimated to be 1.5 million EUR. If the enterprise has a fixed yearly contract for electricity priced at 0.198 EUR per kWh, the electricity consumption would cost 53,779.18 EUR, equivalent to 3.59% of the manufacturing costs of the products sold in the last financial year.

To generate enough power to meet the total consumption, a solar panel system with a capacity of 270 kW would be required, but there are several limitations. 1) Some enterprises may face space limitations when installing solar panels. Generating 271 MWh of electricity would require at least 720 panels, each with a nominal power of 375W, occupying approximately 1,500–1,700 m^2 with proper spacing. 2) Solar panels have lower output from October to March compared to April to September. If panels were installed to meet full annual electricity consumption, there would be excess electricity production for half of the year and only partial for the other half, which would not be sufficient to meet the total consumption. 3) Solar panels generate electricity solely during daylight hours and may experience a decrease in output due to higher air temperatures.

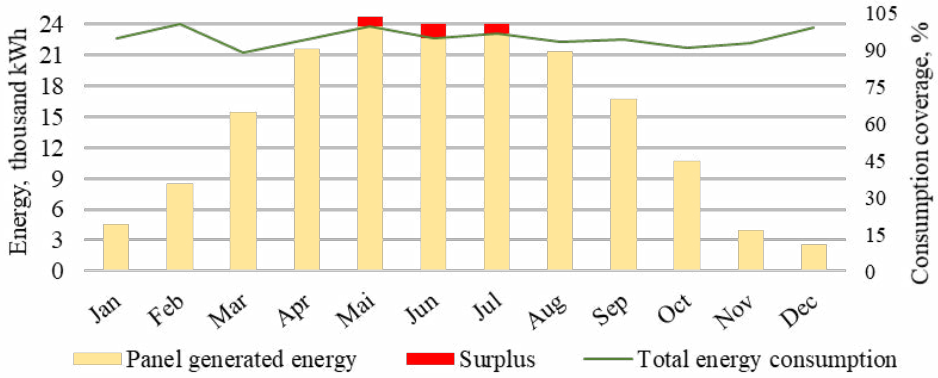

Figure 2. Monthly energy consumption and coverage by a 162kW solar panel system, kWh.

To determine the optimal panel capacity for the enterprise's peak consumption from April to September, the European Commission's Photovoltaic Geographical Information System tool was used (European Comission, 2022). By specifying the approximate location of the enterprise in the central part of Latvia, several situations were modelled with various solar panel capacities until a suitable result of a 162 kW solar panel system was obtained to cover the previously generated electricity consumption. When installed on the ground, the system would generate 178 MWh of electricity per year, covering an average of 34% of the total consumption from October to March, 74% in September, around 96% in April and August, and fully meeting the consumption from May to July, resulting in excess electricity production. If solar energy is fully consumed according to demand, the system will produce a surplus of 3,428 kWh of electricity (Figure 2). With estimated installation costs of 950 EUR per kW, the installation of a 162 kW solar panel system on the ground would amount to 153,900 EUR. Considering an electricity price of 0.198 EUR per kWh and not factoring in any surplus electricity transmitted to the grid, the investment, utilizing a discount rate of 10.04% as indicated on the State Treasury's website for forecasting future cash flow, would be fully repaid in five years with an expected return on investment (ROI) of 7.52%. Upon evaluating the variations in the payback period of a solar panel system at different electricity prices, the conclusion was that even if the electricity price were to decrease to 0.13 EUR per kWh, the investment of 153,900 EUR for a 162 kWh solar panel system would take ten years to repay under constant conditions. However, the ROI in this case would be lower – only 5.2% (Table 1). In the long term, investment in a solar panel system would reduce the proportion of electricity costs in manufacturing costs by 2.8 times.

Table 1

Payback period and return on investment (ROI) at different electricity prices

Electricity price, EUR per kWh	Payback period, years	ROI, %
0.198	5.46	7.52
0.188	5.84	2.09
0.178	6.29	8.03
0.168	6.82	1.96
0.158	7.45	5.06
0.148	8.2	6.22
0.138	9.14	5.66
0.13	10.08	5.2

One of the positions that make up at least 10% of the solar panel system total costs (based on the costs provided by 'Enefit') is the cost of metal mounting brackets. Although serving as a durable means of support, the metal structures tend to heat up and, as a result, heat the solar panels too. Thus, it leads to reduced panel efficiency and a consequent decrease in electricity production. To avoid that, wooden constructions can be used as an alternative to metal. Timber enterprises can manufacture the necessary constructions for solar panels by themselves, utilizing their available resources, manufacturing equipment, and employee knowledge. Although wood may initially appear less fire-resistant and more susceptible to environmental conditions, advancements in modern technology have significantly improved wood durability and safety. Impregnating wood can increase its resistance to fire, water, and decay, making it a durable and reliable option for various construction needs. After reviewing several wood preservatives, it was found that using a wood antiseptic can protect the wood against mould, fungi, and insects for up to 15 years when used outdoors. By performing regular protection control every two years, it is possible to extend the lifespan of wood up to 30 years. Achieving successful results, timber industry enterprises will have an opportunity to diversify their product range and start producing and selling wood constructions for solar panel systems, thus increasing their market share. Industry experts 'KRONUS' and 'RAUKO' were introduced to this alternative. Both recognized it as practical and technically feasible.

6) Wind energy is another renewable source of energy. However, wind stations are less prevalent in Latvia than solar panel systems. According to the annual wind energy report by the European Wind Energy Association 'WindEurope', Latvia had the third-lowest installed wind energy capacity in European Union in 2021, with only 66 megawatts (MW) (WindEurope, 2022). Estonia and Lithuania have much higher wind energy capacity, with 320 MW and 668 MW installed, respectively. A variety of factors contribute to Latvia's relatively low wind energy capacity. High costs for wind technologies, lack of financial support, public objections to noise and vibrations caused by wind turbines, and environmental concerns are among the most significant. As wind generators have not gained as much popularity in Latvia as solar panels, the exact costs for wind power plant construction remain uncertain. However, the approximate cost of constructing a wind power plant in Latvia is around 1.2 million EUR per megawatt of capacity, according to online information about wind parks built in Latvia and Lithuania.

While wind stations offer significant benefits in providing green energy and supporting climate neutrality goals, they have particular installation requirements. First, an environmental impact assessment must be conducted before constructing the wind station, and all potential risks associated with it must be analysed, such as noise pollution and vibrations that could affect nearby buildings and the local fauna. Additionally, wind generators require more space than solar panels, and regulations state that wind power plants with a capacity of 20 kW to 2 MW cannot be installed within 500 meters of residential and public buildings. For capacities exceeding 2 MW, the distance increases to 800 meters (Republic of Latvia Cabinet of Ministers, 2013). Despite generating sufficient renewable electricity, it remains critical to assess the overall impact of the production process on the environment and the local community. Additionally, it is important to note that turbines are inactive during calm weather, and measures must be taken to prevent overloading during strong winds, which can result in additional expenses.

7) Electrification of loading equipment has both advantages and disadvantages. In timber industry, vehicles are used not only for employees to move from one facility to another but also to move raw materials and manufactured products within the premises. The internal combustion engine forklift remains the most common vehicle in factories and warehouses. Given the European Parliament's decision to gradually prohibit internal combustion engines in cars and vans (European Parliament, 2022), transitioning loading vehicles to electric power would be beneficial as well. Replacing an internal combustion engine forklift with an electric one promotes energy efficiency, fuel cost savings, improved employee health and the overall climate by reducing emissions and noise pollution. However, the initial cost of purchasing electric forklifts

is higher than those with internal combustion engines. Summarising the loading equipment costs available online, a 2022 forklift with a gas or petrol engine costs around 18,000 EUR, a comparable model with a diesel engine is approximately 19,000 EUR, the same forklift with an electric motor has a starting price of 22,000 EUR. Besides, an enterprise must plan for the necessary charging infrastructure, which can add approximately 2,500 EUR to the electrification cost, depending on the type of charging station chosen. While charging times may require adjustments if employees work in multiple shifts, investing in the electrification of loading equipment can pay off in short time, especially when paired with solar energy. Eventually, the operating costs of an electric forklift will be lower than a forklift with an internal combustion engine.

In conclusion, timber industry enterprises can increase the proportion of renewable energy resources in their overall consumption in the future. Achieving this goal involves utilizing wood residues produced during the manufacturing process to generate heat energy and installing renewable energy technologies that enhance energy autonomy, making the manufacturing process more eco-friendly. While the primary advantage of cost-reducing activities is moving towards environmentally sustainable business practices and improving the value of the enterprise, a drawback is the high initial costs involved, which may discourage some entrepreneurs from pursuing such activities. However, businesses prioritizing renewable energy sources to reduce their dependence on fluctuating energy markets and implement cost-reducing activities into their management strategies to lower energy consumption and manufacturing costs will gain increased attractiveness to customers and partners, resulting in enhanced competitiveness.

Conclusions

1. Electricity is the second most consumed energy resource, accounting for nearly 15% of the total energy consumption of timber industry enterprises annually. Its increasing price has emerged as a significant threat that may reduce turnover, profit margins and the ability of enterprises to compete in global market.
2. The results of the expert interviews show that the energy price hike has had less impact on an enterprise whose management strategy focuses on sustainability, forecasting possible scenarios in the future, timely identification of potential risks, and implementation of risk preventive measures.
3. To address high electricity costs, enterprises have the opportunity to install solar panels. Calculations show that, at an electricity price of 0.198 EUR per kWh, investments may lead to a five-year payback period with an ROI of 7.52%. At a lower electricity price of 0.13 EUR per kWh, the payback period extends to ten years but still provides a reasonable ROI of 5.2%. In the long term, investment in a solar panel system may reduce the proportion of electricity costs in production costs by 2.8 times.
4. To reduce the costs of the solar panel system, ensure full-fledged electricity production from panels and promote the competitiveness of timber industry enterprises, it is possible to replace the steel constructions of the solar panel system with self-made constructions from wood. Achieving successful results, timber industry enterprises will have an opportunity to diversify their product range and start producing and selling wood constructions for solar panel systems, thus increasing their market share.

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DEVELOPMENT OF AN IMPROVED LOGISTICS MANAGEMENT MODEL FOR FUEL RETAIL ENTERPRISES

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Abstract
The objective of this research was to design an economically efficient logistics management model for fuel retail enterprises to improve their competitiveness. In the current global market situation, fuel retail enterprises face various challenges, such as sharp increase in raw material price, intense market competition, high price sensitivity, low profitability, and significant logistics costs. By combining theoretical and practical insights, an improved logistics management model was designed, which provides significant competitive advantage for fuel retail enterprises. The designed model incorporates and integrates three distinct logistics arrangements, resulting in considerable advantages for fuel retail enterprises. These advantages include a reduction in logistics costs and increased independency from the fluctuating logistics service expenses. To determine the economic efficiency of the designed logistics management model, it was validated by using data obtained from a fuel retail enterprise based in Sweden. Results of the research indicated that the fuel retail enterprise can anticipate an annual reduction in logistics costs ranging from 2.91% to 3.32% from the implementation of the improved logistics management model. On top of that, the developed logistics management model is projected to be economically viable until 2027, assuming the continuation of the current market trends and conditions. The findings of the research suggest that other fuel retail enterprises may also benefit from implementation of the designed model in the current market conditions.
Key words: fuel retail, logistics management, logistics service providers.

Introduction

In the current global market situation, fuel retail industry is characterized by intense market competition. Reduction of operational costs has become a crucial activity for fuel retail enterprises to enhance their competitiveness within the market. By achieving reduction of operational costs, fuel retail enterprises can offer competitive prices to their customers, which allows them to grow their market share. The significance of operational cost reduction has been emphasized by M. Porter, who posits that by enhancing its primary activities, an enterprise can create greater value in the market, and as a result gain competitive advantage over its competitors (Porter, 1991). This theory is particularly relevant in the fuel retail industry, where enterprises sell homogenous products to their customers, which results in an intense price competition. Therefore, any cost reduction in the fuel retail industry has a significant impact on the competitiveness of an enterprise.

One of the primary activities over which fuel retail enterprises have a direct control over is logistics management. Fuel retail enterprises rely on logistics service providers (LSP) to manage their logistics operations. Selection and integration of appropriate LSPs in supply chains is a critical factor for the competitiveness of fuel retail enterprises. For example, an enterprise that relies on outsourcing of logistics services may expose itself to the risks associated with fluctuations in logistics service charges. On the other hand, an enterprise that manages its logistics operations solely with in-house logistics is likely to incur significantly greater logistics costs compared to utilizing outsourced logistics services. Therefore, to make an informed decision regarding the selection and integration of appropriate LSPs, an in-depth analysis of different types of LSPs is required.

The objective of this research was to design an economically efficient logistics management model for fuel retail enterprises in order to improve their competitiveness. To develop an improved logistics management model for fuel retail enterprises, various theoretical and practical aspects regarding LSPs have been integrated into the model, such as specifics of different types of LSPs and the current situation of the fuel retail industry.

Materials and Methods

To reach the objective of the research, various qualitative and quantitative research methods were used. A literature review on various types of LSPs was conducted. The study also employed a range of quantitative research methods to analyze the data, such as correlation analysis, linear regression analysis, time series analysis and ABC analysis. The designed model was validated by using data obtained from a fuel retail enterprise based in Sweden. The enterprise generates annual fuel sales of approximately 1.77 billion liters and incurs annual logistics costs of approximately 19.9 million EUR.

Results and Discussion

Most widely adopted LSPs by fuel retail enterprises are first party logistics (1PL), second party logistics (2PL) and third-party logistics (3PL). 1PL, also referred to as in-house logistics, is a logistics arrangement where the fuel retailer manages its logistics operations with the use of its own vehicles and resources. Implementation of 1PL is often associated with 'make-or-buy' decision making process, in which an enterprise evaluates the economic efficiency of producing logistics services in-house versus outsourcing them (Fadile, Oumami, & Beidouri, 2018). Primary drivers that motivate an enterprise's decision to implement 1PL logistics are cost reduction associated with economies of scale, the ability for an enterprise to allocate its resources towards its core business operations and improved customer service (Zhu *et al*., 2017). Therefore, it can be concluded that although implementation of 1PL results in higher logistics costs for a fuel retail enterprise, it provides a significant competitive advantage in the market. Moreover, 1PL arrangement provides the highest level of control over logistics operations as all operations are managed in-house by the enterprise itself.

2PL is a logistics arrangement where fuel retail enterprise outsources transportation function to a LSP. The primary benefits from integrating 2PL providers in supply chains include the ability for enterprise to retain control over other aspects of logistics operations and allows retailer to benefit from the expertise of the 2PL service provider (Płaczek, 2010). Therefore, it can be concluded, that 2PL logistics arrangement is beneficial for a fuel retail enterprise that wants to maintain control over its logistics operations but lacks resources or expertise to transition to in-house logistics.

3PL is a logistics arrangement where fuel retail enterprise outsources all of its logistics operations to a LSP. Compared to 2PL arrangement, a 3PL provider fulfills a wide range of logistics functions, such as procurement, transportation, planning, inventory management, order fulfillment and others. 3PL arrangement is associated with having lower average logistics costs, due to LSP's ability to leverage its expertise, resources and economies of scale (Skjoett-Larsen, 2000). By implementing a 3PL solution in their supply chains, an enterprise can expect a lower control level over logistics operations, since LSP has a complete control over logistics management (Zacharia, Sanders, & Nix, 2011). Therefore, it can be concluded that by integrating a 3PL service provider within its supply chain, fuel retail enterprise exposes itself to the risk of substantial increase of logistics costs, connected to the fluctuation of logistics service charges. This risk is particularly pronounced in markets characterized by limited competition among LSPs.

While implementation of different types of LSPs has distinct advantages and disadvantages for fuel retail enterprises, the benefits of combining multiple logistics arrangements simultaneously has not been researched in the scientific literature. To assess the potential benefits that fuel retail enterprise may accrue from concurrent implementation of multiple types of LSPs, a theoretical model incorporating 1PL, 2PL and 3PL was designed (Table 1). The designed model segments the sales points of the fuel retail enterprise into three distinct market segments of varying strategic significance and applies different logistics arrangements to each of the identified segments. By tailoring logistics arrangements to the unique requirements of each market segment, fuel retail enterprise can expect more effective resource allocation.

The model combines three different logistics arrangements, thus necessitating the implementation of a segmentation method, which would divide the sales points of a fuel retail enterprise into three segments with varying strategic significance. The most appropriate method for this task is ABC analysis, as it enables the categorization of items based on their strategic significance. Factor which most appropriately characterizes the strategic significance of a sales point is fuel sales volume. It is logical to suggest that higher volume of fuel sales would result in a greater revenue for the fuel retail enterprise, making it a suitable factor to use in the ABC analysis. In the context of the designed model, a distribution proportion of 70% was selected for segment 'A', 25% for segment 'B', and 5% for segment 'C' (Figure 1). It is worth noting that the proportions defined for this analysis are not fixed and alternative distribution proportions can be used in the context of the designed model.

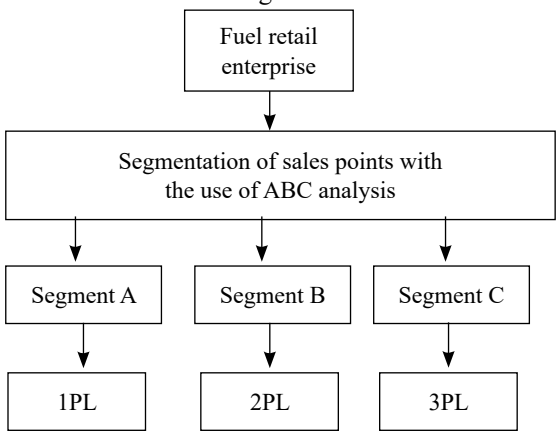

Figure 1. Visualization of the designed logistics management model for fuel retail enterprises.

To evaluate the economic efficiency of the designed logistics management model, it was validated using data obtained from a fuel retail enterprise based in Sweden. The enterprise operates 460 sales points and generates annual fuel sales of approximately 1.77 billion liters, while incurring annual logistics costs of approximately 19.9 million EUR. The reasoning for validating the designed model on the specific enterprise is because it operates all three different logistics arrangements simultaneously, allowing for a more practical calculation and evaluation of the model's economic efficiency. Based on the available dataset, the enterprise serves 69% of its sales points with 1PL, making it the primary logistics arrangement within the supply chain. 2PL is used for 30%, while 3PL is only used for 1% of its sales points. The enterprise currently does not use any sort of segmentation method for its sales points.

Table 1

Optimal logistics arrangement selection for market segments of varying strategic significance

Strategic importance of market segment	Optimal logistics arrangement	Justification for the appropriateness of logistics arrangement selection
High	1PL	• The fuel retail enterprise can reap the advantages of economies of scale due to the substantial fuel sales volume. • 1PL provides the highest level of control over logistics management; therefore, better visibility of logistics operations can be expected.
Medium	2PL	• The fuel retail enterprise retains control over logistics management, because 2PL provider fulfills only transportation function. • 2PL arrangement does not require investments for fuel retail enterprise.
Low	3PL	• Segment generates low income; therefore, high level of control over logistics management is not practical. • Compared to other logistics arrangements, 3PL provides the lowest logistics costs.

The initial stage of evaluating the economic efficiency of the designed model was to determine the existing trends of logistics costs in the fuel retail industry. To test the assumption that logistics costs are directly correlated with diesel fuel retail prices, data was collected from the fuel retail enterprise covering fuel sales from January 2020 to July 2022. In addition, data on the average diesel retail prices was collected from the European Commission database (European Commission, 2023). The collected data was compiled and analyzed using Microsoft Excel.

By conducting a visual analysis of the data, a positive correlation was observed between the two variables (Figure 2). Based on the calculations

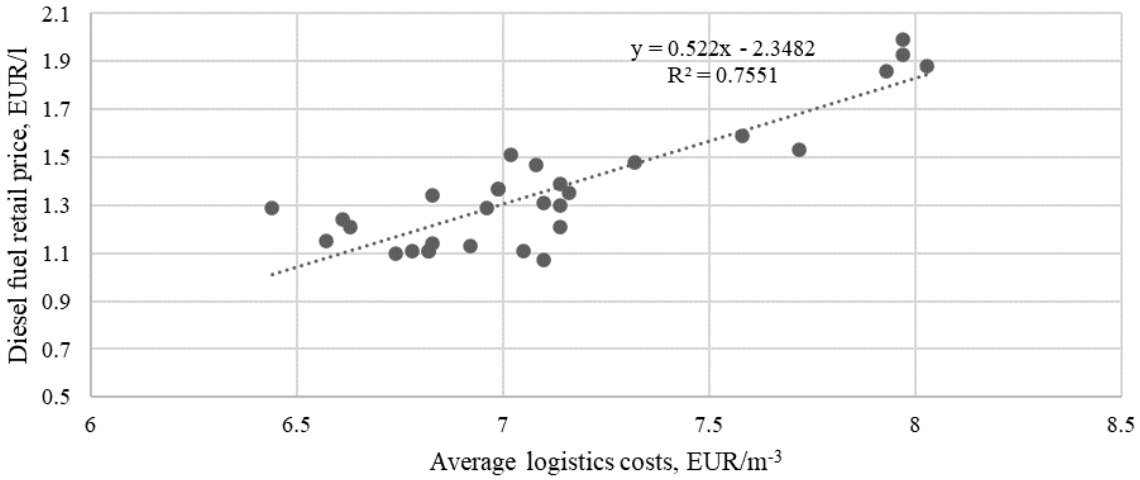

Figure 2. Scatter chart depicting the relationship between diesel fuel retail prices and average logistics costs.

performed by Microsoft Excel's Data Analysis tool, a correlation coefficient of 0.87 was determined between the two variables. The findings indicate that fluctuations in diesel retail prices are a statistically significant factor that affects the logistics costs of fuel retail enterprises.

As fuel retail prices tend to increase annually, it can be deduced that fuel retail enterprises should anticipate a corresponding growth in logistics costs. To quantify this effect, the available data from the fuel retail enterprise used in the analysis was used to calculate the annual growth rate of logistics costs for each of the three logistics arrangements. Time series analysis was conducted using data from July 2021 to July 2022 to derive the most accurate and recent logistics cost growth rate.

By performing visual analysis of the data, it is evident that 1PL incurs the highest logistics costs compared to other two logistics arrangements (Figure 3). The collected data indicates that outsourced logistics services result in lower logistics costs, which may be attributed to the high maintenance costs associated with in-house logistics arrangement.

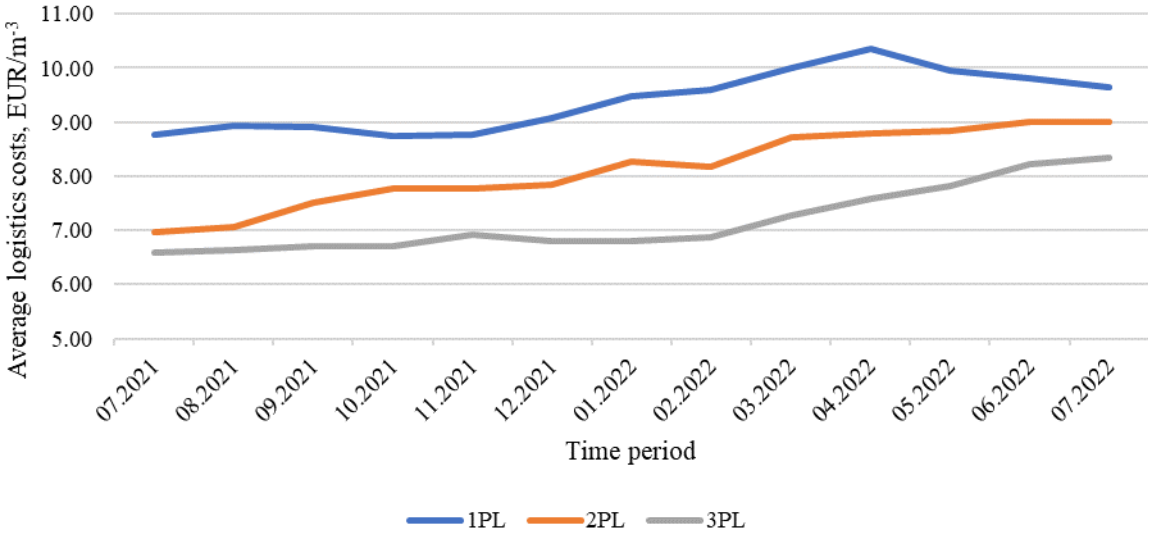

Figure 3. Average logistics costs of the fuel retail enterprise by logistics arrangement (2021–2022).

The calculation of logistics cost growth rates indicates that 1PL arrangement, despite incurring the highest logistics costs, has the lowest growth rate among the three logistics arrangements (Table 2). The analysis of the data indicates that the logistics costs for the 1PL arrangement increase at an annual rate of approximately 0.8%, whereas the logistics cost growth rates for outsourced services are 2.2% and 2.0% for the 2PL and 3PL arrangements, respectively. From the performed calculations it can be concluded, that a fuel retail enterprise capable of achieving economies of scale in the long term may gain a competitive advantage in the market by implementing 1PL arrangement, as it provides independency from the fluctuations of logistics services charges, and yields the lowest logistics cost growth rate, which can be attributed to the higher level of control over logistics management.

The subsequent stage in assessing the economic efficiency of the designed model involved conducting ABC analysis on the data available of the fuel retail enterprise. The purpose of this analysis was to segment the sales points of the fuel retail enterprise into three categories based on varying levels of strategic importance. As previously mentioned, the fuel retail enterprise operates 460 sales points. Specifically, 69% of the sales points are being serviced via 1PL arrangement, while 30% and 1% of the remaining sales points are served by 2PL and 3PL arrangements, respectively. The sales points were classified into three segments based on their fuel sales volume, in line with the distribution proportions of the proposed logistics management model. Upon performing the ABC analysis on the data obtained from the fuel retail enterprise, the results indicated a revised distribution of logistics arrangements. The analysis suggests that the fuel retail enterprise would be serving 46.1% of its sales points with 1PL arrangement, 35.4% of its sales points with 2PL arrangement, and 18.5% of its sales points with 3PL arrangement (Figure 4). Based on the analysis, it can be inferred that the implementation of the improved logistics management model would facilitate a higher level of integration of outsourced logistics services for the fuel retail enterprise.

Table 2

Calculation of average logistics cost growth rate for all three logistics arrangements

Time period	Logistics cost growth rate compared to previous period, %		
	1PL	2PL	3PL
07.2021	-	-	-
08.2021	2.1	1.5	0.9
09.2021	-0.4	6.3	0.9
10.2021	-1.9	3.5	0.1
11.2021	0.3	0.1	3.2
12.2021	3.5	0.8	-1.5
01.2022	4.4	5.3	-0.2
02.2022	1.4	-1.0	1.0
03.2022	4.1	6.7	5.9
04.2022	3.4	0.7	4.3
05.2022	-3.7	0.6	2.9
06.2022	-1.5	1.8	5.1
07.2022	-1.7	-0.1	1.5
Average	0.8	2.2	2.0

To determine the economic benefit of the improved logistics management model, the subsequent step involved calculation of the average logistics costs associated with each of the three logistics arrangements. For the calculation of the average logistics costs the following formula was used:

$$AC = \frac{TC}{Q} \quad (1)$$

where: AC – average logistics costs of a logistics arrangement per one cubic meter of fuel sold, EUR; TC – total annual logistics costs of a logistics arrangement, EUR; Q – total volume of fuel sold per year, m^3.

To calculate the average logistics costs, the available data of the fuel retail enterprise for the year 2021 was utilized. The data used for the calculation of the average logistics costs of the fuel retail enterprise consisted of the fuel volume sold and the logistics costs for each of the three logistics arrangements. The calculations of the average logistics costs for each of the three logistics arrangements were summarized in a table (Table 3). Based on the calculations, in 2021 the fuel retail enterprise incurred logistics costs of approximately 19.88 million EUR.

To calculate the projected logistics costs for the fuel retail enterprise after applying the improved logistics management model, it was necessary to determine the fuel sales volume for each of the three segments identified through the ABC analysis. Upon obtaining this data, the projected logistics costs for each of the three segments could be computed by using the formula:

$$C = AC * Q \quad (2)$$

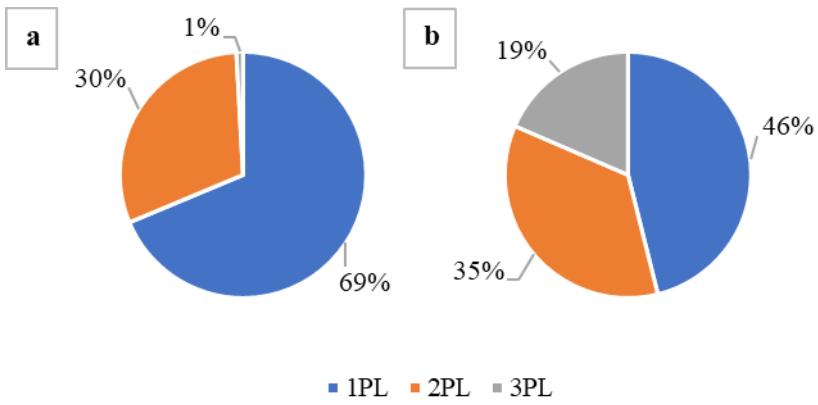

Figure 4. Distribution of LSPs in the fuel retail enterprise: in the current situation (a), and after applying the designed logistics management model (b).

where: C – annual logistics costs of a segment, EUR; AC – average logistics costs of a logistics arrangement per one cubic meter of fuel sold, Q – total volume of fuel sold, m^3.

The results of the projected logistics costs calculation for the fuel retail enterprise were summarized in a table (Table 4). Based on the calculations, it was determined that the implementation of the improved logistics management model for the fuel retail enterprise would result in a total annual logistics cost of approximately 19.23 million EUR. The results of the analysis indicate that implementation of the improved logistics management model would result in a reduction of logistics costs of approximately 650 thousand EUR, equivalent to a 3.3% decrease in logistics costs for the fuel retail enterprise.

An important factor for determining long-term economic efficiency of the designed logistics management model is the growth rate of logistics costs associated with the three different logistics arrangements. As previously analyzed, the logistics cost annual growth rate for the 1PL arrangement is approximately 0.8%, while that of the 2PL and 3PL rangements are 2.2% and 2.0%, respectively. By considering the aforementioned growth rates, a calculation was conducted to project the logistics costs for the fuel retail enterprise until the year 2027 (Table 5). Calculation was performed until the year 2027, as the fuel retail industry is subject to many unpredictable factors that can significantly affect logistics costs. By projecting logistics costs for a five-year period, the analysis becomes more realistic and provides insights for potential long-term economic efficiency of the logistics management model.

The results of the calculation until 2027 suggest that the implementation of the improved logistics management model can lead to a reduction in logistics costs for the fuel retail enterprise ranging from 2.91% to 3.32%. (Table 6). This suggests that the model has the potential to yield sustained economic benefits in the long term.

Although the calculations of potential economic benefits from implementing the improved logistics management model were based on data from a single fuel retail enterprise, they provide an indicative illustration of the potential benefits that may be realized by fuel retail enterprises that adopt the proposed logistics management model. The utilization of multiple logistics arrangements in combination allows for efficient allocation of resources, while the use of a 1PL arrangement provides independence from the rapidly growing logistics service charges and affords the highest level of control over logistics management.

Table 3

Calculation of the average logistics costs in 2021

Logistics arrangement	Total annual logistics costs, EUR	Fuel volume transported by each of logistics arrangement, m^{-3}	Average logistics costs, EUR/m^{-3}
1PL	16,752.397	1,380.246	12.14
2PL	3,019.390	371.370	8.13
3PL	109.642	15.229	7.19
Total	19,881.429	1,766.845	11.25

Table 4

Calculation of projected logistics costs in 2021 after applying the improved logistics management model

Segment category	Logistics arrangement used for segment	Average logistics costs, EUR m^{-3}	Fuel volume transported within segment, m^{-3}	Projected logistics costs, EUR
A	1PL	12.14	1,234.064	14,981.537
B	2PL	8.13	444.380	3,612.809
C	3PL	7.19	88.401	635.603
Total	-	-	-	19,229.950

Table 5

Projection of logistics costs for the period 2022–2027

Year	Period	Projected annual logistics costs, thousand EUR			Projected annual logistics costs after applying improved logistics management model, thousand EUR		
		1PL	2PL	3PL	1PL	2PL	3PL
2022	0	16,886	3,085	111	15,077	3,692	647
2023	1	17,021	3,153	113	15,197	3,774	660
2024	2	17,157	3,223	116	15,319	3,857	673
2025	3	17,295	3,294	118	15,441	3,942	686
2026	4	17,433	3,366	120	15,565	4,028	700
2027	5	17,572	3,440	123	15,689	4,117	714

Table 6

Calculation of projected logistics cost reductions through the implementation of the designed model

Year	Period	Projected annual logistics costs, thousand EUR	Projected annual logistics costs after applying improved logistics management model, thousand EUR	Logistics cost reduction	
				Thousand EUR	%
2022	0	20,083	19,416	667	3.32
2023	1	20,288	19,631	657	3.24
2024	2	20,496	19,848	647	3.16
2025	3	20,706	20,069	637	3.08
2026	4	20,919	20,293	626	2.99
2027	5	21,135	20,520	615	2.91

Additionally, the 1PL arrangement demonstrates the lowest logistics growth rate, making it a preferred solution for fuel retail enterprises that seek to leverage economies of scale.

Conclusions

Based on the research, the following conclusions can be made:

1. Implementation of 1PL arrangement for fuel retail enterprises can provide significant competitive advantage for fuel retail enterprises that are able to leverage economies of scale, as 1PL has a lower logistics cost growth rate compared to outsourced logistics services.
2. The disproportionate growth of outsourced logistics service charges compared to the in-house logistics costs can be attributed to the inadequate competition between logistics service providers in the fuel retail industry.
3. The proposed logistics management model, which utilizes ABC analysis, can enable fuel retail enterprises to enhance their resource allocation and optimize their logistics operations, leading to greater efficiency and potential logistics cost reduction.
4. Development of sustainable logistics management model for fuel retail enterprises requires long-term projections of logistics cost growth rates.
5. Further research is needed to explore the potential benefits and limitations of implementing the designed logistics management model for different fuel retail enterprises in various locations and under different circumstances.

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HIGHER EDUCATION AND LABOR MARKET TRENDS IN THE TRANSPORT AND LOGISTICS SECTOR

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Abstract
Developed transport and storage sector has up-most importance for production capacities in regions, especially in rural areas, ensuring supplies and deliveries, including well-developed and maintained infrastructure, transport vehicles, IT systems and human capital. Till 2040 demand for highly-educated and qualified logistics specialists will increase in Latvia due to growing labor costs, introduction of new technologies and digital solutions. The aim of the study is to identify the recent trends that give valuable findings for education and regional development policy elaboration and implementation in order to achieve balanced regional development promoting also rural development. The findings reveal that the higher the share of population with higher education the higher the wages. The regions with the larger share of population with higher education are mainly urban and pre-dominantly urban regions. However, transport and logistics sector is in all regions as well as demand for logistics specialists. Balanced regional development is crucial for sustainable development in national and the European Union level.
Key words: logistics, demand for logistics specialists, regional development, rural regions, higher education.

Introduction

Higher education has been with growing importance in many sectors for a long period; the more educated and skilled employees and investments in advanced technologies ensure growing productivity and competitiveness in local and global market.

Regional logistics is closely related to the wholesale and retail trade (Feng, 2018), and it interacts with the regional economy as such (Yin & Peng, 2021). Moreover, logistics has a strategic role in optimizing resource allocation, improvement of investment environment, which can improve the competitiveness of the regional economy (Bi *et al*., 2020; Guo *et al*., 2021). Policy factors also play a major role in the development of regional logistics (Wang & Li, 2021).

COVID-19 crisis has shown that it is important to establish taskforce teams, enable information digitalization and quickly prepare capacity calculations, which is possible only if logistics management can be described as forward-thinking leadership (Durugbo *et al*., 2022).

There are several job responsibilities that will be influenced by digitalization resulting in lower demand for such specialists (Bavrin *et al*., 2021). Moreover, increasing automation can help speed up different logistics processes and reduce staff. However, the lack of appropriate training may hinder such developments (Koshal *et al*., 2019). As supply chains expand, complexity also increases, thus, demand for well-skilled supply chain professionals also increases (Mageto & Luke, 2020). Another issue is the aging population, which also influences the labor force in logistics (Gruchmann *et al*., 2021).

Rurality has impact on students' postsecondary institution selection and are clear differences in postsecondary attendance amid rural and urban students (Byun *et al*., 2015; Koricich *et al*., 2018).

Supply-chain education at universities has been evaluated by various methods and perspectives, such as in graduate supply chain management courses taught at universities globally (Lutz *et al*., 2022) and at national level (Jordan & Bak, 2016; Staricco & Vitale Brovarone, 2018).

The study on land-use transport (LUT) education (Staricco & Vitale Brovarone, 2018) reveals that topics covered in programs if not pre-determined depend on instructors and professors' preferences; as a result, some topics are more dominant to the scientific debate than in education. University–industry collaboration accelerates supply chain management learning (Gibson *et al*., 2016).

The aim of the study is to identify the recent trends that provide valuable findings for education and regional development policy elaboration and implementation in order to achieve balanced regional development promoting also rural development.

Tasks:

1. To analyze theoretical aspects of higher education role in development of logistics sector;
2. To collect and analyze statistical data about labor market trends in transport and logistics sector in different regions;
3. To collect and analyze statistical data about trends in higher education and education in transport and logistics;
4. To develop model of targeted state supported education.

Transport and logistics industry is H industry

according to NACE rev. 2; however, several indicators are published only for aggregated sectors as H-J and G-I, then a note is made.

Materials and Methods

The research is based on many data sources as topical labor market trends has limited coverage in official state or the European Union (EU) level statistical data bases due to time delay in publishing, hence also additional sources were selected as data available from State Employment Agency, two national level online job offer websites – ss.com and cvonline.lv. Also, information on selected logistics higher education programs of Riga Technical University (RTU) are introduced in the research.

Research period is 2020–2022. Databases of Eurostat and National statistical offices are used. Data obtaining (mining) in public sources (ss.com (Vacancies, 2023) and cvmarket (Job offers, 2023)) – Feb 8-Mar 13, 2023.

The research methods applied include graphical and content analysis.

Results and Discussion

Labour demand is determined by sectoral, regional, social and other trends that impact selection of technologies, investments, cost structure, austerity measures in industry and selection of study program, starting or postponing university level studies at individual level, etc.

Sectoral structure and development has been recently heavily impacted by costs increase that leads to changes in demand for labor.

Regional location of transport and storage is the result of many factors. Several regional disaggregation approaches are applied, as NUTS 3 level, urban-rural typology, local or national level taxonomy, etc.

In predominantly rural regions close to the city Wholesale and retail trade, transport, accommodation and food service activities (NACE G-I) accounted for 4.9% of gross value added at basic prices of (according to Eurostat (Eurostat, 2022) applied other typologies), and remote predominantly rural regions – 4.5%; in total, 9.5% of Wholesale and retail trade, transport, accommodation and food service activities were generated in predominantly rural regions in 2019. In turn, predominantly urban regions accounted for 57.0% and intermediate regions – 33.6% (21.1% in close to city intermediate regions; 12.6% in remote intermediate regions). On average, 14.3% of total economic activity was generated in predominantly rural regions indicating that other economic activities (not only farming and supplement services) are located more in rural areas than trade and transport.

Transportation, storage, information and communication (including NACE H-J industries) sector employed 11.6% in 2021; however, the share varies significantly – in Vidzeme, only 6.4% are employed in the sector, meanwhile in Riga region – 15.6% (Table 1).

Table 1

Share of employed in transportation, storage, information and communication, administrative territories, in 2021, % (Official Statistics Portal of Latvia, 2023a)

Region	Share, %
Total	11.6
Riga region	15.6
Pierīga region	11.0
Vidzeme region	6.4
Kurzeme region	10.3
Zemgale region	8.9
Latgale region	9.7

Until COVID-19, transport and storage sector has been having relatively minor producer price changes (low increase and some sub-sectors as NACE H5224 Cargo handling had a decline) since 2015 (Figure 1). Unquestionably, COVID-19 changed the demand side as well the costs (due to lock-downs, restrictions, unavailability, delayed deliveries, shortages or certain products and services, etc.).

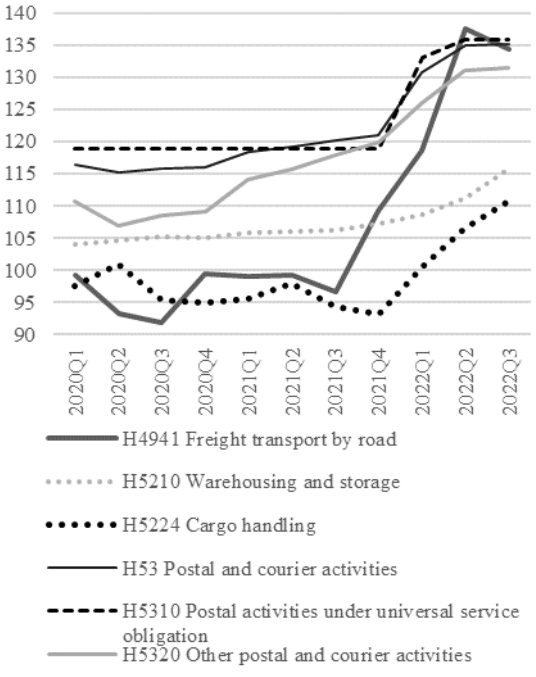

Figure 1. Producer price indices in service sectors (2015=100) (NACE Rev.2) in 2020Q1–2022Q3.

Transport and storage sector experienced huge and rapid producer price increase in recent periods (in 2022 Q2 and Q3 increase was higher than 35% over the corresponding period of previous year (Figure 2)) due to growing fuel prices, labor costs. The highest producer price increase in 2022Q3 compared to 2015 was in H5310 Postal activities under universal service obligation (135.9; 2015=100) and H4941 Freight transport by road (134.3).

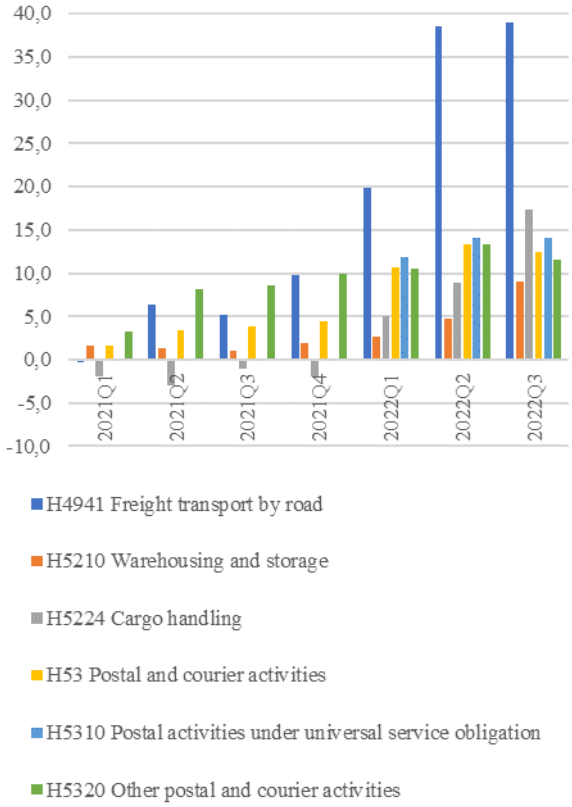

Figure 2. Producer price indices in transport sub-sectors (% over the corresponding period of previous year) in 2021Q1-2022Q3 (Official Statistics Portal of Latvia, 2023b).

General trends in demand for specialists in transport and logistics in Latvia in 2020–2022, using quarterly data and representing registered vacant job offers (SEA registered vacancies) outline fluctuations caused also by seasonality (Figure 3).

Dynamics of registered vacancies in transport and storage (H industry) in regions in 2022 highlight the growing share of vacancies in Riga regions (from 72% to 84%), significantly minor share are vacancies in other regions (Figure 4).

Higher education significantly correlates with productivity and wage in result. The analysis of wage

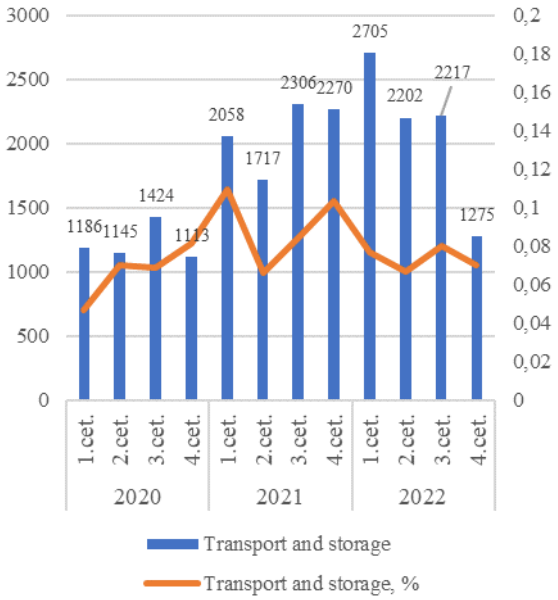

Figure 3. Registered vacancies in transport and storage (H industry) 2020Q1-2022Q4 (State Employment Agency, 2023).

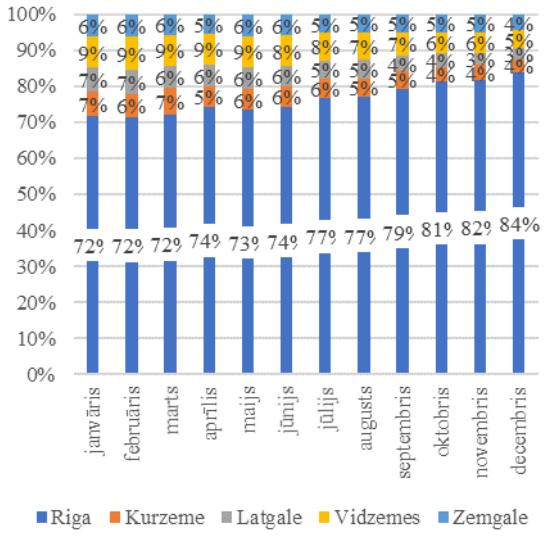

Figure 4. Registered vacancies in transport and storage (H industry) in regions in 2022 (%) (State Employment Agency, 2023).

levels in regions and share of persons with university level education (bachelor or higher) argues on a noticeably positive correlation – the more employees proportionally have higher education, the higher the wages in the region (maps in Figure 5 and Figure 6). The regions that are dominated more by rural areas and are less populated, also have limited access to education, including the transport sector.

Despite a high demand for logistic specialists,

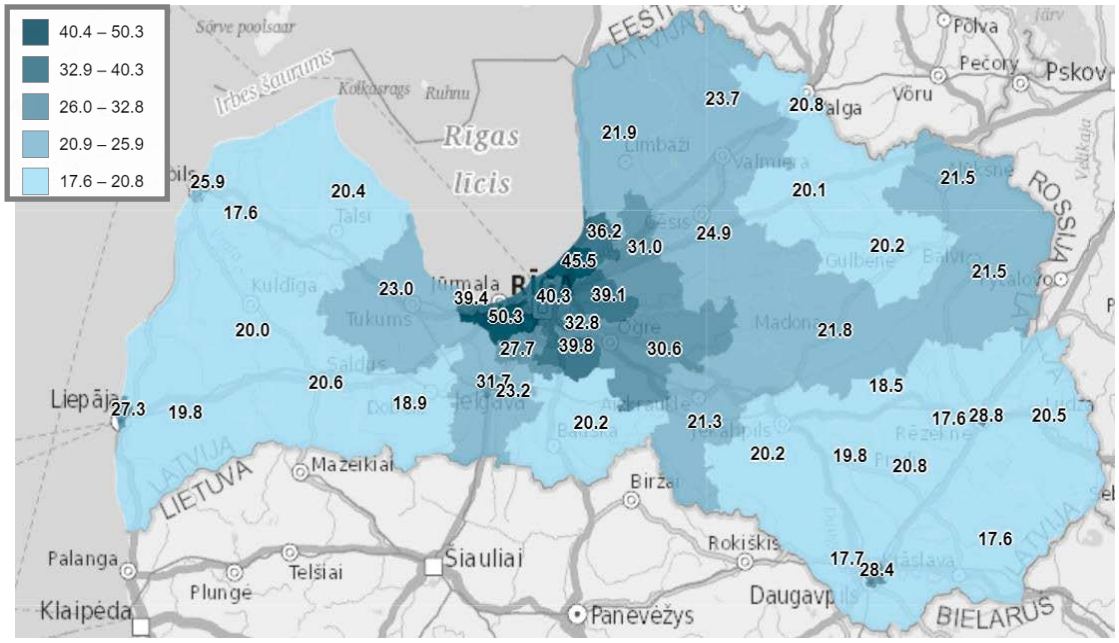

Figure 5. Share of population that has a higher education or doctorate degree by actual place of residence, administrative territories, in 2021, % (Official Statistics Portal of Latvia, 2023a).

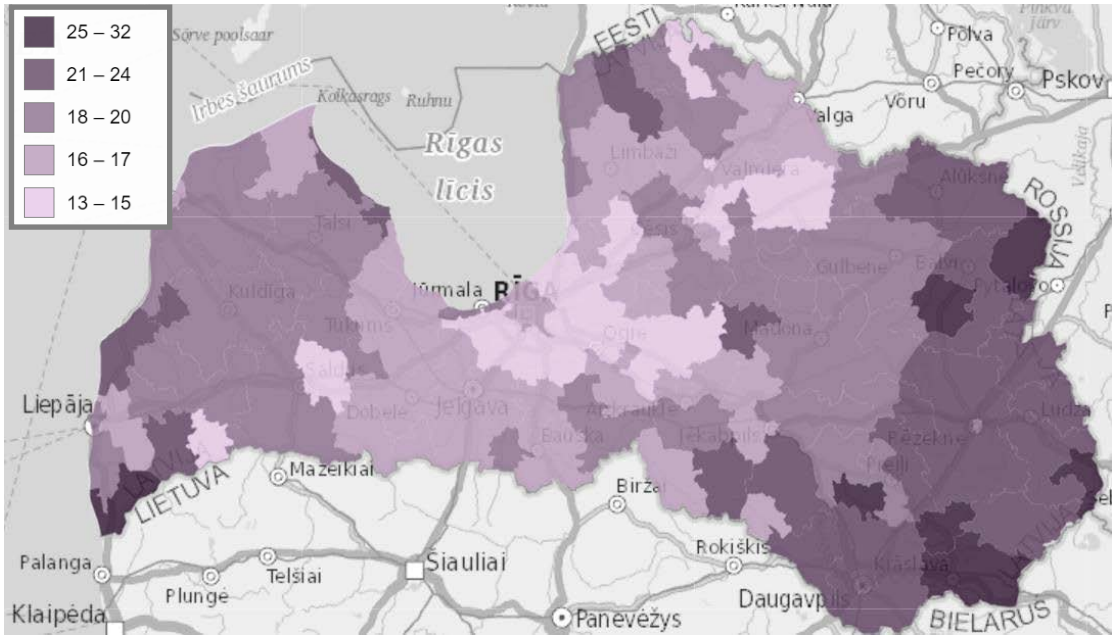

Figure 6. Share of employees with a minimum wage or less by declared place of residence, Administrative territories, in 2021M07 (Official Statistics Portal of Latvia, 2023a).

the number of students studying without tuition fee (budged students) are constant. In recent 3 study years (2020/2021; 2021/2022; 22022/23), there have been only 28 students in the corresponding program. Majority of students are paying tuition fees (80%) (Figure 3).

Monitored actual regional demand for employees in transport and logistics (February 8-March 13) outlines the technical problems in data collection, differences how companies specify the region, the job offer, the industry and responsibilities. The obtained data claims that there is a stable demand with significant regional bias towards predominately-urban areas (Riga and Pierīga (if specified separately), or Vidzeme (if Riga and Pierīga included) (Figures 8; 9).

If in data selection only vacancies for 'logistics specialists' selected very limited number of actual job offers are represented due to input information in job offers (Figure 9).

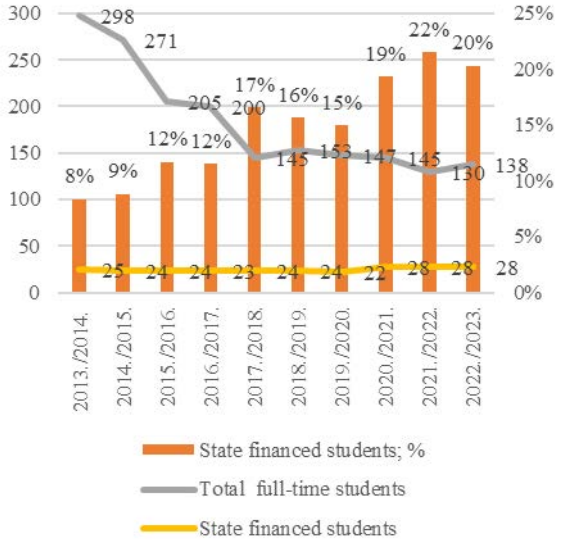

Figure 7. Number of full-time students in RTU logistics program (full-time state financed students and tuition fee-paying students).

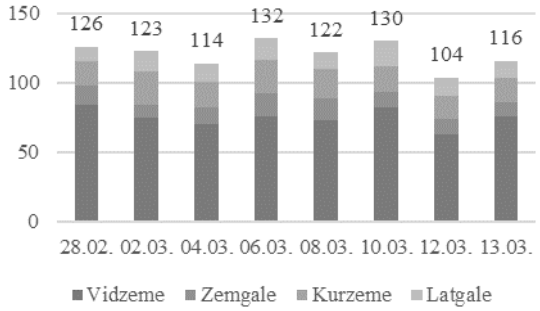

Figure 8. Job offers in logistics by regions (Vacancies, 2023).

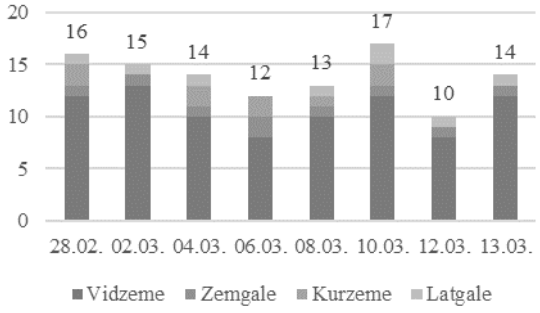

Figure 9. Logistics specialists' job offers by regions (Vacancies, 2023).

Monitoring of demand for employees in CVmarket database reveals that the companies note that vacancies are in warehouses and technical jobs in logistics (Figure 10).

According to the labour market forecasts of Ministry of Economics of Latvia, till 2040 demand for highly-educated and qualified logistics specialists

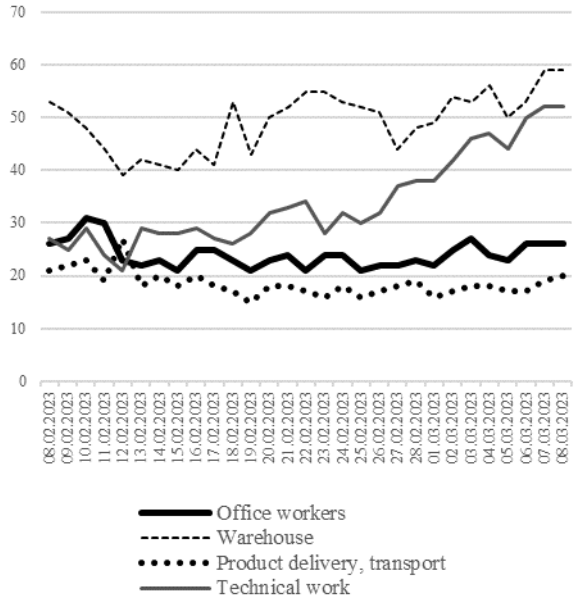

Figure 10. Job offers in logistics by possitions, Feb 8-March 8, 2023 (Job offers, 2023).

will increase in Latvia due to growing labor costs, introduction of new technologies and digital solutions (Ministry of Economics, 2023). Universities have a significant role in educating new and existing professionals in all higher education levels.

Targeted policy and resources allocated to improve the access to qualitative education that is industry-university interaction leads to regional and national level gains for many stakeholders as transport and logistics companies, employees, local business and international companies allocated in regions, local communities, etc. (Figure 11). The increased number of highly-educated and qualified specialists in transport and logistics can be through increased number of state financed students and as the income level in rural regions limits options to have access to tuition fee-paying studies.

Conclusions

1. Despite recent producer price increase in the economy, including transport and storage sector, the demand for specialists has not diminished significantly.
2. Demand for highly-educated and skilled specialists in logistics depend on availability of higher education. Low income level in rural areas limits access to education and higher labour productivity in companies and higher wages for employees.
3. Universities have direct impact on economic development in regions. Statistical data shows that in regions with more higher education holders develop faster because of higher wages of potential employees.

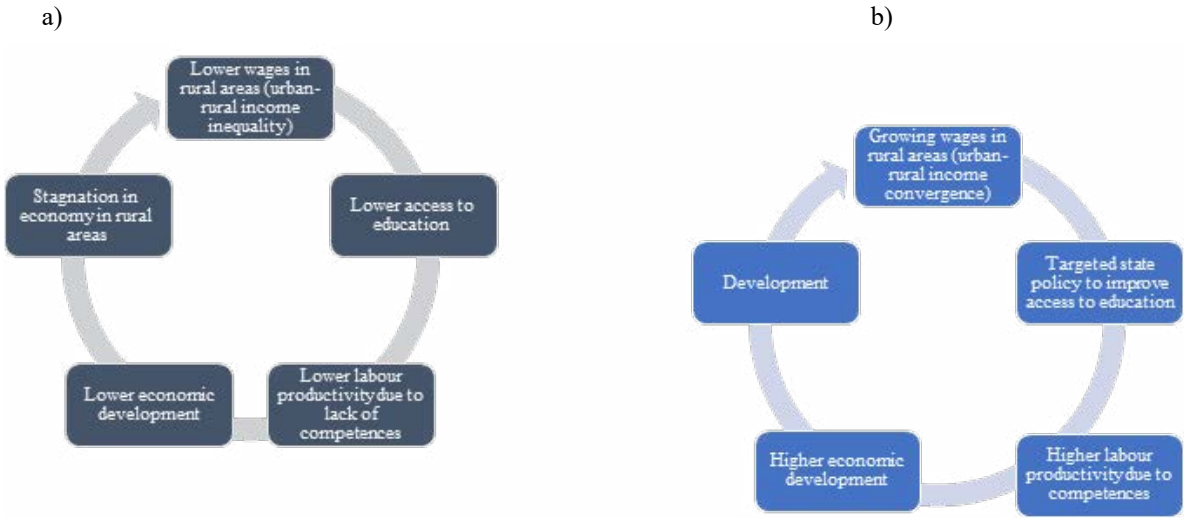

Figure 11. Schematic model of impact on rural development of negative spiral effects and (a)) and *proposed* targeted state supported higher education (positive spiral effects) (b)).

4. Despite the necessity of highly-educated and skilled specialists in logistics, the total number of full-time students in transport and logistics study programs is steadily decreasing.
5. Companies have limited options to invest in new technologies in conditions due to lack of highly-educated and skilled specialists in logistics.

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INFORMATION SOURCES ON INNOVATIONS AND INNOVATIVE ACTIVITIES FOR ENTREPRENEURSHIP DEVELOPMENT – VIEWS OF ENTREPRENEURS IN KURZEME REGION

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Abstract
Innovations are very important condition and tool for competitive entrepreneurship. To obtain more effective approaches, researchers are devoting deepened analysis for many factors influencing innovations and innovative activities indicating that there is an important influence on different sources of information on innovations – own company, co-operation with universities and business incubators, with research organisations. Empirical research results were based on survey results of entrepreneurs and on analysis of obtained survey results by use of descriptive statistics indicators confirmed that entrepreneurs in Kurzeme region biggest inspiration get in their own company as well as from suppliers of equipment, programs and materials but they have less influence on information about innovations from universities and other higher education institutions as well as private organisations, also research organisations.
Key words: innovations, density of innovative companies, information sources on innovations.

Introduction

Innovations are becoming more and more required for successful entrepreneurship and it takes place in all developed countries to be competitive internationally. Those aspects are on deep analysis by researchers around the globe pointing out several aspects and indicating initiatives and sources having influence on successful applications of innovations and innovative activities. The aim of this research is to suggest most important aspects influencing innovations in companies based on entrepreneur's survey in Kurzeme region. Tasks of this paper are as follow: 1) consider several aspects recognized by researchers as important for innovations in entrepreneurship, especially in the regional aspect; 2) analyse the tendencies of density of innovative enterprises in different fields (industry, manufacturing, services and total) in Latvia; 3) suggest the most important sources of information on innovations by entrepreneurs. Researchers have indicated that initiatives and inspiration for innovations has several roots (Mitra *et al*., 2011; Stefenberga *et al*., 2022) where knowledge creation and human capital (Maalaoui *et al*., 2020; Smith *et al*., 2022) is of great importance. Actual are issues on energy prices (Hussain *et al*., 2022) which influence innovations. For information on innovations, marketing aspects are also important (Cacciolatti & Fearne, 2013; Braslina *et al*., 2020; Braslina *et al*., 2021; Behmane *et al*., 2021) getting more and more recognition and practical application by entrepreneurs. Analysis of several business models (Silva *et al*., 2020) and communication with different social levels (Seimuskane *et al*., 2017) has led to practical and research based recommendations where digital solutions (Sergejeva *et al*., 2022; Sloka *et al*., 2017), technological aspects (Bikse *et al*., 2022) and approaches (Kitsios & Kamariotou, 2019) as well as financial aspects (Romanova *et al*., 2018; Roundy, 2018) are of great importance for practical innovations creation. In different fields (Petrolo *et al*., 2022; Daugėlienė, 2020; Ahmad *et al*., 2023) as well as traditions and approaches in different countries (Xia *et al*., 2020; Jones *et al*., 2021; Andersone *et al*., 2021) and in regions (Sotarauta *et al*., 2023; Šimanskienė *et al*., 2022) are specific conditions and factors influencing innovations have to be taken into consideration and respected for decision-making in entrepreneurship.

Materials and Methods

The research results reflected in the current paper are based on statistical data analysis in Official Statistics database of Republic of Latvia and entrepreneurs in Kurzeme region survey on several aspects related to innovations in entrepreneurship, role of different information channels to gain most effective source of information for innovations by the evaluations of entrepreneurs to develop their business and be competitive. For deeper analysis there were applied questions with invitation to make evaluations by entrepreneurs using evaluation scale with evaluations 1–10 to reflect better the views of

entrepreneurs on each analysed aspect. Evaluations are analysed by indicators of descriptive statistics: indicators of central tendency or location (arithmetic mean, mode, median), indicators of variability (range, standard deviation and standard error of mean).

Results and Discussion

Innovations are becoming more and more important around the globe and also in all branches in Latvia. Data indicate that all enterprises introduce more innovations and innovative activities. The data of Official statistics (Official Statistics, 2023) in Republic of Latvia on density of innovative enterprises depending on the company size by employees in the company every second year from 2008 till 2020 are reflected in Figure 1.

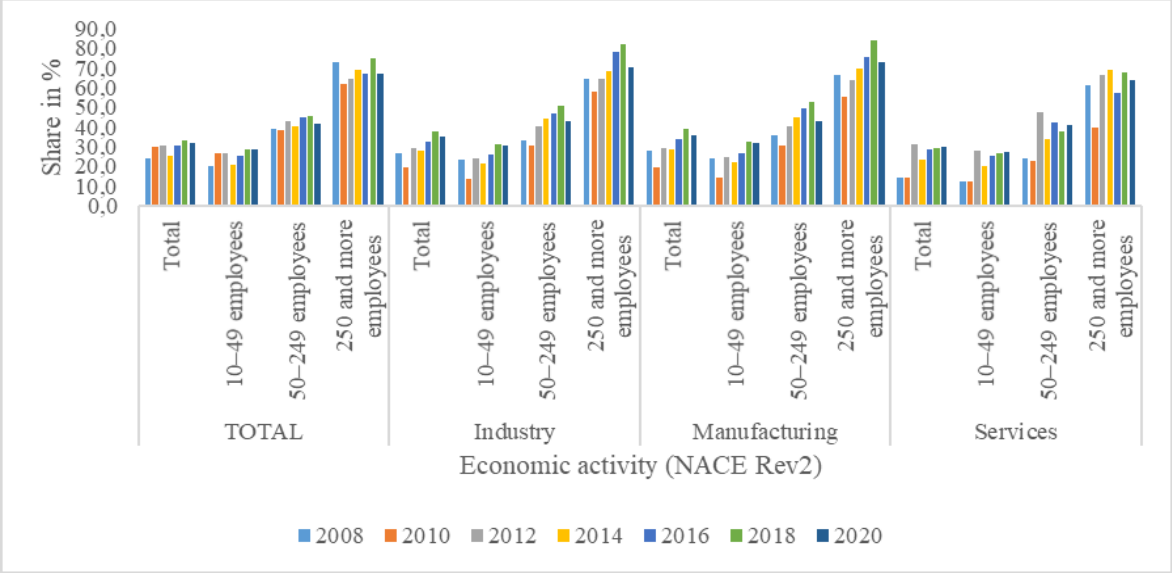

Figure 1. Density of innovation-active enterprises by economic activity (NACE Rev.2) by number of persons employed in 2008–2020 in Latvia.
Source: Author's construction based on Official Statistics portal database IUS010.

Data reflected in Figure 1 indicate that density of innovation-active enterprises are in enterprises with more than 250 employees and more innovation active enterprises are in industry and manufacturing, but less in services. This has been indicated by data on innovative-active enterprises in the last period 2019-2020 compared to two previous periods. Innovations introduction and support of their realization is created by entrepreneurs and theoretical analysis of scientific publications has confirmed that ministries and government agencies, research organisations and laboratories, private organisations, universities and other higher education institutions, fairs and exhibitions, professional literature, press and databases, professional conferences, meetings, industry/production professional standards, health and safety regulation standards, environmental regulation standards, other company in respective company group, own company, suppliers of equipment, programs and various materials have the influence. On those aspects for evaluation were invited entrepreneurs to make their evaluations in scale 1–10, where 1 – not important; 10 – very important. Results using descriptive statistics are included in Tables 1–3.

Judging by their evaluations, entrepreneurs have indicated that ministries and government agencies, research organisations and laboratories, private organisations, universities and other higher education institutions do not have important influence on their information in innovations – the evaluations on entrepreneurs have the lowest arithmetic mean and modes of those evaluations were 1 – it means that those sources are evaluated as not important for entrepreneurs for information on innovations. The differences in evaluations by entrepreneurs the biggest are for private organisations – there are the biggest indicators of variability (standard deviation and standard error of mean) and the highest evaluation used by entrepreneurs for evaluations was 8, half of entrepreneurs gave evaluation 3 or less and half of entrepreneurs gave evaluation 3 or more – characterised by median, arithmetic mean of the evaluations here was 3.6.

Table 1

Main statistical indicators on evaluations of entrepreneurs on sources of information on innovations/ innovative activities

Statistical indicators		Ministries or government agencies	Research organizations, laboratories	Private organizations	Universities, higher education institutions
N	Valid	30	31	30	30
	Missing	7	6	7	7
Arithmetic mean		3.67	3.65	3.60	3.40
Standard error of arithmetic mean		0.430	0.439	0.454	0.411
Median		3.5	3	3	3
Mode		1	1	1	1
Standard-deviation		2.354	2.443	2.486	2.253
Variance		5.540	5.970	6.179	5.076
Range		8	9	7	7
Minimum		1	1	1	1
Maximum		9	10	8	8

Source: Author's calculations based on Dace Stefenberga conducted survey results, Evaluation scale 1–10, where 1 – not important; 10 – very important.

Table 2

Main statistical indicators on evaluations of entrepreneurs on sources of information on innovations/ innovative activities

Statistical indicators		Fairs, exhibitions	Professional literature, press, databases	Professional conferences, meetings	Industry/ production technical standards	Health and safety regulations and standards	Environmental regulations and standards
N	Valid	30	29	30	30	30	30
	Missing	7	8	7	7	7	7
Arithmetic mean		4.50	5.79	4.93	4.77	4.27	4.00
Standard error of arithmetic mean		0.550	0.469	0.500	0.509	0.536	0.472
Median		4.5	7	5	5	3.5	4
Mode		1	7	1; 5	1; 6	1	1
Standard-deviation		3.014	2.527	2.741	2.788	2.935	2.586
Variance		9.086	6.384	7.513	7.771	8.616	6.690
Range		9	9	8	8	9	8
Minimum		1	1	1	1	1	1
Maximum		10	10	9	9	10	9

Source: Author's calculations based on Dace Stefenberga conducted survey results, Evaluation scale 1–10, where 1 – not important; 10 – very important.

Entrepreneurs have indicated that fairs and databases, professional conferences, meetings, exhibitions, professional literature, press and industry/production professional standards, health

and safety regulation standards, environmental regulations and standards have medium influence on their information in innovations – the evaluations on entrepreneurs have rather low arithmetic means and in several cases modes of those evaluations were 1 – it means that those sources are evaluated as not very important for fairs and exhibitions for information on innovations, half of entrepreneurs gave evaluation 4 or less and half of entrepreneurs gave evaluation 5 or more – characterised by median which in the evaluations for this aspect was 4.5. The differences in evaluations by entrepreneurs the biggest are for fairs and exhibitions – there are the biggest indicators of variability (standard deviation and standard error of mean) and all evaluation scale is covered by the entrepreneurs. Professional literature, press and databases were considered as more important by the entrepreneurs as arithmetic mean of the evaluations by entrepreneurs was 5.79 and most of the evaluations by entrepreneurs was 7 (characterised by mode), half of entrepreneurs gave evaluation 7 or less and half of entrepreneurs gave evaluation 7 or more – characterised by median.

Table 3

Main statistical indicators on evaluations of entrepreneurs on sources of information on innovations/ innovative activities

Statistical indicators		Another company in your company group (both in Latvia and abroad)	Your company	Suppliers of equipment, programs and various materials
N	Valid	31	31	30
	Missing	6	6	7
Arithmetic mean		6.13	6.77	6.23
Standard error of arithmetic mean		0.516	0.526	0.436
Median		7	8	7
Mode		8	9	8
Standard-deviation		2.872	2.929	2.388
Variance		8.249	8.581	5.702
Range		9	9	9
Minimum		1	1	1
Maximum		10	10	10

Source: Author's calculations based on Dace Stefenberga conducted survey results, Evaluation scale 1–10, where 1 – not important; 10 – very important.

Entrepreneurs have indicated that other company in respective company group, own company, suppliers of equipment, programs and various materials – the evaluations on entrepreneurs have rather high arithmetic means and modes of those evaluations were 8 and 9 – it means that those sources are evaluated as very important for information on innovations, half of entrepreneurs gave evaluation 8 or less and half of entrepreneurs gave evaluation 8 or more for other company in respective company group and for suppliers of equipment, programs and various materials – characterised by median, for own company median of the entrepreneurs evaluations was 8. The differences in evaluations by entrepreneurs the biggest are for own company – there are the biggest indicators of variability (standard deviation and standard error of mean) and all evaluation scale is covered by the entrepreneurs. Own company information for innovations were considered as more important by the entrepreneurs as arithmetic mean of the evaluations by entrepreneurs was 6.77 and most of the evaluations by entrepreneurs was 9 (characterised by mode), half of entrepreneurs gave evaluation 8 or less and half of entrepreneurs gave evaluation 8 or more – characterised by median. It means that entrepreneurs believe in their own companies and their views.

Conclusions

1. Density of innovation – active enterprises is growing in all fields in Latvia with a bigger share for enterprises with 250 and more employees and in industry and manufacturing but growing also for services.
2. Entrepreneurs have indicated that the most important sources of information on innovations are in their own company as well as for suppliers of equipment, programs and various materials.

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REGIONAL ANALYSIS OF PERFORMANCE INDICATORS OF LATVIAN BUSINESS INCUBATORS

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Abstract
A regional analysis of performance indicators for Latvian business incubators provides a valuable insight into the performance of the business incubator ecosystem in various regions and helps to make future policy decisions on providing funding for the incubators that aim to support the growth and success of startups.
The present research performed a regional analysis of operational programmes for two periods from 2007 to 2021. The strengths and weaknesses of Latvian business incubators across various regions of Latvia could be identified based on the analysis. This can help to make policy decisions and guide resource allocation to contribute to the development of the business incubator ecosystem in the future.
Key words: business incubators, regional economy.

Introduction

The needs for business development stated in national policy documents and the reasons for the emergence of business incubators since 2005 have been analysed as part of the research.

In July 2005, the European Council approved the Integrated Guidelines for Growth and Employment, which combined general economic policies and employment (Commission of the European Communities, 2005).

In accordance with the guidelines, the Ministry of Economics launched the implementation of the Innovation Centre and Business Incubator Development Programme in 2007. Its purpose was to promote the development of innovation infrastructure as well as support the creation and operation of innovation centres and business incubators and the provision of services by innovation centres and business incubators for startups in the regions of Latvia.

Business incubators as entities contributing to the development of the business environment were only at the initial stage in Latvia in 2007; however, already in the first years of the implementation of the programme, it was established that the business incubators also helped new businesspersons to start successful businesses in Latvia.

In 2007 in Latvia, 11 projects implemented by innovation centres and business incubators received support from the Ministry of Economics (Ministry of Economics of the Republic of Latvia, 2008).

Later, the business incubator programmes were transferred to the Investment and Development Agency of Latvia (hereinafter LIAA) for administration.

In Latvia, the support provided by the LIAA business incubators could be divided into two stages:

1. Public procurement 'Procurement of business incubation services in the regions of Latvia' under the operational programme Business and Innovation, activity 2.3.2.1 Business incubators. Activity 2.3.2.1 Business incubators, measure 2.3.2 Improving business infrastructure and equipment, priority 2.3 Increasing business activity and competitiveness under the 2007–2013 operational programme Business and Innovation. Activity 2.3.2.1 was implemented in two periods: period 1 that lasted from 2009 to the summer of 2014, while in 2014 a new call for tenders for the transitional period (period 2) was announced to procure business incubation services until 31 October 2015.
2. The program was continued with the implementation of the project Regional business incubators and the Creative Industries Incubator under the operational programme Growth and Employment administered by LIAA. Measure 3.1.1.6 was implemented in the 2014–2020 programming period as measure 3.1.1.6 Regional business incubators and the Creative Industries Incubator under specific support objective 3.1.1 Promoting the establishment and development of SMEs, especially in the manufacturing industry and RIS3 priority industries.

The research analysed performance indicators for Latvian regional business incubators administered by LIAA by employing multivariate statistical analysis.

Materials and Methods

The research used the results of business incubator programmes administered by LIAA, which were implemented in two periods: from 2009–2014 for main procurement for activity 2.3.2.1 Business incubators and from 2017–2021 for activity 3.1.1.6

Regional business incubators and the Creative Industries Incubator, and the targets achieved by the project participants were summarized as on 31/12/2021.

The research analysed the performance of regional business incubators during both LIAA-administered programmes. The research identified key factors in the performance of business incubators, the influence of the factors, as well as regional incubator clusters. IBM SPSS software was employed to analyse data on business incubators, which revealed the factors in their performance to be further used to assess their development.

The research employed cluster analysis to divide regional business incubators into groups, considering complex factors. Such an analysis of factors and clusters made it possible to analyse the performance of business incubators in the regions, identifying the most innovative, active and effective regional business incubators.

The data collected by LIAA were used for factor analysis.

Results and Discussion

The research data were divided into two parts representing each period of administration of business incubators because their origin and amount were different.

Under the first programme for business incubators, LIAA announced a call for tenders to procure services with the aim of transferring the operation of business incubators to private companies, associations or universities. In fact, under this programme, the business incubators represented mostly legal entities that provided business incubator services under the supervision of LIAA in all regions of Latvia. The research analysed the collected data on main procurement carried out by LIAA in the period 2009–2014.

In the second period, LIAA itself took over the administration of business incubators by hiring regional incubator managers and providing services as a state-owned institution. The targets achieved by the participants of the second period activity Regional business incubators and the Creative Industries Incubator have been summarized for the period 2017–2021.

The collected data on both programmes were different and could not be analysed as a whole; therefore, each period was analysed separately, and the results were summarized in the form of common conclusions.

Analysis of data on main procurement for activity 2.3.2.1 Business incubators for the period 2009–2014:

The research processed the data, calculated correlations between the variables and performed factor and cluster analyses.

Initially, the correlations between the variables were calculated, and it was concluded that there was a statistically significant correlation between the following variables for business incubators:

1. Office spaces rented to SMEs and the number of virtually incubated SMEs (0.968);
2. The number of incubated SMEs and growth of exports by the incubated SMEs, % (0.760);
3. The number of jobs created/maintained by the incubated SMEs and the average increase in their turnover, % (0.801);
4. The number of new products developed by SMEs and the number of SMEs that left the incubator (0.925);
5. The amount paid out and increase in the average SME turnover, % (0.953);
6. The total amount of the contract, EUR, and the number of SMEs that left the incubator (0.958);
7. Support used, % of the total, and increase in the average SME turnover, % (0.891);
8. Increase in the average SME turnover, %, and taxes paid correlate almost with all other variables, as they are some of the main results of incubator performance;
9. However, the growth of exports by the incubated SMEs, %, strongly correlated with the above-mentioned variables: increase in the average SME turnover, %, and taxes paid;
10. The number of SMEs that left the incubator strongly correlated with the number of new products developed by SMEs, increase in the average SME turnover, %, and the total amount of the contract, EUR.

For further data analysis, the data were tested for suitability for factor analysis. Based on the Kaiser-Meyer-Olkin (KMO) and Bartlett tests, the authors found that a KMO value for the sample was 0.5, and the sample was adequate for factor analysis. The Bartlett test significance value (Sig.=0.000) was less than 0.05, also indicating that the sample was suited for factor analysis.

To identify complex factors, the research employed the principal component method and the Kaiser criterion for determining the number of factors. As a result, three complex factors were identified, which explained 71.7% of the total variance. To equalize the load on the complex factors, factor rotation was performed by applying the Varrimax method, and the results are shown in Table 1.

Table 1

Rotated Component Matrix[a]

	Component		
	1	2	3
Office spaces rented to SMEs, m^2	-0.127	**0.789**	-0.519
Number of incubated SMEs	**0.728**	0.487	-0.359
Number of virtually incubated SMEs	**0.821**	-0.052	-0.229
Number of jobs created/ maintained by incubated SMEs	**0.624**	0.578	0.235
Number of new products developed by SMEs	-0.058	**-0.783**	-0.142
Increase in the average SME turnover, %	-0.027	-0.113	**0.519**
Growth of exports by incubated SMEs, %	-0.2	0.318	**0.701**
Number of SMEs that left the incubator	**-0.771**	0.338	-0.312
Amount paid out	**-0.863**	-0.125	0.161

The factor analysis allowed the authors to identify the following factors:

1. The first factor was explicitly **economic** and had the following main components: the number of incubated SMEs, the number of virtually incubated SMEs, the number of jobs created/maintained by incubated SMEs, the number of SMEs that left the incubator and amount paid out.
2. The second factor was **innovation** – the number of new products developed by SMEs that was associated with a practical component – office spaces rented to SMEs, m2.
3. The third factor was **financial**, which showed financial performance: increase in the average SME turnover, %, and growth of exports by incubated SMEs, %.

In view of quite strong correlations between the variables for business incubators, it could be concluded that all the three factors were also very steady and logical. The economic factor represented the key variables that showed the growth of enterprises in relation to the innovation factor – the number of new products – and the financial factor – increase in turnover and exports.

A cluster analysis was performed based on the results of the factor analysis. The research identified the desired number of clusters by using the Elbow rule, and it was 4. After that, the k-means method was used to group business incubators into four clusters. An analysis of variance (ANOVA) showed the statistical significance of all the complex factors for cluster analysis (Sign. = 0.000< 0.05). An overview of the cluster analysis is given in Table 2.

Table 2

Final Cluster Centres

	Cluster			
	1	2	3	4
Economic	1.40	-1.23	-0.34	0.23
Innovation	0.81	0.52	0.44	-1.33
Financial	-0.52	-0.94	1.14	-0.17

1. Cluster 1: VBII Ltd incubator (Valmiera, Gulbene), (Vidzeme region 1), foundation Ventspils High-tech Park (Ventspils, Talsi), (Kurzeme region 1).
2. Cluster 2: Kurzeme Business Incubator Ltd (Liepaja, Saldus, Kuldiga), (Kurzeme Region 2), general partnership JIC Business Incubator (Jelgava, Dobele), (Zemgale Region 1), general partnership JIC Business Incubator (Jekabpils, Aizkraukle), (Zemgale region 2).
3. Cluster 3: general partnership Riga Region Business Development Incubator (Ogre, Tukums, Limbazi), (Riga region), HUB Riga Ltd (Riga), (Creative Industries Incubator), society Business Incubator Cesis (Cesis, Aluksne, Madona), (Vidzeme region 2).
4. Cluster 4: association Latgale Apparatus Construction Technological Centre (Daugavpils, Livani, Preili), (Latgale region 1), association Latgale Apparatus Construction Technological Centre (Rezekne, Balvi), (Latgale region 2).

The cluster analysis performed revealed how all the ten incubators were distributed by region:

1. Cluster 1: Vidzeme region (Valmiera, Gulbene) and Kurzeme region (Ventspils, Talsi).
2. Cluster 2: Kurzeme region (Liepaja, Saldus, Kuldiga) and Zemgale region (Jelgava, Dobele, Jekabpils, Aizkraukle).
3. Cluster 3: Riga city and Riga region (Riga, Ogre, Tukums, Limbazi) and Vidzeme region (Cesis, Aluksne, Madona).
4. Cluster 4: Latgale region (Daugavpils, Livani, Preili, Rezekne, Balvi).

Cluster 1 was characterized by the positive coordinates of centres of two factors, i.e. the economic and innovation factors, which were strongly positive, which meant that the business incubators of Vidzeme (Valmiera, Gulbene) and Kurzeme regions

(Ventspils, Talsi) were strong in achieving their main or economic performance targets and also the most innovative in creating new products. For Clusters 2 and 3, Kurzeme region (Liepaja, Saldus, Kuldiga) and Zemgale region (Jelgava, Dobele, Jekabpils, Aizkraukle), as well as Riga city and Riga region (Riga, Ogre, Tukums, Limbazi) and Vidzeme region (Cesis, Aluksne, Madona) were positively characterised by the innovation factor, which also indicated the positive trend of creating new products. Cluster 3, i.e. the cluster including Riga city and Riga region, was characterised by a pronounced financial factor, which could be explained by the capital's greater opportunities in fostering turnover and the related export growth. In contrast, Cluster 4 including Latgale region (Daugavpils, Livani, Preili, Rezekne, Balvi) performed well in the provision of basic services, i.e. performed the necessary functions of a business incubator, yet the creation and exports of new products were not so pronounced.

Analysis of data on activity 3.1.1.6 Regional business incubators and Creative Industries Incubator for the period 2017–2021:

The results of the data processing, correlation analysis and factor and cluster analysis for the second period of operation of business incubators are summarized below. In the period 2017–2021, the analysis involved two fewer indicators, while the incubators were analysed by region and there were 13 regional incubators, compared with 10 in the previous period.

After performing the correlation analysis, it was concluded that a statistically significant correlation existed between:

1. Turnover and the balance sheet total (0.908).
2. Turnover and exports (0.930).
3. Turnover and profit (0.768).
4. Turnover and taxes paid (0.982).

For further data analysis, the data were tested for suitability for factor analysis. Based on the Kaiser-Meyer-Olkin (KMO) and Bartlett tests, the authors found that a KMO value for the sample was 0.73, and the sample was adequate for factor analysis. The Bartlett test significance value (Sig.=0.000) was less than 0.05, also indicating that the sample was suited for factor analysis.

To identify complex factors, the research employed the principal component method and the Kaiser criterion for determining the number of factors. As a result, two complex factors were identified, which explained 83.7% of the total variance. To equalize the load on the complex factors, factor rotation was performed by applying the Varrimax method, and the results are shown in Table 3.

Table 3

Rotated Component Matrix[a]

	Component	
	1	2
Turnover, EUR	**0.983**	-0.003
Balance sheet total, EUR	**0.916**	0.334
Number of employees/ average number of employees	0.350	**0.711**
Exports as a share of turnover, EUR	**0.954**	0.138
Profit, EUR	**0.850**	0.135
Taxes paid, EUR	**0.964**	-0.085
Number of enterprises	0.129	**-0.832**

The factor analysis allowed the authors to identify the following factors:

1. The first factor was explicitly **economic and financial** and had the following main components: turnover, a balance sheet total, exports as a share of turnover, profit and taxes paid.
2. The second factor was **structural** and included the average number of employees and the number of enterprises.

A cluster analysis was performed based on the results of the factor analysis. The research identified the number of clusters in the similar way by using the Elbow rule, and it was 4. An analysis of variance (ANOVA) showed the statistical significance of all the factors for cluster analysis (Sign. = 0.000< 0.05). An overview of the cluster analysis is given in Table 4.

Table 4

Final Cluster Centres

	Cluster			
	1	2	3	4
Economic and financial	1.68	-0.33	-1.53	1.11
Structural	-0.31	-0.38	1.62	2.41

Based on the results of the cluster analysis, the incubators were divided into four clusters:

1. Cluster 1: the incubators of Daugavpils and Ogre.
2. Cluster 2: the incubators of Jelgava, Jurmala, Kuldiga, Liepaja, Madona, Rezekne, Valmiera and Ventspils as well as the Creative Industries

Incubator.
3. Cluster 3: the incubator of Jekabpils.
4. Cluster 4: the incubator of Sigulda.

Although the economic and financial factor was common in this case, the analysis found that it was strongly positive for Clusters 1 and 4, i.e. the Daugavpils, Ogre and Sigulda Business Incubators. In contrast, the structural factor was very strong for the Jekabpils and Sigulda Business Incubators, which had a significant number of enterprises to be incubated, which resulted in a significant number of employees working for the enterprises.

The overall interpretation of the data and the conclusions are given in the conclusions.

Conclusions

1. After summarizing the data on both programmes, it could be concluded that the first business incubator programme, which was characterized by services provided mostly by enterprises to three cluster incubators, had a positive innovation factor, i.e. the creation of new products, which related to office spaces rented. The positive value of this factor could be viewed as the success of the incubator programme, as it involved the creation of new products, which was the initial business goal, followed by the development or failure of the product.

In the period from 2009 to 2013, almost 500 enterprises received support, and the highest activity (in granting support) was reported in 2010. Five years after the public support had been granted, only 17% of the initial number of enterprises continued their economic activity. Overall, it could be concluded that almost a fifth (17%) of all the supported enterprises were financially steady after five years of development and did their active economic activity, thereby ensuring an increasing turnover and an increase in the number of employees, yet the rest had not been able to compete and stopped operating (Initial Assessment by the Ministry of Economics).

In the opinion of the authors, such a number of enterprises that had been able to grow in a business incubator and continued developing was sufficient to consider the business incubator programme as successful.

2. The second business incubator programme was characterized by an interesting distribution of incubators into clusters, as Cluster 1 with Daugavpils and Ogre had a distinctly positive economic and financial factor. The successful performance of Daugavpils was surprising because in the previous business incubator programme, the Latgale (4) cluster had rather low factor values. Such a situation could be explained by the fact that in the second business incubator programme, the incubators were under the supervision of LIAA and were administered jointly; therefore, the second cluster also included the incubators from nine cities that performed similarly, while successful performance was achieved by the incubators with more active managers who were able to demonstrate a more positive factor performance. The analysis allows us to conclude that the most successful business incubators have been in Daugavpils, Ogre and Sigulda.
3. Research by other authors has identified a correlation between incubator services and programme outcomes. The reasons for the success of enterprises related to the practices of business incubator programmes. In addition, decision makers who make public investments in business incubators need to be aware of the regional economic environment and design policies that best support the incubation capacity of the region (Harper-Anderson & Lewis, 2018).
4. It is the physical presence of a would-be businessperson in a business incubator that helps the incubator with marketing and sales through using the experience and existing contacts, as well as disciplines the businessperson and creates his/her professional image, which is not so pronounced in other settings (Flavel *et al*., 2008).
5. Overall, business incubators should be promoted as opportunities for supporting new businesspersons. Business incubators tend to motivate individuals to start a business. The motivation affects the performance of new businesspersons as proved by motivation theory because the businesspersons can access both financial and non-financial services (Matotola, 2016).
6. Just like other research studies, the present research also has found that both incubator programmes have been generally successful in Latvia, and they provided the necessary support for regional economic activity, which consequently helped to develop the country's export capacity and increased the amount of taxes paid and reduced unemployment. In the opinion of the authors, the funding programme for business incubators should be continued, involving businesspersons and universities in it.

Research studies by other authors have found that university incubators also contribute to economic development in a similar way. University-incubated enterprises achieve higher employment and sales than non-incubated ones (Lasrado *et al*., 2015).

7. Overall, with the support of regional business incubators, the performance of would-be

businesspersons helps to reduce unemployment, raise the standard of living of the businesspersons and society, as well as contributes to the whole regional economy.

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ANALYSIS OF INAPPROPRIATELY PERFORMED EXPENSES OF THE REVITALIZATION PROJECTS OF DEGRADED AREAS

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Abstract
One of the most pressing problems of sustainable spatial development in Latvia is the existence of degraded areas. To address the issues of revitalization of degraded territories and to ensure sustainable development of the territory, Latvian municipalities could apply for support under the Specific Support Objective 5.6.2 (SSO 5.6.2) 'Revitalization of territories through regeneration of degraded territories in accordance with integrated development program of municipalities' during the European Union (EU) Structural Funds programming period 2014–2020. According to the Ministry of Finance (MF) data on project costs, it was found that during the implementation of the projects for revitalization of degraded territories, the local governments have not ensured an effective project management process in accordance with the implementation requirements of SSO 5.6.2, resulting in irregularities detected in the audits carried out on the projects, which have led to the decision on inappropriately performed expenses (IPE). Considering that the deadline for the implementation of projects under the 2014–2020 EU funds programming period is 31.12.2023, it is necessary to carry out an analysis of IPE to identify the reasons for the occurrence of IPE and to plan timely preventive actions to eliminate mistakes in the new programming period 2021–2027. The relevance and importance of the study lies in the analysis of the factors holding projects back - mistakes and irregularities and their prevention to ensure an efficient project management process.
Key words: municipality, revitalization projects, degraded area, requirements, inappropriately performed expenses, EU fund.

Introduction

The main objective of the SSO 5.6.2 project program is to prevent the existence of former industrial sites and other degraded areas, to promote employment and economic activity in municipalities, in accordance with the municipality's development program. The implementation of projects under SSO 5.6.2 is carried out in 4 project selection rounds and municipalities of national development centers – Daugavpils, Jelgava, Jekabpils, Jurmala, Liepaja, Rezekne, Riga, Valmiera and Ventspils – and municipalities of regional development centers are eligible for support. Within the framework of the projects, the municipality must involve as a cooperation partner, a business operator investing in the infrastructure owned by the applicant, which will be used for the benefit of the business operator (Stepina & Pelse, 2022).

According to the information report 'On the state of play of EU funds and foreign financial assistance under the responsibility of the Ministry of Finance until 1 September 2022 (semi-annual report)', the total investment allocation for the programming period 2014–2020 in the field of 'Information and Communication Technologies, Environment and Regional Development and Competitiveness of Merchants' is 744 million euro, of which the total amount disbursed in the field of environment and regional development is 35 million euro (Ministry of Finance, 2022).

According to the theory by Dubrin, an effective management process is planning, organizing, controlling, and directing the implementation of activities to achieve the organization's goals (Dubrin, 2021). Considering the fact that the project as a set of activities aimed at achieving the goal and is limited in resources, which in the context of municipal operations are public funds, the implementers of municipal projects must effectively manage the use of financial resources (Mothupi, 2018). In the context of this study, the authors consider the effective use of funds to be the management of financial resources that ensures compliance with project requirements, avoiding mistakes that may result in IPE. The project implementation process in the context of the EU Funds is strictly regulated by the requirements of EU and Republic of Latvia (RL) legislation and the guidelines developed by the MF as the managing authority for monitoring the implementation of the EU Funds, non-compliance with which may dangers not only the achievement of the project objective, but also make the project implementation more difficult from the financial point of view, which may result in the identification of irregularities in the project. According to the Ministry of Finance Guidelines No 2.7 'Guidelines on the application of financial corrections, reporting of irregularities detected in the implementation of

EU funds, recovery of irregular expenditure in the 2014–2020. programming period', an irregularity is a breach of EU or national legislation in relation to its application, resulting in IPE (Ministry of Finance, 2022). In addition, the Guidelines define IPE as expenditure at the level of an individual project which, in accordance with the requirements set for the project, cannot be recognized as legal and regular expenditure and is recoverable from the EU budget. As mentioned in the mid-year report, from the beginning of the 2014–2020 programming period until 30 June 2022, a total of 64 million euro of IPE have been detected in EU Fund projects, which creates significant difficulties not only at project level but also additional burden for the municipality budget.

The inability to successfully implement projects in the municipality is the result of ineffective project management – non-compliance with administration requirements and inconsistent implementation of project management principles cause projects to fail to meet intended goals. Consequently, local governments must implement strict internal control functions to ensure that they effectively and economically implement their priorities. Analyzing errors in project implementation, municipalities can develop and implement appropriate policies and support mechanisms that ensure successful compliance with project requirements, thereby ensuring inefficient use of public funds (Makwetu, 2017).

The European Commission (EC) has set the maximum allowable level of error in project implementation, which is 2%. Consequently, the project implementers have been provided with a project management process developed by the EC and the RL that complies with the requirements of regulatory acts (Ministry of Finance, 2022). To provide recommendations to municipalities for successful implementation of degraded areas revitalization projects in the new programming period – 2021–2027, it is necessary to study the mistakes of the previous programming period in terms of project requirements, to analyze the main causes of project IPE, thus ensuring legal absorption of EU funds. Therefore, the author of the article has set the aim of the study – to analyze the inappropriate expenditure incurred by municipalities in the revitalization of degraded areas and to develop recommendations for municipalities to eliminate the non-compliance.

Materials and Methods

The following research methods were used in the study: 1. Analysis of theoretical literature sources. This method was chosen because it provides an opportunity to analyze the theoretical aspects of project management – the project life cycle model, the role of planning in project management and the indicators of project requirements – using scientific literature sources. The analysis of theoretical literature sources is based on scientific publications, conference papers, project management books. 2. The authors used statistical data analysis method – cluster analysis to identify similar and dissimilar municipalities as project implementers, and by combining them according to certain characteristics into one cluster, to analyze their unifying regularities and to interpret the results. The interpretation of the results deepens the understanding of the likely aspects of municipal performance that influence project implementation. The statistical data used were the indicators of irregular expenditure for SSO 5.6.2 projects collected by the MF, as well as publicly available statistical information on the overall absorption of ERDF funding in the cluster of municipalities (Ministry of Finance, 2022). The study analyzed all Latvian municipalities implementing degraded area revitalization projects under SSO 5.6.2. 3. The variables selected for this method are the IPE of degraded area revitalization projects and the reasons for their occurrence. Document analysis, within the framework of which, taking into account the object of the study – inappropriate expenditures of degraded areas revitalization projects, as well as in accordance with the aim of this study, the regulatory enactments regulating SSO 5.6.2 – Cabinet of Ministers Regulation No 645 of 10 November 2015 'Operational Program 'Growth and Employment' Special Support Objective 5.6.2 'Revitalization of the territory through regeneration of degraded areas according to local government' – were analyzed. Integrated Development Programme' (Cabinet Regulation No.645) and Guidelines No.2.1 'Guidelines for determining eligible and ineligible costs in the 2014–2020 programming period', Guidelines No.2.7 'Guidelines for applying financial corrections, reporting irregularities detected in the implementation of European Union funds, recovery of expenditure unduly incurred in the 2014–2020 programming period' developed by the Ministry of Finance, 03.07.2014. Law on the Management of the European Union Structural Funds and Cohesion Fund for the 2014–2020 programming period (EU Funds Management Law). The analysis of the documents was used with the aim to investigate the main requirements to be met by local authorities when

implementing projects under the SSO 5.6.2 program, as well as the potential risks of non-compliance.

Results and Discussion

The European Commission defines the term 'project' in the context of EU funds as a set of actions aimed at achieving a clearly defined objective within a given timeframe and budget (European Commission, 2004). SSO 5.6.2. project applicants – municipalities, when applying for EU funds support in project implementation, develop and prepare a project application that complies with the regulatory framework. A project application prepared in accordance with the regulatory framework and the project's objective is an integral part of a successful project, and weaknesses in its preparation are one of the main reasons why projects fail (Stepina & Pelse, 2021).

Project management is implemented according to the project life cycle model, which is a purposeful logical and sequential ordering of project phases and activities that ensures optimal project management and continuity (Takwi, 2014). Different literature sources interpret the project life cycle differently, considering the uniqueness and specificity of the project content, but in general the life cycle phases range from 4–6 phases and are similar in key aspects: initiation, planning, implementation, and closure. The Project Management Institute (PMI) proposes a five-phase project life cycle model - initiation, planning, implementation, control, closure (Project Management Institute, 2021). The above project life cycle models are defined in project management theory at project level, which municipalities should consider in their project management. The European Commission (EC) has defined a conceptual model of project implementation to be considered at national level, considering aspects of national development planning. The EC defines a model for project implementation consisting of six stages: program design (national development planning documents), tendering (preparation of project application), decision-making (contracting), implementation (preparation of progress reports), evaluation (evaluation report), audit (European Commission, 2004). As project promoters, it is the responsibility of the municipalities to be aware of and follow the project implementation process developed by the EC and to study the requirements set out in the documents to be prepared, considering that the final phase of implementation of projects co-financed by EU funds is subject to project audits by the supervising authorities. The purpose of the audit is to provide assurance on the compliance of expenditure with the binding regulatory enactments (Ministry of Finance, 2022). According to the project life cycle model, which defines the phase of the project life cycle in which certain activities are to be carried out, it can be concluded that the development of a project application is the outcome of the project planning phase, which includes the main project requirements (Friberg *et al*., 2016). Effective planning is not just about developing a detailed project application, it is about exploring the success criteria and identifying the potential risks of the project (Baker *et al*., 2008). During the project planning phase, defining the project requirements is one of the key tasks to prepare the project for its execution. Requirements definition and management in a project is the term used to describe the process of defining, documenting, analyzing, prioritizing, and agreeing, controlling, and managing change and risk (Oberg *et al*., 2000). The failure to define and manage project requirements, or the lack of quality of requirements, is one of the main causes of project failure. However, not all organizations successfully manage project requirements and follow up on requirements, addressing potential risks in a timely manner, resulting in errors that lead to project failures (Yang *et al*., 2010). According to a study by Coventry T., published at the Project Management Institute (PMI) conference on 11.05.2015, the project requirements management process can be divided into the following stages: 1. Requirements definition – requirements are identified and grouped into areas based on the requirements and needs of the project stakeholders. 2. Capturing requirements and incorporating them into project plans; 3. Delegation of responsibility for the implementation of the requirements and definition of areas of responsibility. 4. monitoring and follow-up of requirements.

In addition, Conventry T. argues that project requirements can be identified under the plans of each project scope or can be developed as a separate project requirements plan (Conventry, 2015).

Burek P. divides project requirements into two categories: activity requirements, which define what is to be accomplished or help to define the goal to be achieved by the project and describe the possible changes that will occur as the project is implemented, and technology requirements, which define how the activities defined in the project are delivered (Burek, 2008). It can be concluded that compliance with the requirements is a key success factor of the project,

ensuring the successful achievement of the project objective. As the project is limited in both time and resources, the most important success factors of the project are – delivering the project on time and within the project budget, which is an indication of quality assurance (Lester, 2014).

To meet the requirements of the project activities, the project application should define the main project activities and identify the resources needed to carry them out. The implementation of the activities can be achieved by meeting the requirements of the project-specific activities – construction requirements, procurement requirements, requirements for the acquisition of fixed assets and services, requirements for the conditionality of State aid, project management requirements (Tuunanen *et al*., 2007). The management of EU funds is divided between the European Commission and the Member States, so the rules and conditions, from a fund management perspective, are partly based on EU law and partly on national law (European Commission, 2014). The implementation of EU Fund projects is possible provided that all requirements are met to receive the public funding for which the municipality commits itself under the EU Funds Implementation Agreement. The agreement is concluded between the municipality as the beneficiary and the EU Funds cooperation body, the Central Financial and Contracts Agency. The agreement is drawn up in accordance with Cabinet Regulation No 645 and the EU Funds Management Law and includes the main types of requirements – 1. The eligible costs of the project, including ERDF funding, local authority funding, the amount of the state budget grant and other sources of funding. 2. Project implementation period. 3. The general obligations and rights of the beneficiary and the cooperation authority. 4. Conditions for commercial support. 5. The terms and conditions of cooperation between the beneficiary and its cooperation partner. 6. Procedures for on-site inspections. 7. Procurement procedures. 8. Procedures for the submission and processing of payment claims. 9. Procedures for reducing the amount of eligible expenditure. It follows that the implementation of EU Fund projects is strictly regulated by requirements and their limitations, as defined by project management theory, have an impact on project finances and timing. In cases where the beneficiary of a project does not comply with the requirements set out in the agreement on the receipt of EU funds, irregular expenditure is detected, resulting in financial losses at project level, as well as an additional burden on the municipality's budget as the expenditure incurred is not recovered and the project may be at risk of non-implementation. Therefore, the challenge for project promoters – local authorities – is to be able to identify the project requirements, gather their underlying conditions and ensure compliance with them to ensure an efficient decision-making process.

The Ministry of Environmental Protection and Regional Development, as the responsible authority for SSO 5.62, has prepared the SSO 5.6.2 project performance assessment on 29.09.2022, which indicates that in the projects for revitalization of degraded areas significant delays have been identified both in the project implementation deadlines due to delays in the execution of construction works and in the project cooperation partners - business operators unable to ensure non-financial investments in their own intangible investments and fixed assets, which creates high risks for the achievement of indicators. In addition, the report indicates that overall, during the reporting period, a total of 64 million euro of public funding, or 1.45% of the project payment claims, was identified as EU Structural Funds IPE, of which 29 million euro were recovered.

To analyze how Latvian municipalities ensured legal project management in the 2014–2020 programming period under SSO 5.6.2, the authors carried out an analysis of the statistical data prepared by the MF - eligible expenditure of implemented projects (until 05.02.2023) by cities/ regions (euro). Initially, the overall absorption of financial indicators was analyzed to assess the level of investment in the rehabilitation of degraded areas. The analysis was carried out using the cluster analysis method, which aims to group sites into subsets or clusters based on a comparison of certain characteristics, to analyze their common patterns and to interpret the results. The interpretation of the results obtained deepens the understanding of the possible aspects of municipal performance that influence the implementation of projects. The object of the study is the municipality, and the descriptive parameters are the project financing by cost item – Europe Regional Development Fund (ERDF) budget, state budget grant to municipalities, municipal funding, other public funding, private investment. The analysis was carried out in the following steps:

1. Data selection and statistical significance. The data were selected based on information provided by the MF as the managing authority for the EU Structural Funds, respecting the principle of limited

availability and the data protection framework. To determine the statistical significance of the data used, the authors performed an analysis of variance (ANOVA). In Table 1, the significance indicator shows that all factors used for the cluster analysis are statistically significant, i.e., Sig.<0.05).

Table 1

ANOVA test result for statistical significance

Cost type	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
ERAF (ReactEU) funding, EUR	167 521 288 842 652.00	3.00	1 128 803 794 416.80	28	148.406	0.000
State budget grants to municipalities, EUR	606 586 341 221.70	3.00	81 055 546 280.67	28	7.484	0.001
Municipality budget, EUR	4 244 437 463 175.20	3.00	1 010 766 108 838.16	28	4.199	0.014
Other public funding, EUR	2 888 964 518.56	3.00	1 380 363 515.15	28	2.093	0.124
Private eligible costs, EUR	2 738 211 362 561.41	3.00	388 278 863 090.70	28	7.052	0.001

** The F tests should be used only for descriptive purposes because the clusters have been chosen to maximize the differences among cases in different clusters. The observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal.*

2. Determining the number of clusters and the standard deviation of each cluster. The number of clusters was determined using the hierarchical clustering method and the Elbow rule and was 4. The municipalities were clustered using the k – means method, where the total number of municipalities is 32. The division of municipalities into clusters is shown in Table 2. The distance indicates the relative 'distance' of the municipality from the cluster center, the smaller the distance the more typical the municipality is for this cluster.

Table 2

Number of clusters of municipalities and standard deviation of clusters

Case Number	Municipality	Cluster	Distance
1	Aizkraukle district	1	1 116 183.84
2	Aluksne district	3	761 664.20
3	Augsdaugava district	1	1 775 338.09
4	Balvi district	3	1 738 899.74
5	Bauska district	1	662 951.36
6	Cesis district	1	1 016 458.87
7	Daugavpils	4	2 523 852.01
8	Dobele district	1	1 164 724.80
9	Gulbene district	3	1 476 213.36
10	Jelgava	3	1 122 506.60
11	Jekabpils district	2	2 117 318.42
12	Jurmala	2	625 926.92
13	Kraslava district	3	1 082 379.05
14	Kuldiga district	3	782 757.17

15	Liepaja	2	2 061 324.01
16	Limbazi district	1	196 554.49
17	Livani district	1	1 690 051.46
18	Ludza district	3	1 483 558.08
19	Madona district	1	722 938.15
20	Ogre district	1	719 876.78
21	Preili district	3	822 755.20
22	Rezekne	4	2 523 852.01
23	Rezekne district	3	1 592 774.44
24	Riga	3	2 934 182.79
25	Saldus district	1	2 787 572.32
26	Sigulda district	1	843 196.36
27	Smiltene district	1	1 320 404.06
28	Talsi district	1	971 506.43
29	Tukums ditrict	1	732 768.23
30	Valka district	1	1 943 412.59
31	Valmiera district	3	842 428.99
32	Ventspils	3	1 008 841.87

3. Interpretation of the results. As a result of the cluster identification, 4 clusters were identified, where the distribution of the studied municipalities by cluster is as follows. In the next step, the characteristics identified above were summarized and grouped by cluster to identify their common and distinctive features (Table 3).

Table 3

Final cluster centers by cost types, EUR

Cost type	Cluster			
	1	2	3	4
ERAF (ReactEU) funding, EUR	4 433 750.2	11 689 378.8	7 938 473.6	19 888 187.2
State budget grants to municipalities, EUR	344 005.6	774 184.5	555 498.8	1 277 073.4
Municipality budget, EUR	1 235 724.6	2 773 737.0	1 771 334.8	3 430 686.9
Other public funding, EUR	0.0	0.0	33 065.3	33 817.5
Private eligible costs, EUR	357 676.59	1 550 145.17	354 952.86	2 002 038.14

According to Table 3, the fourth cluster, which is the smallest in terms of the number of sites, has the highest financial indicators in all cost groups, which shows that these municipalities – Rezekne and Daugavpils – have invested the most in the revitalization of their degraded areas. However, data for the first cluster show that the municipalities belonging to this cluster have invested the least in the revitalization of their degraded areas, which can be explained by the fact that the first cluster represents regional centers of regional importance, does not include any of the cities of national importance, whose

financial capacity is different, and the priorities set for the development of the territory differ from the small municipalities. One of the conclusions of the authors is that these municipalities have the smallest number of degraded territories and relatively low chances for projects to attract entrepreneurs who would undertake to develop their business on the site of the degraded territory, ensuring the indicators to be achieved by the project – creation of new jobs. In terms of the indicators studied, except for 'other public funding' and 'private funding', the second and third clusters are the most similar although the number of sites in the cluster is very different - the second cluster has 3 municipalities, while the third has 12 municipalities. The second cluster is represented by two national cities – Liepaja and Jurmala, as well as the Jekabpils region, which leads to the conclusion that the development prospects of the national cities and the financial resources required for its provision are significantly higher than those of the municipalities represented by the third cluster. In addition, the authors suggest that most entrepreneurs are concentrated in the cities of national importance, which have the potential to invest as project partners to create new enterprises in degraded areas.

To gain confidence in the total eligible expenditure and the financial size of the IPE under SSO 5.6.2, the authors used statistical data provided by the MF and summarized the results in a graph (Figure 1). The figure shows the eligible expenditure for SSO 5.6.2 projects by cost item – ERDF funding, state budget grant to local authorities, local authority funding, other public funding, private contributions and IPE identified because of mistakes by local authorities.

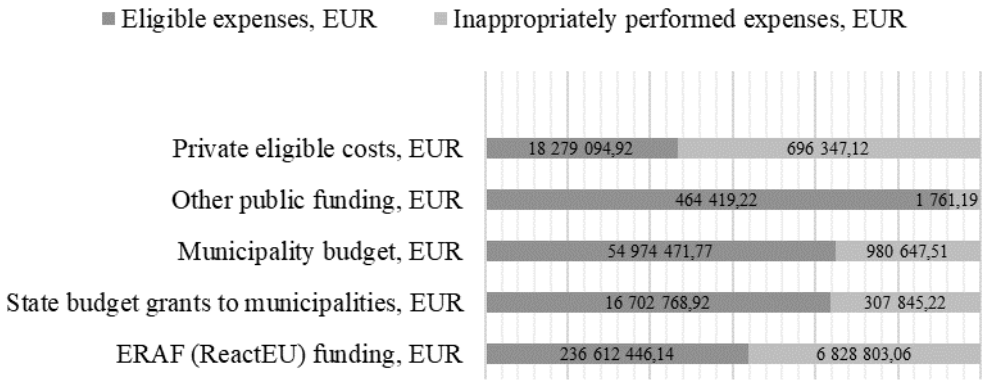

Figure 1. Eligible and inappropriate expenses, EUR (period 2016–2022).

Overall, the total amount of NSIs in euro in relation to eligible expenditure ranges from 0.5%–3.8%. The highest NCI rate was found in the ERDF funding section – 3.8% of project eligible expenditure, which is explained by the fact that the implementation of projects respects the ERDF aid intensity of 85% of total eligible costs, i.e., ERDF funding accounts for most project funding. According to the European Commission's tolerable error rate for projects of 2%, the implementation of SSO 5.6.2 projects exceeds the tolerable limit, indicating the need to investigate the reasons for the occurrence of IPE so that an error analysis can be carried out in the next programming period. The statistical data provided by the MF showing both the reasons for non-compliance and the number of non-compliances detected by type of projects audited is presented in Figure 2.

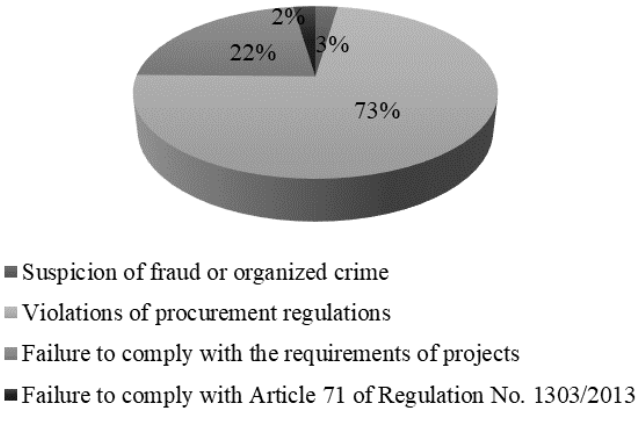

Figure 2. Types of non-conformances in project implementation.

According to the information presented in Figure 2, it can be concluded that the highest number of IPE was found in the non-compliance with the project procurement norms, which amounted to 62 violations or 73% of the total number of violations found – 85. The above shows that the procurement process and its management provided by local governments is ineffective and needs improvement. In addition, audit findings concerning non-compliance with project implementation requirements – 22% or 19 breaches out of the total number of breaches – also require attention. In general, according to the information provided by the MF, these mistakes concern non-compliance with the conditions of the project implementation agreement, non-compliance with the requirements of the Cabinet Regulations on SSO 5.6.2, as well as breaches of the procurement contract which are not classified as a breach of procurement rules. A relatively small percentage of the total IPE – 2% – is accounted for by audit findings in cases of suspected fraud or organized crime. Although this percentage does not indicate serious risks, it is nevertheless significant as the EC has firmly established that EU public funds are in no case or form linked to fraud and crime and in such cases the implementation of the project is suspended.

Conclusions

1. The implementation of EU Fund projects is strictly regulated by the requirements of national and EU legislation, and non-compliance risks the repayment of funds paid to the EU budget and the termination of project implementation. Compliance with requirements and the adoption of legally compliant decisions is an indicator of the effectiveness of EU Funds project management.
2. The projects implemented by municipalities in the revitalization of degraded areas have been implemented using the level of EU Fund support that addresses the specific territorial development issues of each municipality, based on the individual development priorities of the municipality, assessing the financial capacity of the budget and the number of degraded areas in the municipality.
3. The project implementation process is assured with an error rate of 3% in the ERDF funding section, which is higher than the tolerable error rate of 2% set by the MoF. This situation may lead to the possibility of an increase in the number of audits to be carried out both by the Latvian Audit Authority and the EC.
4. The main causes of IPE concern the area of non-compliance with procurement rules and non-compliance with project requirements, which reflects insufficient knowledge, lack of risk management and ineffective decision-making.
5. Weaknesses in knowledge of legislation and regulations in the project management decision-making process.

Recommendations:

1. Ensure an effective project management process in the implementation of projects, with senior professionals with the appropriate level of knowledge and expertise to ensure that all project requirements are met.
2. Use the advisory support of the EU Funds' cooperation body, the Central Financial and Contracts Agency before starting the procurement process or making changes to the project, thus ensuring a common understanding of the interpretation of legal requirements.
3. Prior to the preparation of the project application, draw up detailed requirements plans to ensure that the entire project team is aware of the most up-to-date and relevant requirements for the project.
4. At the end of the 2014–2020 programming period, carry out an evaluation of the projects implemented and analyze the mistakes made to avoid potential risks in the new programming period.
5. Ensure effective control of the tasks to be carried out in the project management process to be able to identify in good time the areas of project implementation exposed to risks.

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CHANGE IN THE AREA OF LITHUANIAN TREES AND SHRUBS GREENERY IN 2002–2022

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Abstract
The topic of this article is relevant because in Lithuania the assessment of the area occupied by plantations and green spaces has shown that the area standards do not meet the requirements and recommendations of the World Health Organisation. Green spaces are regulated differently in different countries of the European Union. Lithuania has also developed a legal framework for the protection, management and establishment of new plantations and green spaces. However, this legal framework is im-proving and new laws are being added to it. Comparative, analytical, as well as statistical, and logical analysis methods were used for the investigation. The data of the Land Fund of the Republic of Lithuania for 2002–2022 were used for comparative investigation. The aim of this article is to perform an analysis of the change in the trees and shrubs greenery area of Lithuania in 2002–2022. In Lithuania, for example, trees and shrubs occupied 84,687.48 ha in 2002. In 2022, the plantation area amounted to 208,609.48 ha. From 2002 to 2022 the area of tree and shrub plantations in Lithuania increased by 123,922.00 ha or 146.33%. The analysis shows that in the period between the years 2002 and 2022 the biggest increase in the area of shrubs and plantations took place in Utena County (32,715.83 ha or 395.27%), but the smallest increase in Tauragė County (2,642.93 ha or 37.69%) and Marijampolė County (4,581.39 ha or 72.25%).The development of plantation areas has been positively influenced by the creation of an appropriate legislative framework and the implementation of plantation programmes in counties and munic-ipalities.
Key words: the trees and shrubs greenery, plantations, area change, development of greenery.

Introduction

The publication of the National Land Service under the Ministry of Agriculture of the Republic of Lithua-nia, Land Fund of the Republic of Lithuania (Nacion-aline…, 2022), contains a definition of tree and shrub plantations, i.e., separate plantations (parks, squares, green links) and areas of plantations (trees and shrubs) that are not classified as forests. Individual trees and shrubs, groups of trees and shrubs, rows of trees and shrubs are included in plantation areas when they form a contour of at least 0.1 ha.

Public and green spaces are open areas where the land is partially or completely covered with grass, trees, water bodies, shrubs or other vegetation. The typology of public and green spaces is defined according to different criteria such as size, amenity or distance from residential areas. Within the United Nations 2030 Agenda, public and green spaces play a key role in promoting urban sustainability and the well-being of citizens, i.e. the connection between people and nature, and the multiple benefits for human health and the environment (Vidal, Barros, & Maia, 2019).

Understanding the relationship between population size and the quality and quantity of green spaces is vital for the sustainability, health and resilience of areas. Quality green spaces improve the quality of life in cities by making them more attractive to residents, employees, tourists, investors and firms (Russo & Cirella, 2018).

Authors Xia, Yabuki & Fukuda (2021) believe that greenery has long played an important role in the quality of landscapes and is closely linked to people's physical and mental health. In addition, the level of street greening is an important indicator of environmental quality. Green spaces, including parks, street trees, community gardens and green roofs, provide numerous ecosystem services at the local level and constitute a potential adaptation strategy to offset the increasing impact of human activity on the urban environment. There is thus an urgent need to assess whether green environments can help mitigate the impacts of climate change on human health, and increase the amount of public green space.

Green spaces make up so-called 'green corridors' or 'green spots' and have cultural, educational and so-cial significance, including recreational and spa func-tions. They are not only a complement to architecture, but can play a primary role in the structure of cities (Jaszczak & Kristianova, 2019).

Urban green spaces (UGS) play a vital role in design and influence the development of compact cities, which has caused scientific controversy over how much green space humans need and to what extent modern approaches address this issue

(Mehta, 2022).

The World Health Organization (2012) recommends a minimum of 9 m^2 of green space per person, with an ideal green space value of 50 m^2 per capita. These statistical values correlate with a number of greening standards, including: core health indicators to monitor progress and measure success, the link between sustainable cities and improved health, food markets and urban infrastructure for social, recreation and livelihoods, increasing the value of health indicators and the validity of data presentation through cross-cutting issues (e.g. equity, governance and climate change), expanding indicator values (e.g. governance indicators, access to services).

Increasing emphasis on urban greening is a recent trend in urban planning and development. This emphasis is evident in the long-term strategic and sustainable development plans of a number of the world's cities, which almost always include promoting urban greening to achieve high quality of life and built environment. Therefore, a high-quality built environment achieved through the functional benefits of urban greenery has become an important urban development goal for creating healthy and livable cities (Tan, Wang, & Sia, 2013).

The development of greenery depends not only on investment and technology, but largely on the attitude and participation of urban residents (Chaudhry, Bagra, & Singh, 2011).

Authors Gatrell & R. R. Jensen (2002) believe that there is an opportunity for communities to develop environmental policies that allow them to remain not only attractive but competitive as well.

The object of article is trees and shrubs greenery of the Republic of Lithuania.

The aim is to perform an analysis of the change in the trees and shrubs greenery area of Lithuania in 2002–2022.

Tasks to be resolved:

1. To analyze the current situation of trees and shrubs greenery in Lithuania.
2. To perform the analysis of the change in the area of Lithuanian trees and shrubs greenery in 2002–2022.
3. To examine the change of trees and shrubs greenery in the counties of the country.

Materials and Methods

Copious methods have been used to prepare the re-search of this article: theoretical and practical.

To achieve the aim, a comparative method was used, which determined the change of tree and shrubs greenery areas in Lithuania and its ten counties in 2002–2022. The received change results are presented in hectares and percentages. The data of the Land Fund of the Republic of Lithuania (Nacionaline…, 2002–2022) for 2002–2022 were used for comparative investigation.

The method of analytical and logical analysis was used to determine the reasons for the increase in the area of tree and shrubs greenery in Lithuania and its ten counties (Table 1).

The article presents the prospects for the development of tree and shrub green areas in Lithuania.

The research also describes the principles of protection, management, and restoration of greenery (Lietuvos Respublikos aplinkos, 2002).

To complement the study, graphical method was used.

Results and Discussion

Existing situation of tree and shrub plantations.

As stated in this article, tree and shrub plantations are classified as a separate green space, i.e. a park, garden, square or other green area of a city or town located on a plot of land that, depending on the use for which it is intended, is classified as separate green space.

Plots of land set aside for individual green areas are created and managed for recreational, scientific, educational, cultural, cognitive, recreational, aesthetic and other public needs. In order to create new individual public green areas or transform existing individual public green areas, it is necessary to prepare a landscaping project (Lietuvos Respublikos želdynų įstatymas, 2007).

The history of Lithuanian green spaces goes back in time. As a set of green spaces, green areas have multifunctional purposes: ecological, protective, recreational, cognitive, aesthetic, architectural, historical, cultural and psychological.

In 2022, tree and shrub plantations in the Republic of Lithuania covered 208,609.48 ha, accounting for 3.20% of the country's area.

Today's landscape is not homogeneous. It is cultivated differently in different parts of the territory, with different social and economic functions, structure, form, expression, cultural and social significance.

There are ten counties in Lithuania where green spaces are unevenly distributed.

An analysis of the area of tree and shrub plantations in Lithuanian counties shows that the largest number of trees and shrubs is found in Utena (40,992.63 ha or 5.70%) and Vilnius (44,706.11 ha or 4.59%) counties, while the smallest number of trees and shrubs is found in the counties of Telšiai (9,518.94 ha or 2.19%) and Tauragė (9,655.40 ha or 2.19%) (Table 1).

Table 1

Trees and shrubs greenery area in hectares and percent in counties of Lithuania in 2022

Counties of Lithuania	Trees and shrubs greenery area	
	ha	%
Alytus	20,106.26	3.71
Kaunas	20,764.69	2.57
Klaipeda	10,793.50	2.07
Marijampole	10,922.81	2.45
Panevezys	20,236.42	2.57
Siauliai	20,912.28	2.45
Taurage	9,655.40	2.19
Telsiai	9,518.94	2.19
Utena	40,992.63	5.70
Vilnius	44,706.11	4.59

Source: author's calculations based on Nacionaline…, 2002–2022.

As plantations serve to conserve biodiversity and the gene pool of the dendroflora, it is necessary to ensure the protection, maintenance and management of plantations, as well as their design and the breeding of new ones.

Changes in the area of tree and shrub plantations in Lithuania.

This paper examines the change in the area of these plantations over 20 years. In Lithuania, for example, the area under trees and shrubs in 2002 was 84,687.48 ha.

In 2002, the Order of the Minister of Environment of the Republic of Lithuania 'On Approval of the Strate-gy for Protection, Management and Restoration of Green Areas' was adopted, which entered into force in 2003 (Lietuvos Respublikos aplinkos, 2002).

This legal document established principles for the protection, management and restoration of green spaces, which are:

1. To provide a legal basis for the protection, resto-ration, management and use of green spaces.
2. To promote a coherent system of green spaces in cities, towns and rural landscapes, forming a natural framework on a national, district, city (or parts thereof) scale. Legislation stipulates that green spaces shall be connected to each other as well as to large green spaces and forests by means of green links.
3. To maintain and properly manage existing green spaces in good condition as they grow, giving priority to maintaining and renewing existing green spaces rather than creating new ones. Of particular importance is the preservation of the integrity of historic green spaces and the integrity of ensembles or complexes of buildings within or adjacent to them, and the harmonisation of their functions with each other.
4. The state, exercising the functions of state regu-lation of all green spaces in the country, developing green space infrastructure, protecting them from natural disasters, mass diseases and pests, recognising all forms of ownership of green spaces, creates legal, financial and other prerequisites for green space conservation, rational management of green spaces, meeting social needs of society and protecting the environment. Policies for the protection, management and restoration of green spaces should ensure that owners, managers and users of green spaces are responsible for the condition of green spaces and their sustainable restoration.
5. Policies should take into account the views of all stakeholder groups in society.

In 2007, the Law on Green Areas of the Republic of Lithuania (Lietuvos Respublikos želdynų įstatymas, 2007) was adopted. The aim of this Law is to estab-lish a legal framework for the protection, management, creation of green areas and planting of greenery in the territory of the Republic of Lithuania on nonforest land, to ensure the stability of the natural and cultural landscape and the right of the population to environmental conditions that improve the quality of life.

The adoption of this law and the implementation of the strategy stimulated the development of planta-tions in Lithuania. As can be seen in Figure 1, the ana-lysed area has started to increase since 2008, and in 2022 the plantation area amounted to 208,609.48 ha.

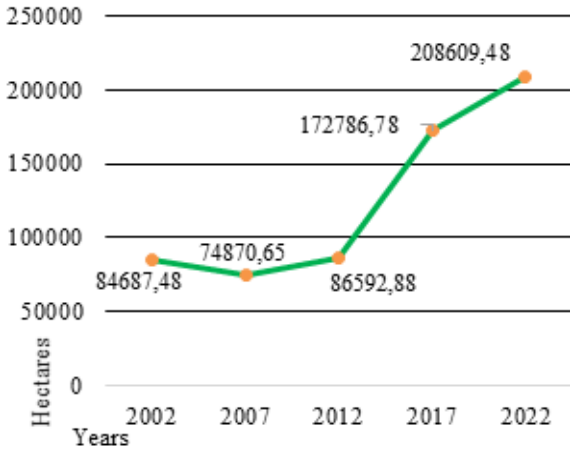


Figure 1. Trees and shrubs greenery area change in hectares in the Republic of Lithuania in 2002–2022 (Nacionaline…, 2002–2022).

From 2002 to 2022 the area of tree and shrub planta-tions in Lithuania increased by 123,922.00 ha or 146.33%. The development of plantation areas has

been positively influenced by the creation of an appropriate legislative framework and the implementation of plantation programmes in counties and their municipalities.

Changes in the area of tree and shrub plantations in the counties.

Tree and shrub plantations are an important part of the landscape. Its planning and management have always been and continues to be an important landscape activity, the nature of which depends on the needs and capacities of society, as well as on levels of planning and management practices.

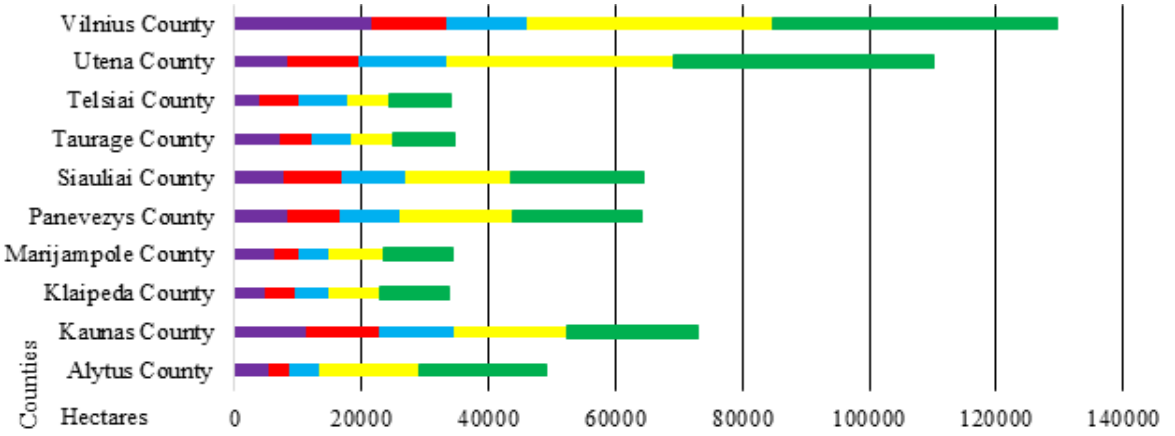
Figure 2 shows that the area of tree and shrub planta-tions in all counties of the Republic of Lithuania has increased from 2002 to 2022.

This means that all counties in the country and their municipalities have expanded their planted areas over the 20-year period.

However, the increase in the area under trees and shrubs was uneven across the counties of Lithuania (Table 2).

The analysis shows that in the period between the years 2002 and 2022 the biggest increase in the area of shrubs and plantations took place in Utena County (32,715.83 ha or 395.27%), but the smallest increase in Tauragė County (2,642.93 ha or 37.69%) and Marijampolė County (4,581.39 ha or 72.25%).

Plantations create green spaces and provide ecological stability.



	Alytus County	Kaunas County	Klaipeda County	Marijampole County	Panevezys County	Siauliai County	Taurage County	Telsiai County	Utena County	Vilnius County
2002	5297,03	11283,59	4758,14	6341,42	8431,97	7826,64	7012,91	3760,99	8276,8	21697,99
2007	3435,84	11417,76	4791,76	3719,59	8021,24	8890,99	5266,26	6336,94	11220,97	11769,3
2012	4713,09	11890,77	5263,56	4601,29	9606,72	10270,98	6066,77	7684,89	13832,18	12662,63
2017	15603,65	17715,95	8182,67	8862,58	17904,62	16652,3	6581,54	6682,86	35799,35	38801,26
2022	20106,26	20764,69	10793,5	10922,81	20236,42	20912,28	9655,84	9518,94	40992,63	44706,11

Figure 2. Trees and shrubs greenery area change in hectares in counties of Lithuania in 2002–2022 (Nacionaline…, 2002–2022).

Scientific research shows that planting greenery not only creates an aesthetic environment, but also improves air composition, provides ionised air, positively affects the microclimate, reduces solar radiation, air pollution, noise pollution and protects areas from erosion.

Also, physical and psychological benefits have been linked to green spaces (Lee & Maheswaran, 2011).

Green spaces and elements provide many functions, services and benefits which are needed for the sustainable development of urban, rural or recreational areas (Jansson, 2014).

Prospects for the development of tree and shrub planting areas in Lithuania.

On 4 June 2020, the Seimas of the Republic of Lithuania adopted a resolution 'On Approval of the Master Plan for the Spatial Development of the State Territory of the Republic of Lithuania and the Functional Priorities for the Use of the Territory of the Republic of Lithuania' (Lietuvos Respublikos Seimo nutarimas, 2020), which provides that in the future the natural framework should cover at least 65% of the country. At present, the proportion of natural frame territories in individual municipalities varies; in Joniškis, Pakruojis and Pasvalys municipalities the natural frame covers 35–40%, and in Varėna and Zarasai municipalities up to 75–80% of the total area of these municipalities. In most of the municipalities of the districts, the area of the natural frame covers 55–65% of their area.

Table 2

Trees and shrubs greenery area change in hectares and percent in counties of Lithuania in 2002–2022

Counties of Lithuania	Trees and shrubs greenery area	
	ha	%
Alytus	+ 14,809.23	+ 279.58
Kaunas	+ 9,481.10	+ 84.03
Klaipeda	+ 6,035.36	+ 126.84
Marijampole	+ 4,581.39	+ 72,25
Panevezys	+ 11,804.45	+ 140.00
Siauliai	+ 13,085.64	+ 167.19
Taurage	+ 2,642.93	+ 37.69
Telsiai	+ 5,757.95	+ 153.10
Utena	+ 32,715.83	+ 395.27
Vilnius	+ 23,008.12	+ 106.04

Source: author's calculations based on Nacionaline…, 2002–2022.

In urbanised areas, the aim will be to improve habitat quality, which requires conditions for expressing biodiversity, living and migratory habitats, and increasing the connectivity of the remaining islandtype natural elements by creating green links – corridors.

The geo-ecological potential of natural framework areas located in intensively populated agro-territories is damaged or severely damaged, and the restoration of its naturalness is planned to compensate for the negative impact of diffuse pollution on soil and aquatic ecosystems or even to contribute effectively to the improvement of these environmental components. Planned planting of protective plantations on water bodies, creation of protective strips on fields, increasing the area of protective forests and stimulating the processes of spontaneous renaturalization of agrarian territories will increase the potential of the natural framework and thus improve the overall ecological status of agrarian territories.

On May 1, 2023, amendments to the Law on Green Areas of the Republic of Lithuania (Lietuvos Respu-blikos želdynų įstatymas, 2007) will come into force that will bring green areas closer to the population, with the norm being calculated at a closer distance from residential buildings – within a radius of up to 1 km. This is a distance that can be walked in no more than 15 minutes. Parks and squares should be created at the rate of at least 12–25 m^2 per inhabitant within this maximum distance, depending on whether it is a city, town or resort.

The standards for green areas in courtyards have also been increased, especially in areas with a natural framework. Where there is not enough space to create green areas, this can be compensated by vertical greening of buildings – up to 5% of the required greening area. A standard of 10% green space has been introduced in the central areas of large cities, which has not been the case in Lithuania so far.

The amendments to the law oblige municipalities to restore street greenery within one year if it had to be removed due to construction work or if it posed a risk to the environment or traffic safety. This is expected to help restore the green balance in urbanised areas.

The implementation of green spaces requires the mobilisation of both national and local government structures, the active involvement of civil society organisations and communities, and the open, constructive and coordinated implementation measures. The spatial planning process also needs to be optimised, creating the necessary conditions for the formation and further development of an ecological compensation system.

Conclusions

1. In 2022, tree and shrub plantations in the Republic of Lithuania covered 208,609.48 ha, accounting for 3.20% of the country's area. An analysis of the area of tree and shrub plantations in Lithuanian counties shows that the largest number of trees and shrubs is found in Utena (5.70%) and Vilnius (4.59%) counties, while the smallest number of trees and shrubs is found in the counties of Telšiai and Tauragė (2.19%).
2. From 2002 to 2022 the area of tree and shrub plantations in Lithuania increased by 123,922.00 ha or 146.33%. The development of plantation areas has been positively influenced by the creation of an ap-propriate legislative framework and the implemen-tation of plantation programmes in counties and municipalities.
3. The analysis shows that in the period between the years 2002 and 2022 the biggest increase in the area of shrubs and plantations took place in Utena county (395.27%), but the smallest increase in Tauragė county (37.69%). In the implementation of trees and shrubs greenery, the spatial planning process needs to be optimised, creating the necessary conditions for the formation and further development of an ecological compensation system.

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TOURISTS' ENVIRONMENTALLY RESPONSIBLE BEHAVIOUR IN RESPONSE TO CLIMATE CHANGE

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Abstract
Tourists' environmentally responsible behaviour (ERB) in response to climate change is a topic that is becoming increasingly important during the Covid-19 pandemic as people's values change. Tourism is facing an economic downturn and now is the time to prepare for a new upswing. Meanwhile, a new narrative is needed in response to climate change, as tourism is a net polluter of the environment. That is why tourist ERB studies are becoming more and more relevant in the world, including Latvia, too. The objective of this paper is to determine the ERB of tourists in response to climate change. The questionnaire included 30 research questions and generated 383 answers from respondents from the Vidzeme region of Latvia. Several research methods were used in the study: descriptive and correlation method, KMO and BARLETT'S, Cohen's Kappa and Cronbach's alpha tests, Exploratory factor analysis and Principal Components Analysis. The study found that the factors attitude, behaviour, awareness, control, environmental knowledge, experience and values influence tourists' ERB; however, environmental knowledge and experience show a slight advantage. To direct the continuation of the research towards the creation of the tourism ERB model in Latvia.
Key words: climate change; environmental behaviour; tourism.

Introduction

Both adapting to climate change and mitigating the causes of climate change have the goal of reducing negative impacts. The Fifth Assessment Report (AR5) assessed human interventions to reduce sources that may directly or indirectly contribute to climate change (IPCC) (IPCC, 2015). The IPCC concludes that there are not only technical, economic, political and institutional barriers, but also cultural, social and behavioural barriers. Choosing a sustainable consumption model depends not only on people's needs, but also on economic opportunities, people's knowledge and awareness (Saari *et al.*, 2021). Such prerequisites and actions also apply to tourism. COVID-19 reduced the flow of tourists, just 52% of Europeans participated in tourism in 2020, compared to 65% in 2019 (Eurostat, 2022).

In Latvia, the largest decrease in the number of guests admitted to tourist accommodation was – 96.5% in May 2020 compared to May 2019, while the largest influx of guests in July 2022 comprised only 57.8% compared to July 2019 (Official statistics portal, 2023, January).

The Covid-19 epidemic has also created new positive trends. Society's awareness for sustainability, and responsibility for the environment and health has increased (Redeemer, s.a.). The results of the European Investment Bank (EIB) study during the Covid-19 crisis on public perception of critical climate change shows that 72% of Europeans and North Americans and 84% of Chinese citizens believe that their individual actions can have a significant impact on the fight against climate change (Tourism 2030, s.a.).

The importance of individual action in this regard in Latvia is also emphasized by the Latvian Tourism Development Plan for 2021–2027, which indicates the need to analyse the behaviour of tourists (Rozīte *et al*., 2019). The authors chose the Vidzeme region (LV008) as the research area, taking into account that it is a European Union (EU) Nomenclature of Territorial Units for Statistics 3 (NUTS3) region with insufficient investments in the transition to a green and smart economy after environmentally responsible behaviour (ERB) (EIB, 2021).

Historically, researchers have defined the term ERB as the tendency to take actions with the intention of positively affecting the environment in order to minimize any negative impact on the natural world as caring for other people, species or ecosystems to reduce negative environmental impacts at home, work or tourist destinations to reduce environmental damage (Stern, 2000; Kollmuss & Agyeman, 2002; Meijers & Stapel, 2011; Chiu, Lee, & Chen, 2013). Barriers to achieving ERB have been studied using different models emphasizing external factors (e.g. institutional, economic, social and cultural) and internal factors (e.g. motivation, environmental awareness, awareness, values, attitudes, emotions and locus of control, as well as responsibilities and priorities) (Kollmuss & Agyeman, 2002).

The authors focused on the barriers identified in Blake's model of ERB: individuality, responsibility and practical dimensions. Individual barriers are within the person himself and his attitude, as well as control factors underlying the individual's belief in his ability to make changes based on his behaviour (Blake, 1999; Hwang, Kim, & Jeng, 2010). Researchers concluded that individuals with

self-control can create significant change, while those with a need for external control were more likely to participate in ERB-promoting activities (Marquart-Pyatt, 2015). A number of researchers have indicated that environmental knowledge is necessary for the creation of ERBs (Cheng, Wu, & Huang, 2013; Chiu, Lee, & Chen, 2013). The goal of environmental education is to shape human behaviour while educating about issues related to the environment in order to develop the ability to respond safely to the environment. Therefore, environmental education is very important for tourism because it offers knowledge that shapes tourist behaviour. No less important is the influence of individual experience (Buonincontri *et al*., 2017).

Factors influencing tourist behaviour are multidimensional and each has its own impacts. There are also differences in the architecture of factor models and ERB assessment methods, which are: regression method; a meta-analysis on environmentally non-friendly behavioural factors, and factor analysis (Stern, 2000; Bamberg & Moser, 2007; Chiu, Lee, & Chen, 2013; Buonincontri *et al*., 2017). Therefore, it cannot be claimed that any of the factor model architectures are more diverse or inclusive, but it is important to base research on the experience of previous researchers (Kollmuss & Agyeman, 2002).

Given the topicality of this topic, some prerequisites must be recognized: (1) the United Nations World Tourism Organization (UNWTO) Davos Declaration encourages tourists to reduce carbon dioxide emissions; (2) climate and environmentally responsible economic recovery is a priority of the EU agenda; (3) society recognizes sustainability issues and responsibility for the environment; (4) The Latvian Tourism Development Plan for 2021–2027 includes activities aimed at conducting a survey of tourists' behaviour; (5) In Latvia, including Vidzeme (LV008), no analysis of environmentally responsible tourism behaviour has been carried out so far. The authors analysed the Latvian statistical region Vidzeme (LV008), taking into account the fact that it is an EU NUTS3 region that lacks targeted investments for the transition to a green and smart economy (EIB, 2021).

The goal of this paper is to determine the tourists' environmentally responsible behaviour in response to climate change. In order to fulfil the goals, the following tasks were carried out: (1) analysis of scientific literature; (2) question analysis, identification and operational definition of variables; (3) determine data applicability and selectivity; (4) exploratory factor analysis and principal components analysis.

Materials and Methods

The population of this study consists of potential Latvian tourists who live in the LV008, where there are 126 529 working age inhabitants, which hold a greater economic opportunity to travel (Official statistics portal, 2020, July). The population size was calculated as n = 383. Taking into account the gender proportion within the given LV008, which stands at 1.017, it was decided to include an equal number of men and women in the questionnaire. Before conducting the survey, questions were validated. Altogether 402 filled questionnaire sheets were submitted of which 9 were partially filled and thus deemed invalid. Data was collected from 2020–2022, during a period when in Latvia, similarly to other regions in the world, the Covid-19 pandemic had spread with structural lock-downs in place that negatively affected data collection efforts. Questions were asked through a telephone survey and by conducting surveys face-to-face when possible. Distributed data collection was also conducted by the next-to-pass method (Kabir, 2016). A total of 30 usable questionnaires were collected. Each questionnaire item was assessed by item analysis, including Cronbach's alpha, means, and standard deviations. In the ERB model, which could react to response to climate change the following seven factors were used: attitude (A); behaviour (B); comprehension (Com); control (Con); environmental knowledge (En); experience (Ex) and values (V). The value of each indicator of the variables in this research was conducted by using the Likert scale of 4 levels, namely 1 = not important; 2 = moderately important; 3 = important; and 4 = very important. Assumption for demographical questions was based on measures of nominal data determined with Cohen's Kappa. The statistical analysis of questionnaire results was conducted while determining distribution frequency of responses according to the corresponding questions. By using Cronbach's Alpha (reliability) test for ordinal data, data suitability and select ability coefficient was conveyed. An internal correlation factor of survey questions was carried out in order to determine important interrelations. For ordinal data (individual Likert-scale questions), non-parametric tests such as Chi-square test for independence was used. Statistical Package of Social Sciences (SPSS 20) was used for analysing the data.

Results and Discussion

It was determined that the proportion between male and female respondents was almost perfectly equal. This population was chosen proportionally to the gender proportion in the LV008. According to age, respondents were mostly comprised of people in the age group of 18–39 years with the presence of almost equal groups. Similarly the % was divided according

to the level of education, where the only group which was not proportionally distributed among others were those respondents with primary or lower than primary level of education (only 7%).

Analysing the gross income per month (EUR), it is noted that approximately 60% receive a salary of approximately 400–1000 EUR per month, while 4.7% earn more, which means that the respondents, as potential tourists, can actually afford the tourist service.

Cross-tabulation of gender and education showed that education and gender reports do not provide similar information about respondents' education, as Cohen's Kappa is equal to -0.037. Women with a higher education constitute 6.6% and women with a secondary education constitute 1.8% more than men. However, within the men group there are 7.3% more people with vocation education or vocational secondary education than those with primary or lower education level.

Assumption for measures of reliability for respondents to compare the given questions was determined by Cronbach's alpha coefficient which is the usual one to report 0.979, but Cronbach's alpha based on standardized Items indicated even 0.980. The alpha for competence scale was larger than > 0.80 indicating good internal consistency. The average scale score for the 30 summed items for the 383 respondents was 76.17. The general linear model was used to carry out Manova.

The test examined whether the education (four education groups: EDUC1 – higher; EDUC2 – vocational or vocational secondary; EDUC3 – general secondary; EDUC4 – primary or lower than primary) differ on a linear combination of the dependent variables: A; B; Com; Con; En; Ex and V. Bivariate scatterplots were checked for multivariate normality. A statistically significant difference was found, Wilk's $\Lambda = 0.521$, $F (21, 1071) = 13.01$, $p<0.001$. The results indicate the percentage of variance in each of the interaction and its associated error that is accounted for by that interaction. These results show that 15.4% of variance is associated with A, 18.7% with B, 28.8% with Com, 26.4% with Con, 19.5% En, 19.3% with Ex and 23.2% of variance is associated with V. This allows to conclude that when evaluating the impact of education on the ERB, the largest dispersion is linked to B, Com and V. The interaction of other dependent variables are also important. When evaluating the educational groups, the following results were obtained in Table 1.

Since in EDUC4 group the number of responses is relatively higher than average number of variables of the general linear model Manova, their results are closer to zero and are not analysed within the SPSS instruments.

Table 1

Manova test results of environmentally responsible behaviour for education groups of potential tourists of Vidzeme region in Latvia (n = 383)

Variable (%)	Education groups		
	EDUC1*	EDUC2**	EDUC3***
Attitude	6.9	2	4
Behaviour	8.6	3	4
Comprehension	13	7	2
Control	9	3	7
Environmental knowledge	13	2	6
Experience	9	2	1
Values	13	1.4	1.4

Note: education groups * EDUC1 – with higher; EDUC2** – with vocational or vocational secondary; EDUC3*** – with general secondary education.

In EDUC1 group, the highest valued values are interaction with En, V and Con. EDUC2 group – Con; EDUC3 – Con and En. Manova test for A, B, Com, Con, En, V by age and gender to assess whether respondents with higher, vocational or vocational secondary, general secondary and primary or lower than primary education have different dependent variable test scores and whether there was an interaction between dependent variables age and gender, was conducted. Bivariate scatterplots were checked for multivariate normality. A statistically significant difference was found, Wilk's $\Lambda = 0.941$,

F (21, 1060) 1, p = 0.357, multivariate η^2 = 02; age – Wilk's Λ = 0.539, F (7, 369) 2, p = 0.06, multivariate η^2 = 0.19; and gender – Wilk's Λ = 0.964, F (7, 369) = 0.20, p = 0.06, multivariate η^2 = 0.4. This indicates that the linear composite of dependent variables test differs for males and females. Follow-up ANOVAs indicate that effects of age are statistically significant for AGE1 by all dependent variables, but not for other age groups. Parameter estimates parameter EDUC of the depend variables A, B, Com, Con, En and V indicated statistically significant values, but parameter gender – was not statistically significant. Meanwhile, by gross income per month (EUR) a statistically significant difference was found, Wilk's Λ = 0.507, F (35, 1563) = 8, p < 0.001, multivariate η^2 = 0.13. This indicates that the linear composite of dependent variables test for gross income per month.

For the multivariate test, eta is 0.36, which is medium effect size. The univariate etas are 0.45 (much large than typical), 0.43, 0.41, 0.40, 0.39, 0.38, for En, A, B, V, Con, Com and Ex, respectively.

Chi-Square test was used in order to test the EDUC impact on the ERB factors A, B, Com, Con, En, Ex and V qualitative indicator changes. The purpose of the test is to evaluate how likely the observed frequencies would be assuming the null hypothesis is true. Based on the acquired results, significant impact was indicated on the relation between the ERB and EDUC and all researched factors, except for factor A and Com. The Kaiser-Meyer-Olkin (KMO) sample fit measure and Bartlett's test of sphericity were used to determine the feasibility of factor analysis. As a result, KMO = 0.913 > 0.9 (absolute fit) and Bartlett's p-value = 0.000 < 0.05 indicate the possibility of factor analysis.

Each factor on the tourists' ERB is important, which is indicated by KMO and Bartlett's test, indicating that correlation matrix is significantly different from an identity matrix, in which correlations between variables are all zero. Rotation factor matrix indicated that the items cluster into these three groups was defined by the highest loading on each item. The highly on item in Table 2 are factors value and environmental knowledge at 1. component, experience and behaviour at 2.

Table 2

Factor analysis test results of environmentally responsible behaviour for education groups of potential tourists of Vidzeme region in Latvia (n = 383)

Variable (%)	Mean	St. Deviation	Communalities	Factor	
				1	2
Attitude	2.46	0.519	0.933	0.740	0613
Behaviour	2.33	0.657	0.940	0.591	0.766
Comprehension	2.48	0.538	0.912	0.556	0.777
Control	2.52	0.537	0.940	0.726	0.656
Environmental knowledge	2.57	0.510	0.907	0.795	0.534
Experience	2.38	0.589	0.907	0.544	0.803
Values	2.56	0.545	0.905	0.800	0.535

The screen plot shows that after the first components the differences between the eigenvalues decrease (the curve flattens) and are less than 1.0. The study confirmed the correlation between the attitude and behaviour of the factors (r = 0.935), as well as the coincidence of the attitudes of potential tourists visiting Latvia's region, with those reflected in the EIB climate study on the relationship of behavioural factors to climate change, the significant impact of knowledge on ERB. In addition, systematic heterogeneity in environmental attitudes and behaviour was noted, mainly in terms of respondents' education, gender, age and income, which coincides with the findings of the authors. However, these studies are mainly focused on the general EU population, while the authors of this study target tourists (DeSombre, 2018; Tourism 2030, s.a.; Saari *et al*., 2021; Meyer, Shamon, & Vögele, 2022).

The presented study is the first step towards determining environmentally sustainable tourist's behaviour in Latvian regions as a countermeasure to global climate change. The presented study is the first step towards determining the environmentally sustainable behaviour of tourists in Latvian regions as a countermeasure to global climate change. The presented study is the first step towards determining

the environmentally sustainable behaviour of tourists in Latvian regions as a countermeasure to global climate change.

Conclusions

1. The study indicates that there are significant differences in terms of gender, gross monthly income (EUR) and the relationship between education and environmentally responsible behaviour (ERB) in general potential tourists who live in the Vidzeme region of Latvia (LV008).
2. The effect of tourists with higher education on ERB is related to factor comprehension (13%), value (13%) and control (9%). The latter is an important factor for respondents with vocational or vocational secondary education. Meanwhile, the education group with vocational or vocational secondary education has the highest dispersion of comprehension (7%) and education group environmental knowledge (6%).
3. The effect of tourists with higher education on ERB is related to factor comprehension (13%), value (13%) and control (9%). The latter is an important factor for respondents with vocational or vocational secondary education.
4. These conclusions will make it possible to create a support system for changing environmentally responsible behaviour of tourists. Considering the influence of tourists as potential environmental polluters, it is important to continue research on ERB patterns of tourists in Latvia.

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LANDSCAPE QUALITY EVALUATION USING CULTURAL ECOSYSTEM SERVICE ASSESSMENT METHODS

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Abstract
Ecosystem services (ES) have been widely researched for several years, but cultural ecosystem services (CES) have gained importance in recent years due to pressure on human well-being and public health. This literature review aims to continue research about ES assessment methods used in the valuation of landscape quality, analysing methods for CES assessment. The most assessed CES is aesthetic value being one of the most appreciated and widely known CES. Landscape quality assessment is complicated and rarely assessed, but several methods evaluate separate features of landscape quality, which gives an insight into accessible methods for landscape valuation. In this article, methods are analysed and categorised into four groups – economic, spatial evaluation, social and statistical analysis. Most analysed articles use several methods in one assessment giving more precise results. In CES assessment, the most used method is surveys and questionnaires and usually incorporating mapping methods to spatially explicitly represent the data.
Key words: cultural ecosystem services, landscape quality, assessment.

Introduction

The ecosystem services (ES) approach has become widely researched and mentioned in different contexts since the Millennium Ecosystem Assessment (2005) was published. After publishing the ES concept every year several new articles and methods appeared for ES assessment, and it had a snowball effect (Brzoska & Spaǵe, 2020). Since the beginning of the ES phenomenon, regulatory and provisioning services were the most assessed due to straightforward methods and easy data collection for assessment and valuation. Recently more and more attention has been drawn to cultural ecosystem services (CES) and their benefits to human health (Spage, 2022). The importance of ES to human well-being has been pointed out by several authors (Havinga *et al*., 2021; López Sánchez, Tejedor Cabrera, & Linares Gómez del Pulgar, 2020; Millennium Ecosystem Assessment, 2005; Van Berkel *et al*., 2018; Zoeller, Gurney, & Cumming, 2022), especially when talking about CES (Hermes *et al*., 2018; Martín-López *et al*., 2012; Sikora & Kaczyńska, 2022). Even though researchers have pointed out this crucial role of CES, this ES section still has been falling behind regulatory and provisioning services due to difficulties in indicator selection, data collection and method choice (Pleasant *et al*., 2014; Vihervaara, Rönkä, & Walls, 2010), there are still complications in CES quantification (Swetnam, Harrison-Curran, & Smith, 2017). CES encompasses multiple benefits that people derive from ecosystems and nowadays with a high rate of urbanisation, constant agricultural intensification (Van Berkel & Verburg, 2014) and urban sprawl processes many of those ES are endangered.

People's perception and understanding of ES delivery from landscapes are closely linked to awareness of the social perspective of the ES concept (Martín-López *et al*., 2012), but overlooking socio-cultural values can become an obstacle in landscape development or protection to maintain a high-quality landscape for future generations. Landscape quality perception is dependent on the understanding of landscape, cultural and historic values, landscape character features and personal attitudes towards landscape (Gottero, Cassatella, & Larcher, 2021; Solecka *et al*., 2022; Wartmann *et al*., 2021). Rising awareness of CES can help to promote public understanding of biological diversity (Assandri *et al*., 2018; Lindemann-Matthies, Junge, & Matthies, 2010), cultural landscapes and heritage sites (Sikora & Kaczyńska, 2022), protected areas and specific landscape values (Sowińska-Świerkosz & Michalik-Śniezek, 2020; Thiele *et al*., 2020).

CES assessment and the importance of landscape quality preservation and improvement have formed the aim of this research to explore methods for CES assessment to evaluate landscape quality in large-scale non-urban territories, and to analyse the most suitable methods for landscape quality valuation using CES assessment.

Materials and Methods

Previously performed systematic literature review (Spage, 2022) was a basis for further exploration of methodology to evaluate landscape quality using the ES approach in non-urban, large-scale territories. As the results of previous research pointed out that the most assessed ES section was CES regarding landscape quality that was a starting point for further research of methods specifically for CES assessment based on references used in the previous article.

The first step of the used review method was to do a thorough analysis of references used in the previous research, gather all research articles that are used as a source for method, indicators or data and all repeating articles were excluded from the list. The second step was the reading of all abstracts to define if the selected article corresponds to landscape quality assessment

using the CES approach. The abstract could not specifically mention the term 'landscape quality' as it could serve as a restrictive element but should correspond to the evaluation of landscape features or the landscape as a whole. Articles that assess landscape features in an urban environment were excluded from the research as the aim of the research is to analyse methods for non-urban landscapes.

After a preliminary analysis of the reference list, additional searches in databases 'Web of Science' and 'Scopus' were conducted to find the latest articles in this very specific research field. The search was conducted with specific keywords 'cultural ecosystem services' and 'landscape quality' in the title, keywords or abstracts. The search was limited to the time frame from April 2022 to February 2023, as the other articles corresponding to the same criteria were already assessed in the previous literature review (Spage, 2022). Search for the most recent research articles concluded with 16 results in the Scopus database and 58 in the Web of Science database. Major difference in the results can be explained due to the Web of Science database search engine not allowing search by specific month, only year. Similarly, abstracts of articles were read and analysed if the topic of research corresponds to the same criteria as in step 2.

After combining both article selection methods research concluded with 37 articles to be analysed for this paper. Analysis of all selected articles was performed and combining all used methods and assessed CES classes in the database. Some of the selected articles were literature reviews (Hermes *et al*., 2018; López Sánchez, Tejedor Cabrera, & Linares Gómez del Pulgar, 2020), which gave insights into the topic, but were not included in the result section.

The research method was selected based on the results of a previous literature review on this topic and this paper gathers an overview of a very specific research field that uses CES for landscape quality assessment. This research aims to analyse methods of CES assessment for landscape quality assessment and to which ES class these methods are used. As the methods of CES valuation vary in the indicator and data usage additional research article would be necessary to analyse these categories and are not included in this paper.

Results and Discussion

For an easy representation of research results, CES were classified according to the Common International Classification of Ecosystem Services (CICES) version 5.1 (European Environment Agency, 2018) classes, but the names of these ES were simplified and few classes have been combined. Based on the CICES classification there are 11 defined CES, but their division is too narrow to be assessed on a large scale and several articles (López Sánchez, Tejedor Cabrera, & Linares Gómez del Pulgar, 2020; Thiele *et al*., 2020) have been joining several classes to not confuse and misdirect the results. CICES classification provides recreation divided into two separate ES (passive and active) as well as education ES (researching and studying nature) and values for preservation and future enjoyment are classified separately. As none of the researched articles breaks down these ES in such classes, for this research these classes were combined and concluded with eight CES to be examined.

Table 1 represents the results of the literature research, and there are clear trends shown in the results. The main assessed CES class was the aesthetic value of the landscape, which was pointed out also in the previous article as the most assessed ES when talking about landscape quality (Spage, 2022). Although landscape quality is a complex feature, landscape aesthetics is still most associated with landscape quality indicators. Several authors point out an interesting connection between landscape aesthetics and biodiversity (Assandri *et al*., 2018; Lindemann-Matthies, Junge, & Matthies, 2010) when biodiversity can serve as an indicator of appreciation of landscape aesthetics. Also, recreation, tourism and cultural and heritage ES were assessed in several articles (e.g. De Vreese *et al*., 2016; Hermes, Albert, & von Haaren, 2018; Mäntymaa *et al*., 2021; Pleasant *et al*., 2014; Ruskule, Klepers, & Veidemane, 2018; Thiele *et al.*, 2020) where data collection is more straightforward. The least assessed CES classes are symbolic values and values for future generations, as these ES are complicated to assess and are time-consuming to evaluate.

The usual method division includes biophysical, monetary and social method groups (Martín-López *et al*., 2012; Yoshimura & Hiura, 2017); however, in this research biophysical method group more corresponds to the mapping of ES, and for this reason, it has replaced the biophysical method group. Also, statistical analysis has been added separately from other methods as in ES assessment a large number of articles used statistical analysis methods (e.g. Assandri *et al.,* 2018; De Vreese *et al.*, 2016; Jovanovska *et al*., 2020; Martín-López *et al*., 2009; Zoeller, Gurney, & Cumming, 2022) as an addition to other methods. For that reason, statistical analysis methods were not broken down in more detail but assessed as one method group.

Monetary valuation of CES is still a rarely used method due to complications to address specific value to intangible things. Proxies for landscape value like willingness to pay or travel cost are frequently used to assess CES. Economical evaluation methods were mostly connected with other methods in the same research, for example, surveys (Mäntymaa *et al*., 2018; Martín-López *et al*., 2009; Niedermayr *et al*., 2018; Van Berkel *et al*., 2018) or mapping of geospatial data (Hatan, Fleischer, & Tchetchik, 2021). The willingness to pay method is directly

connected with people's perception of landscape and their willingness to pay for the improvement or loss of some features in landscape (Niedermayr *et al*., 2018; Mäntymaa *et al*., 2021; Van Berkel & Verburg, 2014). Another economical method used in researched articles was the travel cost estimation method where the estimation of travel costs for travelling to a specific landscape and appreciation of it was calculated based on survey results from landscape visitors (Martín-López *et al*., 2009; Van Berkel *et al*., 2018). A novel method in economic CES assessment is the discrete-choice equilibrium model which allows the estimation of the value of CES in natural and agricultural landscapes and value loss due to urban sprawl and agricultural expansion (Hatan, Fleischer, & Tchetchik, 2021). Overall, economic methods are not widely used in CES assessment, and it is still complicated to use economic methods in this field due to lack of data or data collection being time-consuming.

The most used method group for CES assessment is spatial evaluation or mapping. Methods that assess the most CES are field observations and GIS mapping, which incorporates different tools. Field observations include systematic fieldwalking (Bieling & Plieninger, 2013), direct observations (Pueyo-Ros, Ribas, & Fraguell, 2018) and on-site inventory (Sikora & Kaczyńska, 2022). Systematic fieldwalking has a strict indicator list and precise method for the assessment of all landscape features and elements that point to CES supply (Bieling & Plieninger, 2013), but can be subjective while based only on surveyor experience and evaluation. Also, the method was employed on orchard territory, which is an open landscape and this method would not be applicable to landscapes where the view can be obscured (Bieling & Plieninger, 2013). On-site inventory used several criteria of eight CES assessment, afterwards using statistical analysis to analyse the data (Sikora & Kaczyńska, 2022). Such methods assess several CES, but these methods are time and source consuming and that can be an obstacle for city planners or decision makers to use such methods. Self-explanatory is the visual quality index (Jovanovska *et al*., 2020; Swetnam, Harrison-Curran, & Smith, 2017; Swetnam & Tweed, 2018) or landscape aesthetic quality index (Hermes, Albert, & von Haaren, 2018), which are methods for landscape aesthetical value. Visual quality index have been used as a method for several research articles but with a different approach to data collection and usage.

Table 1

Used methods for CES evaluation and CES classes (simplified)

Cultural ES	Method															
	Economic methods			Spatial evaluation (mapping)							Social methods					
	Discrete-choice equilibrium model	Travel cost estimation method	Willingness to pay	Field observations (species mapping, inventory, structured walkthrough)	Photo-based method (Geotagged photos, social media photos)	Visual quality index (Landscape aesthetic quality index)	Landscape quality index	CAESaR indicator framework	Viewshed modelling	GIS mapping (Hot spot/cold spot analysis, route mapping, buffer zones)	Survey, questionnaire	Workshops	Interviews	Experiment	Expert assessment	Statistical analysis
Recreation, tourism value		■	■	■			■	■		■	■		■		■	■
Nature education, knowledge value		■		■							■		■		■	■
Cultural and heritage value		■	■	■			■	■		■	■		■		■	■
Aesthetic value	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■
Symbolic value															■	
Spiritual or religious value		■	■	■						■	■					■
Entertainment value				■											■	
Values for future generations											■					

Note: in the table, it is marked in green whether the specific CES has been assessed by the specific method. Explanation of acronyms: CAESaR – Cultural Ecosystem Services of River landscapes; GIS – Geographic Information System.

The initial article using the visual quality index method in Wales (Swetnam, Harrison-Curran, & Smith, 2017) was based on large datasets and high-quality GIS data, assessing landscape visual quality based on five indicator categories – blue space, greenspace, physical, human and historic. The same method in different renditions was performed in Iceland (Swetnam & Tweed, 2018) where the evaluation was performed by field observations of 32 specific landscape views. Jovanovska et al. (2020) were combining two data collection methods and adapted the visual quality index method once again by using remote and field observations of the Shar Planina mountain landscapes. Two other methods are based on landscape visual values, viewshed modelling which calculates the object diversity in a view and the views from specific points in landscape (Swetnam, Harrison-Curran, & Smith, 2017; Van Berkel *et al*., 2018; Yoshimura & Hiura, 2017) and nowadays more and more popular geo-tagged photo analysis method derived from social media (Havinga *et al*., 2021; Sottini *et al*., 2019; Van Berkel et al., 2018; Yoshimura & Hiura, 2017). Social media photo analysis methods can give an insight into tourist and local inhabitant preferences regarding landscape aesthetics and also point out the demand and supply of CES (Yoshimura & Hiura, 2017). Such methods are useful for mapping people's preferences but could be complicated to use in data-scarce areas or areas that are not so widely used for recreation. The photo-based method could include different assessments of photos and landscapes, for example, taking photos from roads and analysing them (Martín *et al*., 2018). Senes et al. developed a landscape quality index method, where multiple ES were assessed including spiritual, recreation and cultural values, by using several geodata sources and using ArcGIS software to calculate the landscape quality index to point out the most precious landscapes to protect them from future land take (Senes *et al*., 2020). A new approach for CES assessment was the CAESaR indicator framework (Thiele et al., 2020), the method applied evaluation of several CES with several indicators for each CES. Method aimed to evaluate river landscapes on a national and local scale (Thiele et al., 2020). The most frequently used method was GIS-enabled mapping which incorporates different tools in GIS software, for example, hot spot/ cold spot analysis (Van Berkel & Verburg, 2014; Vannoppen, Degerickx, & Gobin, 2021), polygon mapping with participation from local inhabitants (De Vreese *et al*., 2016) and several authors used GIS mapping after gathering data from surveys and interviews (De Vreese *et al*., 2016; Plieninger *et al*., 2013; Ruskule, Klepers, & Veidemane, 2018) to spatially represent data. The spatial evaluation method group is the most diverse in method choice, but also very varied in data usage starting from very time-consuming collection and massive amounts of data to simplified methods with publicly available data. Simplified methods with no detailed data are good for estimation and overall understanding of CES supply, but these methods can be biased and not correspond to real-life situations in detail.

Widely used methods for CES assessment are qualitative surveys and interviews (Bieling & Plieninger, 2013) to gather trustworthy information about landscape perception and demand from local people, tourists and stakeholders. As mentioned before several authors that used the survey method incorporates some sort of GIS mapping tools to visually represent data or include separate assessment layers (De Vreese *et al*., 2016; Dramstad et al., 2006; Plieninger *et al*., 2013; Ruskule, Klepers, & Veidemane, 2018). Zoeller, Gurney, & Cumming (2022) method incorporated statistical analysis and researched an interesting connection between bird occurrence and people's perceptions of landscape. The same approach was used together with a questionnaire, species mapping and using statistical analysis for data processing (Assandri *et al*., 2018). Research by Pleasant *et al*. (2014) used surveys and interviews with environmental managers from local municipalities. Few authors used experiments as a method for visual choice assessment (Ungaro *et al*., 2016) or to assess plant diversity appreciation (Lindemann-Matthies, Junge, & Matthies, 2010). Results from surveys and questionnaires which do not incorporate spatial mapping and data that is not spatially explicit can be difficult to incorporate in further evaluation of landscape (Bieling & Plieninger, 2013).

Interesting that methods based on social media data which is becoming more and more popular nowadays are used only for the aesthetical value assessment, but location data collection could be used for recreation, tourism or other CES evaluation. As mentioned before, the aesthetic value is the most assessed CES and multiple methods have been adapted to measure aesthetic landscape quality, but overall landscape quality is still not addressed widely. Several authors stressed the importance and influence of people's perception on CES assessment (Hermes et al., 2018; Martín-López et al., 2009; Plieninger et al., 2013; Thiele et al., 2020), which include several interesting points for future research, for example, perception of cultural landscape (Plieninger et al., 2013; Van Berkel & Verburg, 2014).

Conclusions

CES assessment methods for evaluating landscape quality are very diverse and differ based on data availability or resources for research. Several articles in this research combines multiple methods, which has the most spatially explicit and trustworthy data. The conclusion from research is that the most appropriate method for CES assessment to evaluate landscape quality is combination of GIS enabled

mapping and surveys with society to cover base information about land structure, usage, etc. and also demand and insights from local people and tourists. Using both methods combined and carefully choosing indicators, it is possible to point out the landscapes with the highest quality from different perspectives and apply specific management tools accordingly.

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IMPACTS OF BIOCOVER COMPOSITION ON GREENHOUSE GAS EMISSION

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Abstract
It is generally estimated that gas, which generates more than half of the greenhouse gas (GHG) emission from waste industries in landfills, is seen as a serious environmental problem worldwide. It is therefore essential to promote management methods to reduce GHG emissions from landfills as well as other sources. One way of achieving this is the usage of different types of biocover applied to them. The aim of this study is to clarify the impact of the biocover created on GHG emissions. An experiment was conducted in laboratory conditions that studied the effectiveness of biocover developed in the laboratory. Three experimental columns with a diameter of 160 mm and a height of 1500 mm were created. Active compost saturated with water at a thickness of 500 mm was used as a source of methane, a permeable layer of sand at a thickness of 300 mm was further formed and finally covered with biocover. Biocover represented 60% of fine-fraction waste, 20% of soil and 20% of compost. The experiment was launched on June 6, 2022, and the first measurements were made two weeks later. All measurements were performed with the CRDS gas measurement device Picarro G2508 (Picarro Inc., USA California). All data analysis was carried out using Descriptive statistics methods. The largest reduction in emissions is projected directly for methane emissions, as biocover technology is appropriate to reduce methane emissions. Other GHG emissions are also expected to be reduced. NH_3 emission measurements were also carried out to investigate the impact of the biocover on it. This experiment shows that the biocover created is effective and can be composed of material that has already been served. The experiment is intended to continue to obtain long-term data on the development of biotransformation and to develop more promising approaches in the future to reduce GHG emissions from landfills.
Key words: Reduction of methane emissions, greenhouse gas mitigation measures, biodegradation, waste disposal.

Introduction

Emissions from municipal landfills can have a significant impact on the local and global environment. By simplifying landfills, local impacts with odour emissions and global impacts with greenhouse gas (GHG) emission can be caused (Pecorini & Iannelli, 2020). The surface of landfills is an interface to an agitating waste layer and atmosphere where the air we breathe is located. It is therefore very important to separate it with a cover or biocover. A well-established biocover is capable of reducing GHG emissions from a landfill, and if it is still composed of a part of the waste, it also reduces its size and allows it to be used as a valuable raw material (Hakemian & Rosenzweig, 2007). The presence of CH_4 and O_2 in landfill biocover provides the necessary conditions for bacteria capable of distributing methane gas. It could become a natural process if we use biocover (Scheutz, Kjeldsen, & Bogner, 2009).

GHG emissions from landfills come from aerobic and anaerobic biological removal of waste. Extensive research has been carried out on GHG emissions from landfills which demonstrate the relevance of this problem (Zhang *et al*., 2019). Various studies have also demonstrated that bioocovers are suitable for landfills (Bogner *et al.*, 2005; Barlaz *et al.*, 2004; Huber-Humer & Lechner, 2001; Huber-Humer, 2004). Planned biocoverings of a thickness of 40 cm or of a more than 40 cm or more have not been systematically studied (Perdikea, Mehrota, & Patrick, 2008).

The developed biocover technology will be used to reduce emissions to smaller or older landfills where methane production or combustion is not profitable. Biocover can be used in landfills with low methane production potential, such as pre-treatment waste storage facilities.
The aim of this study is to clarify the impact of the biocover created on GHG emissions.

Materials and Methods

The overall performance of the biocover system is determined by measuring greenhouse gas (GHG) emissions, in particular by focusing on CH_4 emissions. The biggest advantage of biocover is methane oxidation, pictured in Figure 1. More than half of the CH_4 concentration as a result of the interaction with O_2 constitutes carbon dioxide and water. In this way, CO_2 is released into the air and at a significantly lower concentration of CH_4 (Scheutz *et al.*, 2011). The largest methane gaze is one of the most dangerous for our climate, with the most attention being paid during the experiment.

The biocover composition was measured using the CRDS gas measurement device Picarro G2508

(Picarro Inc., USA California). Emissions were measured both from and without the biocover system so that the actual and total reductions in GHG emissions from biocover could be assessed. Each camera was measured for 250 seconds (Grinfelde *et al.*, 2017).

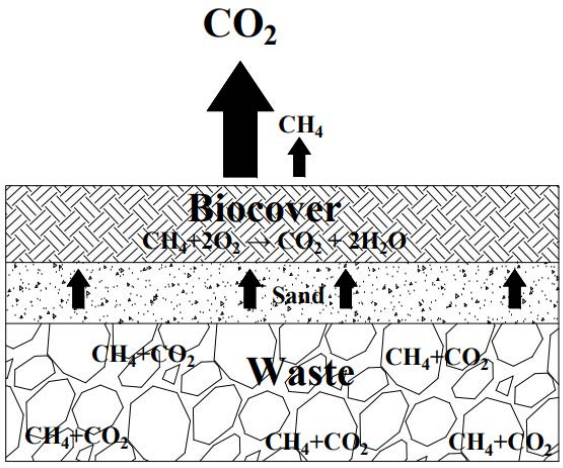

Figure 1. CH_4 and CO_2 flow from landfill through sand and biocover.

NH_3 emissions were also occurring during the measurement and are not one of the GHG emissions. It was determined because the measuring equipment also measures this gas, and its interest was applied to measurements and data analysis. Possibly, however, the installation of biocover also influences the release of this gas.

The experimental part of the study partly used the data already obtained on the dynamics of methane emissions and the analysis performed during the first three months of the experiment (Siltumens *et al.*, 2022). This helped to continue the experiment, already with a small pretext.

The whole course of the experiment was done in the laboratory, creating tube columns. Water-saturated compost was selected as a source of GHG emissions, which was mixed with small fraction waste. This constructed mass was placed at the bottom of the tube at a thickness of 500 mm. In order not to mix the compost with the bio-coating, a layer of sand was placed on top of it at a thickness of 300 mm. Finally, the biocover was applied at a thickness of 400 mm (Figure 2).

A fine fraction of waste, soil and compost was selected as a biocover stock. They were mixed in such proportions: 20% soil, 20% compost and 60% fine fraction of waste. Biocover composition is considered in Figure 3.

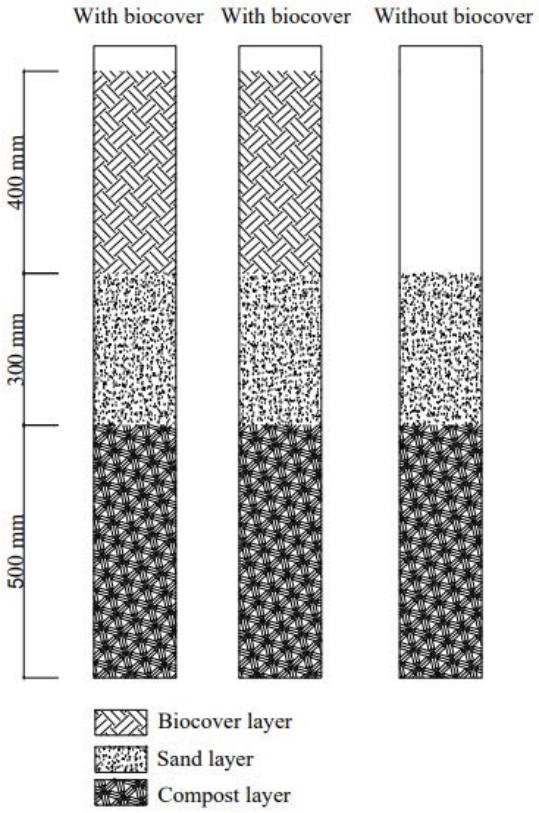

Figure 2. Schematic representation of experimental tubes.

Three tube columns were created during the experiment, two with bicover and one without. This is due to a comparison of GHG emissions with and without biocover, as well as a more realistic repetition and accurate data. Tube columns are shown in Figure 4 and and mesurment process in Figure 5.

Figure 3. Coposition of the biocover **(**20% soil, 20% compost and 60% fine fraction of waste).

Figure 4. Three experimental tubes. Two with a layer of biocover, one without.

Figure 5. Performing measurements for experimental tubes. The humidity and temperature of biocover are determined. The results obtained are given to a measuring device that determines the amount of emissions. In parallel, emissions measurement is carried out.

The experiment was launched on 6 June 2022, when all the necessary raw materials were brought in. The first measurements were made two weeks from the time of installation. This was done with a view to making the biocover sit and settle down. Measurements were carried out on a weekly basis, for 9 months. A total of 36 measurements were made. Columns created each week were sprinkled with 250 mL of water to prevent completely drying and mimic field conditions.

A suitable lid was found for experimental tubes before the measurement work was carried out. Two tubes were added to the lid, one for air intake and the other for air discharge (Figure 5). At the beginning of the measurements, the lid was placed on the particular tube and pumped through the air outlet pipe to the CRDS gas measurement device Picarro G2508 (Picarro Inc., USA California) (Figure 6). The air flow rate in the tube was 5 mL s^{-1}. In order to avoid entering the surrounding air into the measuring equipment, a seal was fitted to the pipe cover, thereby creating a closed measurement environment.

Figure 6. CRDS gas measurement device Picarro G2508 (Picarro Inc., USA California) with a vacuum pump. This combination enables the measurement process.

CRDS gas measurement device Picarro G2508 (Picarro Inc., USA California) displays the emission amounts obtained in real time during the entire measurement period (Figure 7). It allows you to follow a specific emission level for the entire measurement period (250 seconds). It was used to follow a tick or have a closed measurement environment, which is very important for quality data acquisition.

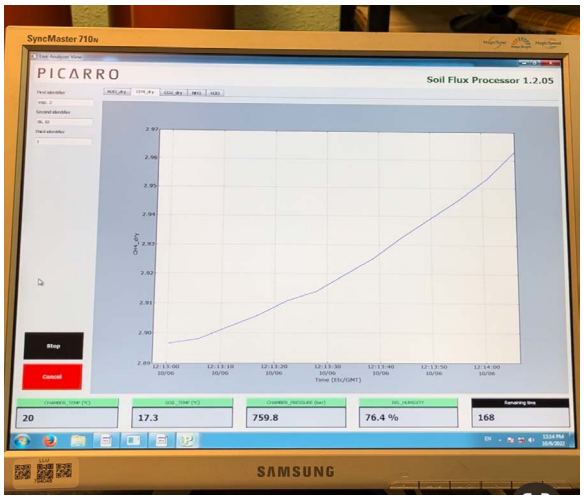

Figure 7. Real-time amount of CO_2 emissions 82 seconds.

Results and Discussion

The data was analyzed using the descriptive statistics method. This method was selected because it provides a clear overview of the properties of the dataset.

Quantitative emissions data from CRDS gas measurement device Picarro G2508 (Picarro Inc., USA California) were processed using the descriptive statistics method. Minimum and maximum values were obtained, mean and standard deviation (Table 1). The resulting values allow you to see these differences between using and not using bicover. These data will be used in the next phase in the creation of box plots to more easily compare the results obtained.

Table 1

Descriptive statistics data

Variable	Minimum	Maximum	Mean	Std. deviation
N_2O, nmol m^{-2} s^{-1} | Compost + Sand	-0.400	21.100	4.939	4.736
N_2O, nmol m^{-2} s^{-1} | Compost + Sand + Biocover	0.100	35.900	5.164	8.588
CH_4 nmol m^{-2} s^{-1} | Compost + Sand	3.800	125.300	40.109	34.973
CH_4 nmol m^{-2} s^{-1} | Compost + Sand + Biocover	0.600	131.000	25.634	31.866
CO_2, µmol m^{-2} s^{-1} | Compost + Sand	1.300	63.800	13.296	18.290
CO_2, µmol m^{-2} s^{-1} | Compost + Sand + Biocover	1.200	118.000	13.647	22.567
NH_3, pmol m^{-2} s^{-1} | Compost + Sand	-300.000	845.000	224.935	299.827
NH_3, pmol m^{-2} s^{-1} | Compost + Sand + Biocover	-270.000	828.000	143.532	187.981

In the next step, a box plot was created to align the resulting emissions data. Each of the biocover gases was compared separately to collona without biocover.

The first of emissions was analysed for NH_3 emission concentrations. When looking at the created chart (Figure 8), it can be seen that a tube column with biocover has a lower data amplitude and that the data is almost equal to the median. In contrast, a column without a biocover has a higher data amplitude and the median is quite different from the mean of the data. After that, we can conclude that biocover has smoothed out NH_3 flow and stabilized it, as well as reduced it slightly.

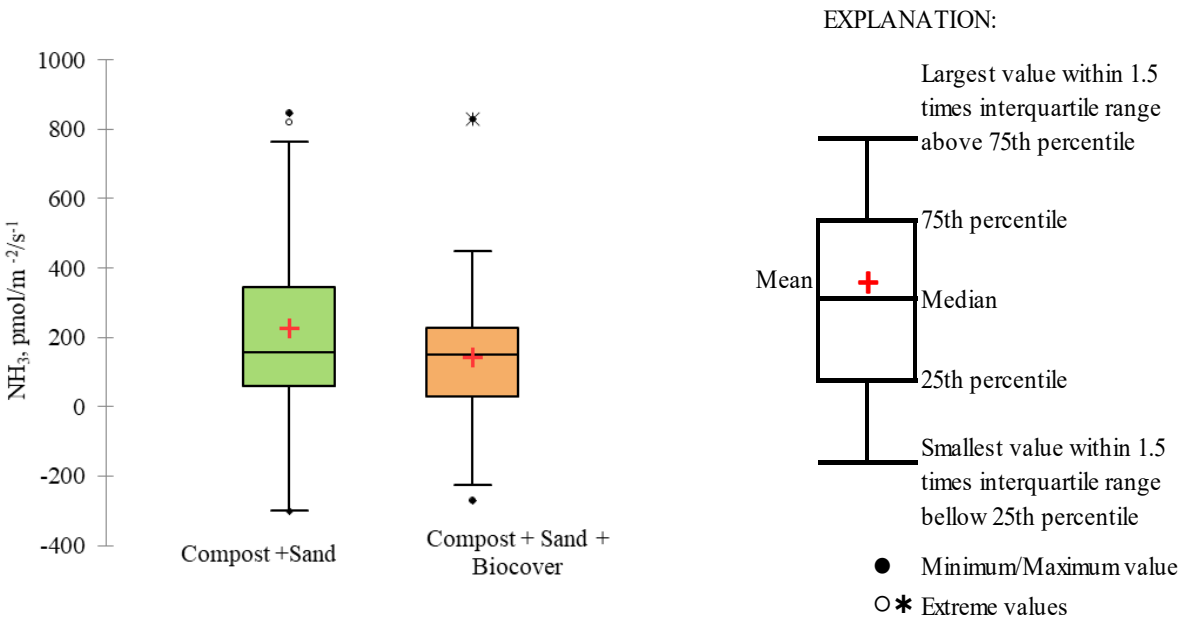

Figure 8. NH_3 emissions by experimental tube columns (NH_3, pmol m^{-2} s^{-1}).

The next analysis was the concentration of CO_2 emissions. When viewing the created (Figure 9) chart, it can be seen that the data ranges are relatively identical for both measurements. Only measurements with biocover have slightly more extreme values. The only difference significantly between the two measurements is that for biocover, most of the data has been concentrated in a smaller amplitude.

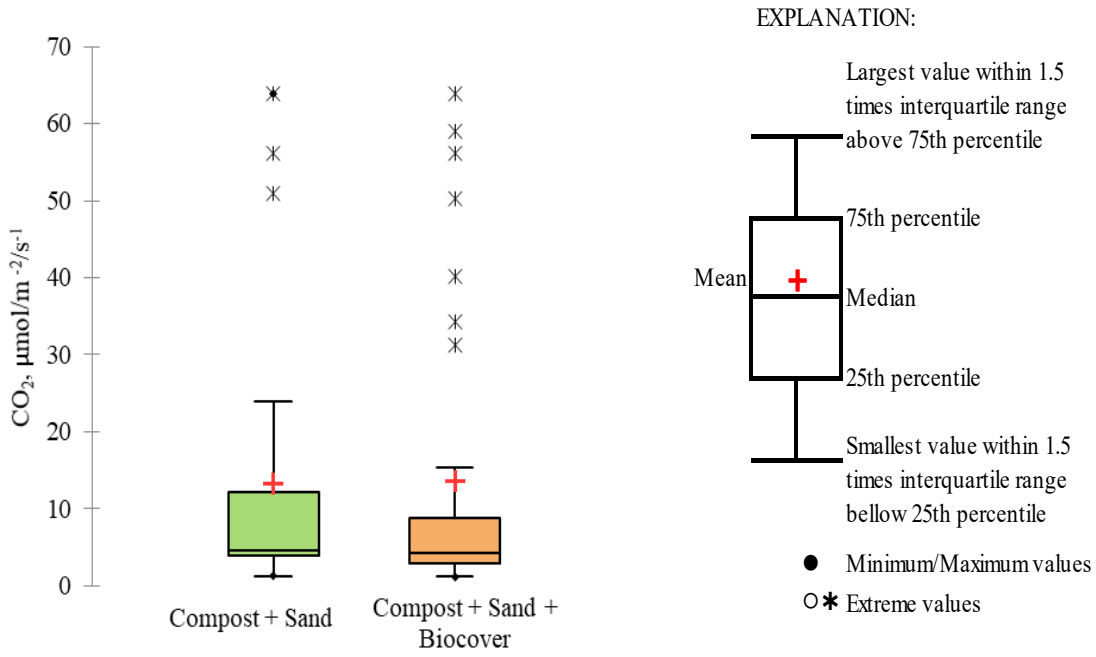

Figure 9. CO_2 emissions by experimental tube columns (CO_2, µmol m^{-2} s^{-1}).

N2O emission concentrations were analysed below. When looking at the created chart (Figure 10), it can be noticed that the tube column with biocover has slightly more extreme values than without. In contrast, the median of the data is significantly less precisely biocover. Other acquired values are relatively similar.

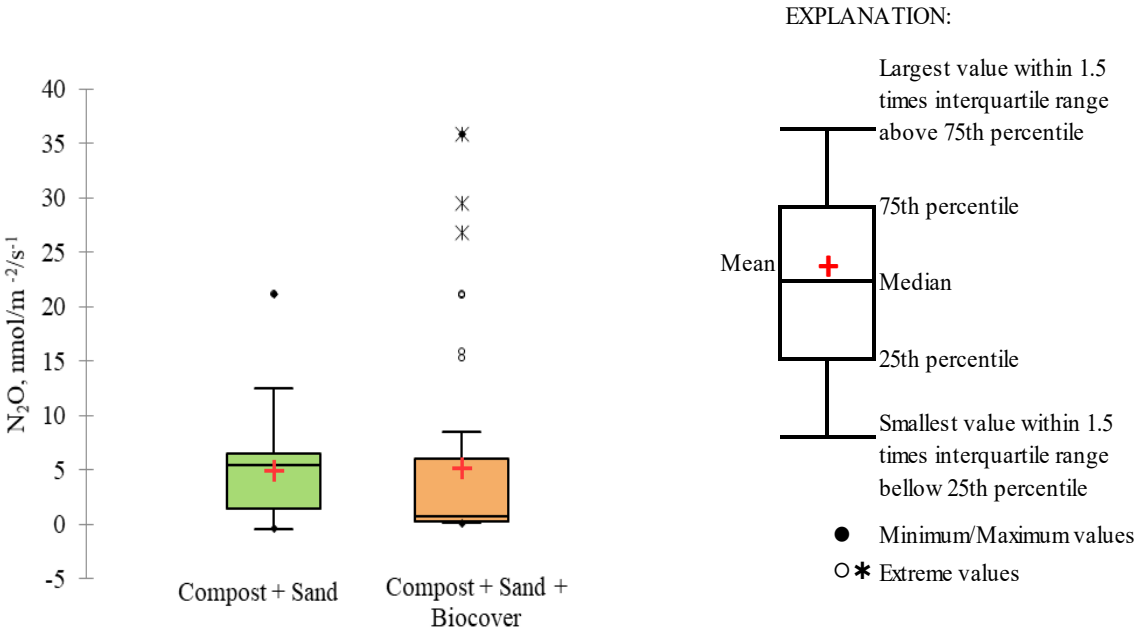

Figure 10. N_2O emissions by experimental tube columns (N_2O, nmol m^{-2} s^{-1}).

Finally, the concentration of CH_4 emissions was analysed. When examining the created chart (Figure 11), it can be seen that methane emissions from the biocover tube columns are significantly lower than without it. Lower is the median, mean of the data, data amplitude, as is the majority of the data in a lower amplitude.

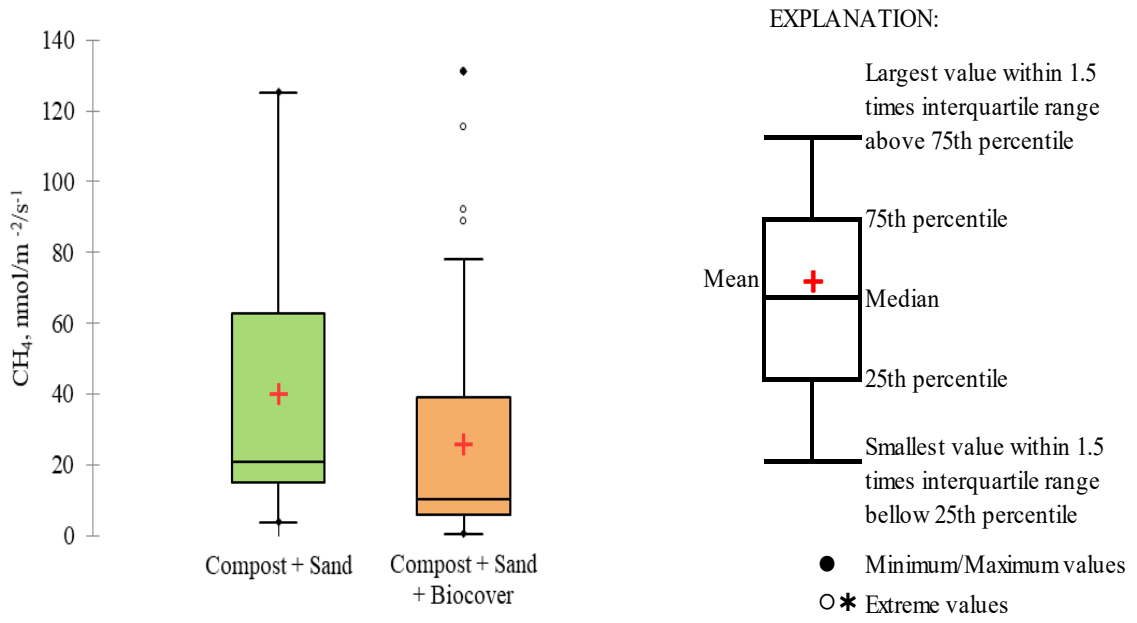

Figure 11. CH_4 emissions by experimental tube columns (CH_4 nmol m^{-2} s^{-1}).

Emissions from greenhouse gases (GHG) have been and will be a topical theme that has been supported by its escalation in recent years. In addition, landfills have a wide focus on air pollution. The results obtained are very positive as biocover was expected to have a positive impact on emissions of methane. However, it also appears to have a positive impact on other GHG emissions as well as on NH_3 emissions. Looking at other similar studies (Bogner *et al.*, 2005; Huber-Humer, 2004; Perdikea, Mehrota, & Patrick, 2008; Siltumens *et al.*, 2022), it may be observed that they place emphasis on methane emissions, which is in some way understandable because methane is the most hazardous GHG emission. After this, it can be considered that the results obtained are unique, covering all greenhouse and NH_3 gases for the materials concerned. Continuing the experiment and obtaining long-term results will be able to judge the use of this material already in landfill pilot sites.

Conclusions

The laboratory biocover experiments play a very important role with a future potential. This enables examination of the created biocover and to study the benefits and disadvantages of it in detail. Following the results, it is possible to identify the weaknesses and improve the composition of biocover. Continuing the study will make it possible to determine its effectiveness and predict the extent of the reduction in GHG emissions of the material in question.

This biocover experiment demonstrates that the created biocover is effective. The highest efficiency is observed directly on CH_4 emissions. This is a very good indicator because methane gas is the most hazardous of GHG emissions to our surrounding air and climate.

The study also shows that a largely existing material, which is a fine fraction of waste and compost, can be used to reduce GHG emissions. Biocover landfills have great potential in the future because all the ingredients used are available around the landfill site.

The experiment will be continued and further studied in order to develop more promising approaches to reduce GHG emissions from landfill in the future.

Acknowledgements

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USE OF ISOTOPES FOR IDENTIFICATION OF N_2O SOURCES FROM SOILS

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Abstract
Natural processes and human activity play a crucial role in altering the nitrogen cycle and increasing nitrogen oxide (N_2O) emissions. Nitrous oxide isotopes ^{15}N and ^{18}O are important parameters that can help to explain the sources of N_2O gas, as well as their circulation under different soil physical properties. The main goal of the study is to analyze the possibilities of using dinitrogen isotopes ^{15}N and ^{18}O, measured in soil samples, for the identification of N_2O sources. A total of 16 plots were sampled. Each soil sample was assigned a code. Wetting of the samples was carried out to create wet aerobic conditions and wet anaerobic conditions. N_2O measurements were performed in laboratory conditions using the Picarro G5131-i device. The $^{15}N\alpha$ and $^{15}N\beta$ values obtained in the measurement data were used to calculate the $\delta^{15}N^{SP}$ and $\delta^{15}N^{bulk}$ values. The obtained $\delta^{15}N^{SP}$ and $\delta^{15}N^{bul}$ values were analysed using two methods – descriptive statistics and Kruskal-Wallis test. The test showed that there are statistically significant differences between $\delta^{15}N^{SP}$ values (p-value <0.0001), and $\delta^{15}N^{bulk}$ there was no significant difference (p-value 0.885).
Key words: N_2O isotopes, soil tillage, Picarro G5131-i.

Introduction

In order for life to form and exist, several important processes take place in nature, which are based on various elements, their mutual interaction and influencing factors. One such element is nitrogen (N). Although nitrogen is the most abundant element in the atmosphere and approximately 78% of the atmosphere is nitrogen gas (N_2), most living organisms cannot use nitrogen in this way. Therefore, through various processes, for example, during the nitrogen cycle, nitrogen fixation takes place, the result of which is the formation of several complex organic compounds that are necessary for living organisms. In order to form the necessary nitrogen compounds, various compounds of nitrogen elements enter both the atmosphere and the hydrosphere as by-products in the circulation cycle, which can have a negative impact on the surrounding environment and climate. One of the compounds that have a negative impact on the climate is N_2O gas – nitrous oxide.

The importance of atmospheric N_2O in the global environment is divided into two distinct features. This property is that N_2O regulates stratospheric ozone. It is a consequence of the reaction of N_2O in the stratosphere with $O(^1D)$ radicals in the following reaction $O(^1D) + N_2O \rightarrow 2\ NO$ or $N_2 + O_2$. The reaction pathway for NO, which occurs in about 60% of cases, is the dominant source of stratospheric NO. NO participates in several catalytic cycles that contribute to the destruction of ozone. In this connection, N_2O affects several properties of the stratosphere and indirectly regulates the amount of ultraviolet radiation reaching the earth. Another important factor is that N_2O is a strong greenhouse gas. This is mainly due to its strong multi-infrared band from 7.7 to 17 mm and its long chemical lifetime of about 130 years (Brenninkmeijer & Röckmann, 1999). Nitrous oxide has 300 times the global warming potential of nitrogen oxide and plays a major role in the depletion of stratospheric ozone (Butterbach-Bahl *et al*., 2013).

Human activity has contributed significantly to global warming by increasing concentrations of greenhouse gases such as nitrogen dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). Of all anthropogenic sources of greenhouse gases, agricultural activity accounts for approximately 13% of all emissions (Abdalla *et al*., 2014).

Soils are the main source of the greenhouse gas (GHG) N_2O, accounting for about 69% of the anthropogenic atmospheric load of this gas. N_2O production is mainly biological and occurs through nitrification (oxidation of ammonia and denitrification of the nitrifier) and dissimilation of nitrates (denitrification and ammonitrification) (Figure 1) (Marinas *et al*., 2010).

GHG emissions from soil are caused by both microbial activity and the chemical processes of root respiration occurring in the soil. Emission flux rates are strongly influenced by soil moisture, soil temperature, nutrient availability and pH values, as well as crop related parameters (Chapuis-lardy *et al*., 2007). Meteorological and climatic parameters, as well as land use information, are very important for estimating GHG emissions from soil. The main factors affecting soil GHG emissions, including N_2O, have been identified (Figure 2).

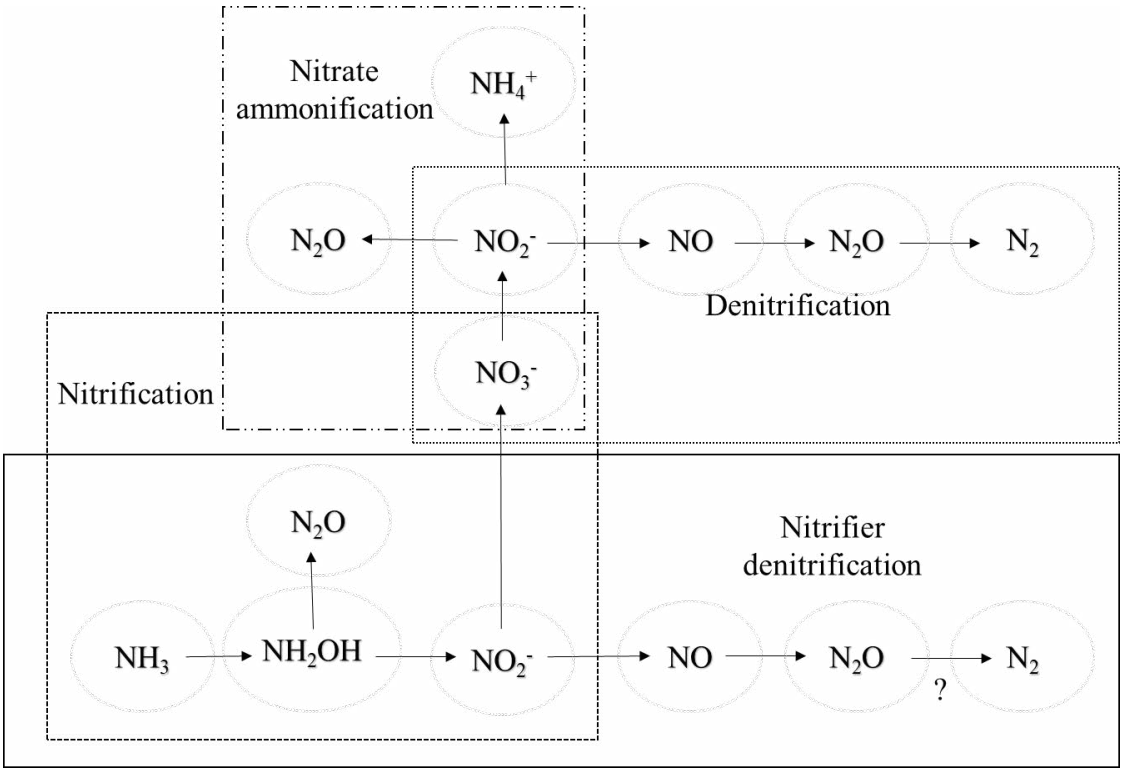

Figure 1. Microbial sources of N_2O in soil (Created by the authors after Marinas *et al*., 2010).

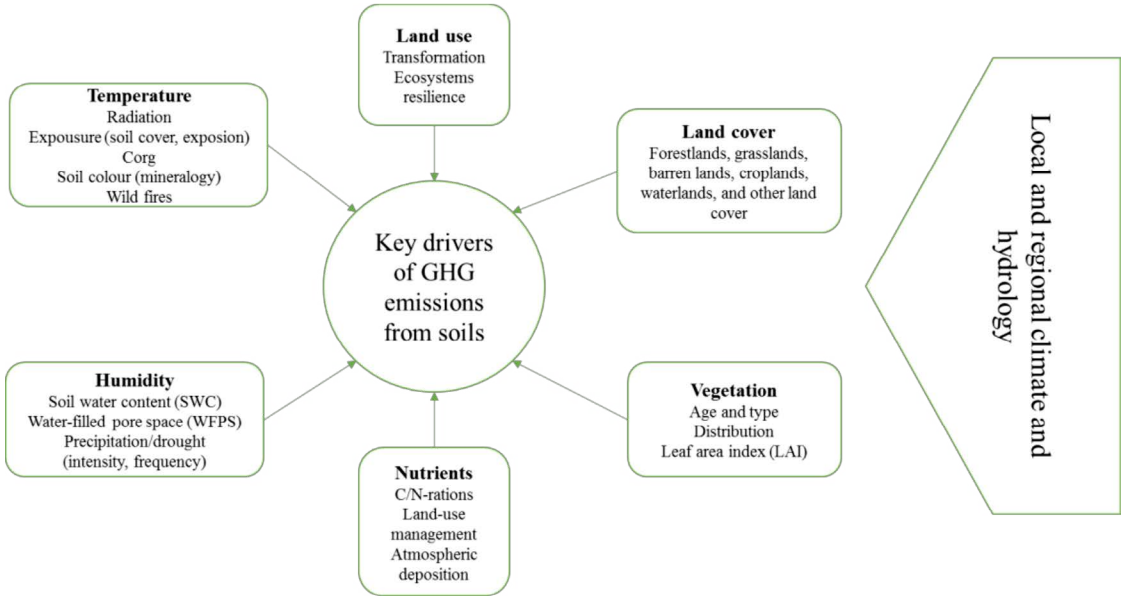

Figure 2. Key drivers of greenhouse gas (GHG) emissions from soil (Created by the authors after Oertel *et al*., 2016).

Minimum tillage and no-till systems have become widespread in various agricultural regions, almost completely replacing traditional tillage systems in North and South America (Alvarez & Steinbach, 2009). The benefits of reduced tillage compared to traditional methods include reduced diesel and energy consumption and higher productivity. Water infiltration is improved and soil erosion is reduced as plant residues are left on the field (Holland, 2004). Under the right conditions, reduced tillage can improve yields and improve energy and resource efficiency.

However, reduced tillage, especially on loam and clay soils, and in cool and wet conditions can reduce

soil aeration and stimulate N_2O emissions that offset the CO_2 reduction effect (Rochette, 2008).

Since climate change is a hot topic not only now, but in the long term, various important studies related to this atmospheric change have been conducted. Most studies related to GHG emissions from the soil are based on the physical properties of the soil – soil temperature, moisture, pH level, as well as the main microbiological processes – nitrification and denitrification. These studies have contributed greatly to understanding the global cycle of nitrous oxide. However, the study of GHG emissions is not limited to this. The role of isotopes in the study of various processes is increasingly emphasized (Zhu *et al*., 2019). Thus, nitrous oxide isotopes ^{15}N and ^{18}O are an important parameter that can help trace the sources of N_2O gas and its circulation in certain processes occurring in the soil.

Materials and Methods

Soil samples collected from 28 experimental fields were used for this study. 12 of fields are managed organically and 16 fields are managed conventionally. Two types of tillage were used for the fields – reduced tillage and conventional tillage. Experimental fields are located near Talsi town in Stende breeding and Research and Study farm of Latvia University of Life Sciences and Technologies 'Pēterlauki' (Figure 3) near Jelgava city (Figure 4).

Soil samples were taken at five locations from the field to obtain one disturbed soil sample (Figure 3, 4). This method was used because the composition of the soil within the field may vary.

Figure 3. Sampling fields points on the map at Stende Research Centre.
Soil samples were taken at five field locations at diagonal intersections, from which one mixed soil sample was created.

Figure 4. Sampling fields points on the map at Research and Study farm 'Pēterlauki'.
Soil samples were taken at five field locations in the corners of the field and in the middle of the field, from which one mixed soil sample was created.

The samples were weighed in 3-liter buckets, each bucket containing 1.5 kg of soil (Figure 5). For each experimental field, two soil samples were created, which were provided with different moisture conditions – one wet aerobic conditions and the other wet anaerobic conditions. Rainwater was used to moisten the soil samples, the samples were moistened once every three days – 150 mL of water was used for one sample and 300 mL of water for the other samples. The amount of water required for wetting the soil was calculated taking into account the weight of the soil before and after wetting and evaporation were calculated. The study was conducted in laboratory conditions.

N_2O measurements were performed in laboratory conditions using the Cavity Ring Down Spectroscopy (CRDS) device Picarro G5131-i device (Picarro, Inc., California, USA). The CRDS device Picarro G5131-i

Figure 5. Three liter buckets with mixed soil samples connected with CRDS device Picarro G5131-i.

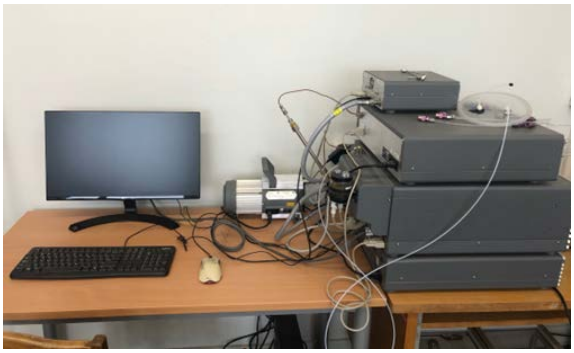

Figure 6. Isotope and gas concentration analyser CRDS device Picarro G5131-i.

Isotope and Gas Concentration Analyser enables simultaneous site-specific and bulk measurements of $\delta^{15}N$ and $\delta^{18}O$ in N_2O (Figure 6). It is an ideal solution to identify and measure the source of N_2O emissions by measuring in the laboratory. N_2O isotopes can be used to identify sources in the global nitrogen cycle by identifying nitrification and denitrification processes in soils. The G5131-i analyser measures $\delta^{15}N$, $\delta^{15}N\alpha$ and $\delta^{15}N\beta$ with an accuracy of 0.7‰, $\delta_{18}O$ with an accuracy of 0.7‰ and N_2O concentration with an accuracy of <0.05 ppb (all accuracy measurements are averaged over 10 minutes).

Each soil sample was assigned a code such as B_BA_O_1 and B_C_O_CT_1, B for organic farming type, BA for cultivated crop, in this sample forests, O for soil type, in this case organic soil, CT for tillage, in this case conventional tillage and numbers 1 and 2 denote humidity mode, 1 – normal humidity conditions, 2 – over humid conditions. These two codes are assigned to samples collected from the same field (Table 1).

The $^{15}N\alpha$ and $^{15}N\beta$ values obtained in the measurement data were used to calculate the $\delta^{15}N^{SP}$ and $\delta^{15}N^{bulk}$ values. Such a calculation is necessary for a more in-depth evaluation of the connection of isotopes with the microbiological processes taking place in the soil and to compare them with the existing research results. Calculation examples are shown in Equations 1 and 2, the data used, as well as the results, can be seen in Table 1.

$$\delta^{15}N^{SP} = \delta^{15}N^{\alpha} - \delta^{15}N^{\beta} \quad (1)$$

$$\delta^{15}N^{bulk} = \frac{\delta^{15}N^{\alpha} + \delta^{15}N^{\beta}}{2} \quad (2)$$

Table 1

Example of data matrix from Picarro G5131-i

Date	Sample	Chamber	$^{15}N^{\alpha}$, ‰	$^{15}N^{\beta}$, ‰	$\delta^{15}N^{SP}$, ‰	$\delta^{15}N^{bulk}$, ‰
18.08.2020	B_C_O_CT_1	1	3.90	2.53	1.37	3.22
		2	2.38	3.42	-1.04	2.90
		3	-0.47	4.34	-4.81	1.94

Notes: B – organic farming type; C – clover; O – organic soil; CT – conventional tillage; 1 – normal humidity conditions.

Using the calculated $\delta^{15}N^{SP}$ values, it is possible to determine and analyse microbiological processes in the soil, nitrification and denitrification can be determined. To date, several studies have been carried out on the use of N_2O isotopes for the determination of nitrification and denitrification, as well as for the observation of microbiological processes. Based on (Sutka *et al.*, 2006) the average values of studies for nitrification in soil are $\delta^{15}N^{SP}$ 33 ‰ and $\delta^{15}N^{bulk}$ – 0.9‰, while the values of denitrification are $\delta^{15}N^{SP}$ 0.1‰ and $\delta^{15}N^{bulk}$ – -23 ‰.

The obtained $\delta^{15}N^{SP}$ and $\delta^{15}N^{bulk}$ values were analysed using two methods – descriptive statistics and Kruskal-Wallis test. The Kruskal Wallis test is a non-parametric alternative to One Way ANOVA. Non-parametric means that the test does not assume that data comes from a particular distribution. The test determines whether the medians of two or more groups differ. Like most statistical tests, it calculates the test statistics and compares it to the cutoff point of the distribution. The test statistics used in this test is called the H statistics. The Kruskal Wallis test indicates if there is a significant difference between the groups.

Results and Discussion

In the conventional tillage fields, the maximum value of $\delta^{15}N^{SP}$ was 18.58‰, the minimum value is -53.41‰, and the maximum value of $\delta^{15}N^{bulk}$ was 16.28‰, the minimum value is -56.97‰. In the fields where reduced tillage was performed, the maximum value of $\delta^{15}N^{SP}$ is 14.34‰, the minimum value is -36.91‰, while the maximum value of $\delta^{15}N^{bulk}$ is 26.76‰, and the minimum value was -56.77‰.

In the table of descriptive statistics (Table 2), it is shown that there were more conventional tillage fields than reduced tillage, so conventional tillage data could be more accurate than reduced tillage. The lowest $\delta^{15}N^{SP}$ value is conventional tillage, but $\delta^{15}N^{bulk}$ minimum values are very close in both types of tillage. The highest $\delta^{15}N^{SP}$ value is conventional tillage. Mean and median values for $\delta^{15}N^{SP}$ values are lower than for bulk values.

Table 2

Descriptive statistics (Quantitative data) of N2O $\delta^{15}N^{SP}$ and $\delta^{15}N^{bulk}$ values by conventional tillage and reduced tillage

Statistics	$\delta^{15}N^{SP}$ | CT	$\delta^{15}N^{SP}$ | RT	$\delta^{15}N^{bulk}$ | CT	$\delta^{15}N^{bulk}$ | RT
No. of observations	1188	324	1188	324
No. of missing values	0	0	0	0
Minimum, ‰	-53.408	-36.906	-56.973	-56.766
Maximum	18.579	14.342	16.279	26.758
1st Quartile	-9.052	-15.369	0.465	2.100
Median	-3.313	-7.542	5.082	4.483
3rd Quartile	2.074	-0.307	8.362	7.569
Mean	-4.086	-7.818	0.275	3.332
Variance (n-1)	75.841	106.624	198.168	126.629
Standard deviation (n-1)	8.709	10.326	14.077	11.253

Analysing the values of $\delta^{15}N^{SP}$ depending on the type of tillage, it can be seen that the largest amplitude is reduced tillage, while the amplitude of conventional tillage is smaller, and more extreme values and outliers are visible in conventional tillage. Median value for conventional tillage are -3.313‰, but for reduced tillage -7.542‰. Mean value for conventional tillage is -4.086‰, but for reduced tillage -7.818‰. We can see that mean values are lower for bot soil tillage's (Figure 7).

Analysing the values of $\delta^{15}N^{bulk}$ according to the type of tillage, it can be seen that the largest amplitude is conventional tillage, while the smaller amplitude is reduced tillage. Maximum values and outliers are significantly more in conventional tillage, but less in reduced tillage. Median value for conventional tillage are 5.082‰, but for reduced tillage 4.483‰. Mean value for conventional tillage is 0.275‰, but for reduced tillage 3.332‰. We can see that mean values are lower for both types of soil tillage (Figure 8).

The obtained $\delta^{15}N^{SP}$ and $\delta^{15}N^{bulk}$ values were analysed using two methods – descriptive statistics and Kruskal-Wallis test. The test showed that there

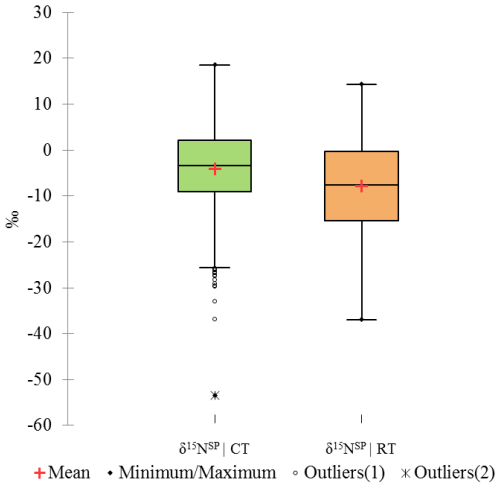

Figure 7. The value of N_2O $\delta^{15}N^{SP}$ distribution by conventional tillage (CT) and reduced tillage (RT).

are statistically significant differences between $\delta^{15}N^{SP}$ values (p-value <0.0001), and $\delta^{15}N^{bulk}$ there was no significant difference (p-value 0.885).

In the past, studies of N_2O GHG emissions from soil have also been conducted, and these studies have

addressed several factors that should be taken into account.

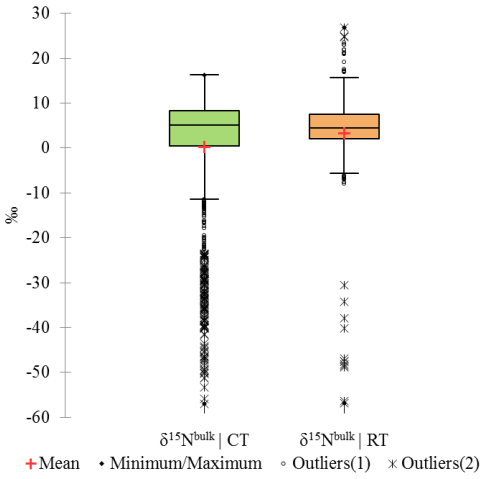

Figure 8. The value of N_2O $\delta^{15}N^{bulk}$ distribution by conventional tillage (CT) and reduced tillage (RT).

In (Zalite *et al*., 2021) research, clay soil and GHG emissions were addressed. GHG emissions from clayed soils by crop groups, the Kruskal-Wallis test shows a statistically significant difference in the effect of cultivated crops on GHG emissions. N_2O emissions showed a statistically significant difference between crop groups. This indicates that the type of soil is also a very important factor affecting greenhouse gases that should be taken into account.

Conclusions

1. The CRDS device Picarro G5131-i is successfully used to measure N_2O isotopes in soil under laboratory conditions, which provides an in-depth study of N_2O.
2. N_2O is an isotopically complex molecule, but isotopes of this molecule and $\delta^{15}N^{bulk}$ and $\delta^{15}N^{SP}$ are valuable for tracking soil N_2O emissions and microbiological processes.
3. The obtained $\delta^{15}N^{SP}$ and $\delta^{15}N^{bulk}$ values were analysed using two methods – descriptive statistics and Kruskal-Wallis test. The test showed that there are statistically significant differences between $\delta^{15}N^{SP}$ values (p-value <0.0001), and $\delta^{15}N^{bulk}$ there was no significant difference (p-value 0.885).
4. The calculated data for $\delta^{15}N^{bulk}$ and $\delta^{15}N^{SP}$ indicate consistent results, with some exceptions, as well as their changes over time. However, it does not give a clear picture of the microbiological processes of the soil under the relevant conditions.
   Median value for conventional tillage are -3.313‰, but for reduced tillage -7.542‰. Mean value for conventional tillage is -4.086‰, but for reduced tillage -7.818‰.

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PERSPECTIVE MOVING TOWARDS THE IMPLEMENTATION OF CIRCULAR ECONOMY IN THE WASTEWATER SECTOR: THE CASE STUDY OF LATVIA

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Abstract
The transformation from a linear to a circular economy model is a political priority of the European Union to develop sustainable and more efficient raw materials and waste management. The wastewater sector is an important element in the circular economy with a great potential for resource recovery such as phosphorus recovery from waste streams. With this in view, the present study's aim was to analyse data on municipal wastewater treatment plants (>2,000 p.e.) in Latvia and the present situation with newly developed circularity indicators on waste reduction, pollutants removal, resource recovery and water reuse; thus, enabling evaluation of the level of transformation towards circularity in Latvia's wastewater treatment plants and their future perspectives. The results showed that the wastewater sector in the country complies with legal obligations, but on the other hand, only a few solutions are practised in compliance with the principles of circular economy, i.e., reduction of wastewater discharge and increasing sewage sludge utilization as fertilizer in agriculture.
Key words: circular economy, wastewater treatment, sewage sludge, nutrients, phosphorus, Latvia.

Introduction

The transition to a circular economy (CE) is a political priority of the European Union (EU) to develop a low-carbon, resource-efficient, sustainable, and competitive economy (Mazur-Wierzbicka, 2021). The CE concept was adopted in 2014 in the first European Commission (EC) communication 'Towards a circular economy: a zero waste programme for Europe'. In 2015, the first CE action plan 'Closing the loop-an EU Action Plan for the Circular Economy' was adopted, including measures and legal requirements to accelerate the transition towards a circular economy (Mazur-Wierzbicka, 2021). In the action plan, a detailed definition of CE was also introduced: 'an economy, where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized' (European Commission, 2015). In 2020, EC adopted 'A New Circular Economy Action Plan. For a Cleaner and More Competitive Europe' which is one of the main building blocks of the European Green Deal. In the second action plan, the importance of the water and wastewater sector in the transition toward CE is highlighted especially in the field of water reuse and recovery of nutrients (European Commission, 2020a; Smol *et al*., 2022).

Water and wastewater management is one of the biggest challenges in CE. Predominantly, the water management sector faces difficulties in implementing the conditions of the Water Framework Directive (2000/60/EC) on how to achieve effective optimisation of wastewater treatment plants to prevent insufficiently treated wastewater discharge into natural streams (Wuijts *et al*., 2023), as well as water scarcity, which affects regions located in the Southeast and Southwest of Europe in particular. Although the risk of water scarcity is not generally forecasted for the Latvian region (Garrote *et al*., 2018), the rapidly increasing effects of climate change indicate that the Latvian region is increasingly predisposed to the risk of seasonal water scarcity in the period from July to September (European Environment Agency, 2023). On the other hand, the effects of climate change pose a threat to urban wastewater management as the stormwater from heavy rainfalls results in overloading of wastewater treatment plants (WWTP) or even causes stormwater overflows and discharge of untreated sewage into the environment. For instance, in Latvia from 2017–2019 regular sewage overflows occurred in at least 7 out of 49 overflow sites of WWTP (> 10,000 p.e.) (The State Environmental Service, 2020). It is considered to be one of the most pressing problems of the water management sector, as its mitigation requires large financial investments (Quaranta, *et al*., 2022). Moreover, sustainable management of solid waste is becoming an increasingly topical issue relevant to the governance of water management, striving towards a circular economy. The management of sludge generated in the water purification process is also included in the agenda of Latvian policymaking. The National Waste Management Plan states that it is essential to establish good

infrastructure in the existing landfills for the processing of biodegradable waste in combination with sludge from domestic wastewater treatment plants (Cabinet of Ministers, 2021a). At the same time, there is no integrated and holistic approach to sludge management in Latvia, one of the shortcomings being the lack of a national strategy for wastewater sludge management (Geo Consultants, 2020). However, Latvia's National Energy and Climate Plan foresees that environmentally and economically sustainable solutions for sewage sludge management will be applied in Latvia by 2030 – wastewater management infrastructure will be modernised and expanded, reducing the risks of environmental pollution, and preventing the accumulation of sludge in water management companies (Cabinet of Ministers, 2021b).

In order to evaluate the current situation regarding the transformation towards the CE model in the water and wastewater sector, a new CE framework monitoring is developed. Based on existing 'xR' models in waste management, the EU waste hierarchy (European Parliament, 2008) and comprehensive literature analysis, Smol, Adam & Preisner (2020) introduce six following actions to implement CE principles in the water and wastewater sector: reduce, remove, reuse, recycle, recover and rethink. 'Rethink' can be applied to all other actions in the CE model (Figure 1).

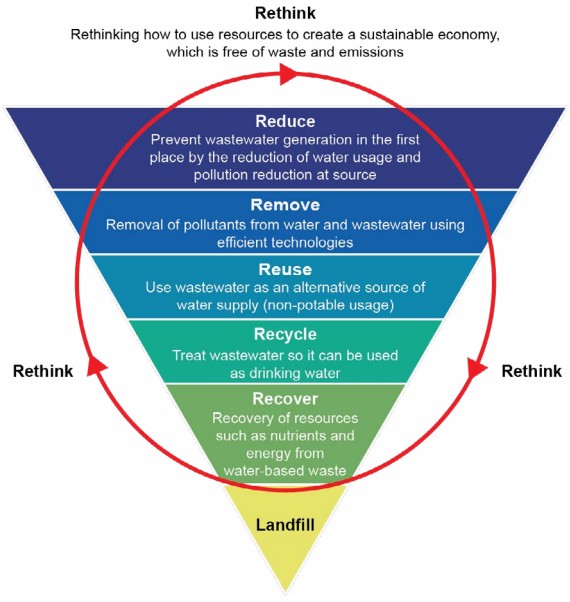

Figure 1. Circular economy model framework in the water and wastewater sector (based on Smol *et al*., 2022).

One of the most frequently applied CE principles in the water management sector is the reuse of water from both treated wastewater and collected stormwater. Good practices cover various solutions in any water use cycle, starting from harmonised water minimum use to a site-based approach for treated wastewater use in agriculture irrigation systems, energy or industrial use like technical water, and effluent discharge in constructed wetlands (Voulvoulis, 2018). As a result, a reduction of the impact of the forecasted water stress and scarcity that will affect half of Europe's river basins by 2030 is expected (European Commission, 2012).

Furthermore, the wastewater sector has been identified to have high potential in terms of nutrient recovery due to the significant amount of phosphorus (P) and nitrogen (N) concentration in all municipal WWTPs (Preisner *et al.*, 2022). For example, numerous pilot and full-scale techniques for P recovery can be integrated into one of three stages of the wastewater treatment process: 1) P recovery from direct agricultural utilization of dewatered sludge; 2) P recovery from undrained sludge after anaerobic digestion, e.g., AirPrex, Seaborne or recovery from sludge liquor after dewatering, e.g., Anphos, Ostara Pearl, Struvia; 3) P recovery from ash after incineration, e.g., AshDec, EcoPhos (Schoumans *et al*., 2015; Chrispim, Scholz, & Nolasco, 2019). Recovery of P via wastewater can decrease imported P lost as waste to 55% (Jupp *et al*., 2021) solving two dovetailing problems: 1) the risk of phosphorus shortage as it is a critical raw material (European Commission, 2020b), 2) the overabundance of P in water systems leading to eutrophication (Smol *et al*., 2020).

This article presents the results of a study aimed at assessing the circularity of the wastewater sector in Latvia using the novel CE model framework proposed by Smol, Adam & Preisner (2020) as well as analyzing the potential for further development.

Materials and Methods

The indicators used to evaluate the transition of the wastewater sector in Latvia to a CE were based on Smol, Adam & Preisner (2020), Preisner *et al.* (2022) and Kruopienė & Žiukaitė (2022) scientific publications where indicators are identified and summarized through a detailed literature review. In this work, 8 indicators were used, covering four actions to implement CE principles (Table 1).

The current situation was evaluated by analyzing data spanning from 2009 to 2021. Data were collected

Table 1

Indicators used in this work to evaluate the transition towards CE in the wastewater sector

No.	Indicators	CE model actions
1	Water consumption and wastewater discharge	Reduce
2	Wastewater service coverage	
3	Nutrient removal efficiency	Remove
4	Effluent inorganic content	
5	Pollutant content indicator for the recovered sewage sludge	
6	Reuse of water for industrial and non-potable applications	Reuse
7	Sewage sludge processing	Recover
8	Biogas production	

on municipal WWTPs in agglomerations where more than 2,000 p.e. of wastewater is generated. In 2019, there were 74 such agglomerations, while in 2021 only 56. Information necessary for computing and evaluating the indicators was obtained from various sources including the 'Latvian Environment, Geology and Meteorology Centre' (LEGMC) database, EC reports, feasibility studies, river basin management plans and LIFE GoodWater IP project's assessments results of the current situation in Latvia regarding the sewage sludge.

Results and Discussion

1. Reduction

It is necessary to integrate the principle of prevention in reducing pollution by enabling the reuse of both purified wastewater and products formed in the purification process as sewage sludge (Mazur-Wierzbicka, 2021). The prevention and reduction principle starts with sewage inclusion into the treatment processes (Voulvoulis, 2018). The number of wastewater treatment facilities in Latvia is increasing, for instance, in 2019, 1,301 wastewater treatment facilities were registered in the LEGMC database. Of these, 302 treatment plants were operating with primary treatment (mechanical WWTP), 936 with secondary treatment (biological WWTP), and 31 with biogenic reduction (WWTP with tertiary treatment in addition to N, P reduction) (State statistics report, 2022). While the total annual amount of wastewater to be treated in Latvia fluctuates, 99% of sewage is treated in line with EU legislation. In addition, 99% of urban wastewater meets all requirements of the Urban Wastewater Treatment Directive (91/271/EEC) (UWWTD) (Water Information System for Europe 2020), instead of 98% of urban wastewater collected and 75.8% satisfactorily treated on average in the EU (European Economic and Social Committee, 2023).

1.1. Water Consumption and Wastewater Discharge. 2009–2021 the total volume of discharged wastewater in Latvia has slightly decreased from 186,9 up to 176,6 million m^3 per year. A significant part of the total volume is carried out by the Riga wastewater district treatment facilities. For instance, in 2020, the total volume in Riga was 52.04 million m^3, which is 27% of the total volume of wastewater discharged into the environment in Latvia (State statistics report, 2022). From the proportion of urban wastewater collected and treated as a percentage of the total population, 62% of sewage is treated with stringent 'tertiary' treatment, mainly to reduce nutrients (European Environment Agency, 2020). Changes in lifestyles, improving the standard of living as well as climate change impacts significantly increased water consumption during recent years both in absolute terms and per capita (Garrote *et al*., 2018). In Latvia, annual water uses at a household level increased from 80.68 million m^3 in 2010 to 96.30 million m^3 in 2019 (Eurostat, 2022a).

1.2. Wastewater Service Coverage. The share of the Latvian population connected to at least secondary urban wastewater treatment has increased significantly from 58.9% in 2010 to 80.4% in 2020. In the period from 2002 to 2010, the increase was less progressive - from 51.1% to 58.9%. Among the Baltic countries, Estonia has the highest coverage with urban wastewater treatment – 83% of the population in 2020, but Lithuania has the lowest – 77% (Eurostat, 2022a). Access to centralised wastewater collection

systems in Latvia by agglomeration division is different. Only two cities – Riga and Daugavpils - correspond to agglomeration with >100,000 p.e. In Riga, access to centralised systems was 95.1%, while in Daugavpils it was 90.9% of inhabitants in 2019. In the division from 10,000 to 100,000 p.e. accessibility was for 95% of inhabitants, and around 62,000 inhabitants have decentralised wastewater systems in 2019. In agglomerations from 2,000 to 10,000 p.e. access was 82%, which is 16% lower than in UWWTD stated, and around 49,000 inhabitants were decentralised wastewater systems in 2019 (Ismade, 2020). The coverage of household water use from public water supply per inhabitant in Latvia has a slight decrease from 37.8% in 2005 to 37.6% in 2020. For Lithuania, the data show a more rapid increase from 19% to 27.4%, but still holding a lower position in 2020 than in Latvia. Data about Estonian household water use from the public water supply is not available (Eurostat, 2022a). Latvia has gradually enhanced the coverage of centralized wastewater systems. However, there is still work to be done on UWWTD goal achievement.

2. Removal

2.1. Nutrient Removal Efficiency. The entire territory of Latvia is defined as a highly sensitive territory, which is subject to higher requirements for municipal wastewater treatment. Such requirements are followed because the eutrophication levels of the inland waters of Latvia and the Baltic Sea are one of the most urgent environmental problems. To address this issue, in Latvia's largest cities, it is crucial to treat collected wastewater and reduce the pollution of N and P. In 2019, from all 1,301 WWTPs (including those in agglomerations <2,000 p.e.) 58 facilities discharged insufficiently treated wastewater into various water bodies in Latvia, thereby significantly worsening the water quality of rivers and lakes. This type of situation arises because the largest number of WWTP in Latvia is located in small agglomerations but enhanced N, P reduction is required only for urban areas where p.e. is more than 10,000 (Water Information System for Europe, 2020; The State Environmental Service, 2022).

2.2. Effluent Inorganic Content. Elevated levels of nutrients in water bodies are a key factor in causing eutrophication, a global issue that causes harmful algal blooms, hypoxia, and degradation of freshwater ecosystems (Smol *et al.*, 2022). Since 2009, the discharge of nutrients into the environment via treated wastewater has fluctuated, but decreasing trends have been evident, particularly since 2011. Analyzing the amount of pollution discharged into the environment, the total amount of N and P concentration from 2015 has decreased annually (Figure 2).

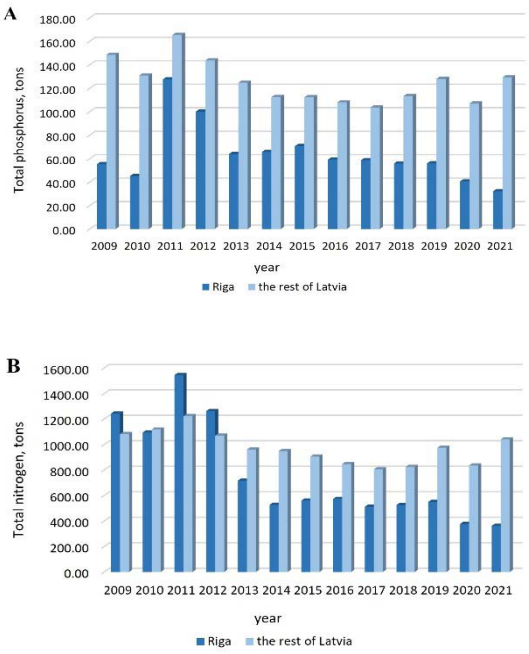

Figure 2. Total phosphorus (A) and total nitrogen (B) discharged with wastewater per year (LEGMC, S.a).

The implementation of Directive 91/271/EEC has led to significant reductions in N and P emissions. However, urban WWTPs are still a significant contributor of these pollutants to the environment (Water Information System for Europe, 2020). Technological advancements and best practices have shown that the current emission limit values set under the directive are outdated and need to be strengthened. To address this, tertiary treatment should be mandatory for all urban wastewater treatment plants with a capacity of 100,000 p.e. or more as they are a significant source of N and P discharge (European Commission, 2022a). The capital of Latvia (Riga) discharges the largest amount of wastewater, resulting in the highest residual N and P pollution being released (LEGMC, S.a). Similarly, in Lithuania, most of the discharge is largely determined by the largest WWTP.

If this plant were excluded, the percentage of N and P in total discharge would be reduced to 54–56% and 40–42%, respectively (Kruopienė & Žiukaitė, 2022).

2.3. Pollutant Content Indicator for the Recovered Sewage Sludge. In Latvia, the possibility of using sludge is affected by the quality class of sewage sludge, which determines the allowable concentration values of heavy metals, the presence of microbiological pathogens and agrochemical parameters by distinguishing five quality classes of sewage sludge (Cabinet of Ministers, 2006; Dejus *et al*., 2021a). Heavy metal pollution in sewage sludge in Latvia mostly corresponds to Class 1 – the highest quality. In the study of the analysis of sewage

sludge, digestate and compost samples carried out as part of the LIFE GoodWater IP project, only one case was found when the concentration of heavy metals exceeded Class 2 (the concentration of nickel and chromium in the sludge), which is most likely related to the uncontrolled discharge of production wastewater into the central sewage system (Dejus *et al*., 2021b).

3. Reuse

It is known that out of 40,000 million m^3 of treated wastewater in the EU, only 964 million m^3 is reused (European Commission, 2022a). Within the Interreg Europe programme AQUARES project, it was determined that the most socio-economically beneficial solutions for water reuse in Latvia should concern management and sustainable use of stormwater. Such good practice examples have also been implemented in Latvia – Bioswale at the shopping centre Spice Home parking lot, and Tukums District Branch of the State JSC 'Latvian Road laying Maintenance' in Kandava, where stormwater was used for car washing and sand reused for road coverage in the winter season, creating company savings on drinking water in the amount of EUR 4089 in six years. Increasingly, solutions relating to rainwater management are more frequent in Latvia with the aim of relieving the burden on centralized wastewater systems. Another good example is Evopipes, a company that reuses water multiple times in the cooling process of the production of plastic pipes, thus reducing the total amount of water used (Interreg Europe, 2020).

4. Recovery

4.1. Sewage Sludge Processing. In Latvia, the production of sludge is growing rapidly – in 2017 WWTPs produced 22,995 t, in 2018 – 23 145 t, and in 2019 – 22,530 t of dry matter of sewage sludge, while theoretical calculations indicate that extent could be even 13–19% higher (Dejus *et al*., 2021b). Latvia's sewage sludge production (dry matter) per inhabitant was 16.5 kg, compared to 22.50 kg on average in the EU (Bianchini *et al*., 2016). 40% of total sewage sludge is generated by WWTP in Riga, which is the largest facility in Latvia and treats about half of the total volume of centrally treated wastewater.

Sludge management solutions have changed significantly over the last decade (2010–2020). The main utilization methods of sewage sludge in Latvia are related to agricultural use, composting and temporary storage (Table 2). Still, a high amount of sludge – 3,600-10,600t – is in temporary storage. Nevertheless, the amount of sludge in temporary storage tends to decrease from 34% to 47% of the total amount in 2010–2014 to 16–22% of the total amount in 2018–2020 (Dejus *et al*., 2021b). In 2018, peak composting proportion was reached, with 36% of the total amount of sludge, but in recent years, a trend of reduction of composted sludge has been observed in Latvia: 23% in 2019, and 20% in 2020. On the other hand, starting from 2018, the proportion of treated sludge in agriculture has been increasing, reaching 28% of the total amount of sludge in 2020. Taking into account that both the compost, in the preparation of which sewage sludge is used, and digestate from biogas production are mainly used in agriculture, it can be considered that the main purpose of utilisation of sewage sludge in Latvia is for field fertilisation in agriculture (Dejus *et al*., 2021b; Eurostat, 2022b).

Table 2

Sludge generation and processing from WWTP in agglomerations > 2,000 p.e. (based on Eurostat, 2022b)

Year	Total	Agricultural use		Compost		Incineration		Landfill	
	Mg $Year^{-1}$	Mg $Year^{-1}$	%	Mg $Year^{-1}$	%	Mg $Year^{-1}$	%	Mg $Year^{-1}$	%
2016	25.92	4.25	16.39	7.71	29.7	0	0	0.15	0.57
2017	24.94	3.32	13.31	5.72	22.93	0	0	0.02	0.49
2018	24.59	4.29	17.44	8.84	35.94	0.98	3.98	0.07	0.28
2019	24.17	6.23	25.77	5.49	22.71	0	0	0	0
2020	23.15	6.46	27.9	4.66	20.12	1.57	6.78	0.73	3.15

Similarly, in neighbouring countries sludge is also significantly used in agriculture and compost, e.g., in Lithuania 30% for agriculture and 21% for compost in 2020 (Kruopienė & Žiukaitė, 2022).

4.2. Biogas Production. Currently, biogas production from sewage sludge is one of the potential future

perspectives worldwide, which can reduce the use of fossil natural gas. Biogas can be produced via anaerobic digestion from municipal waste, sewage sludge and animal waste rich in organic matter (Makisha & Semenova, 2018). In 2020, there were 49 operating biogas power plants owned by agricultural organizations in Latvia with a total capacity of 56,636 MWe. According to the data provided by the Latvian Biogas Association, there is currently one biogas plant in the country which operates using only sludge (WWTP 'Daugavgriva'). Two plants use food production residues and/or sewage sludge, while the other biogas plants mix sewage sludge with biomass from the agricultural sector (Dejus *et al.*, 2021c).

In Latvia, one of the challenges regarding sludge usage in biogas plants is the price of biogas which is higher than for other energy resources, incl. fossil fuel, so the maintenance of its market requires subsidy-type support, about which there is currently no clarity, and it is possible that its payment can be terminated, thus endangering the future availability of existing infrastructure and the long-term stability of sewage sludge treatment, recycling and utilization (Dejus *et al*., 2021b).

Conclusions

The data analysis, which aimed to evaluate the circularity and perspective of the wastewater sector in Latvia, indicated the main achievements and challenges that should be focused on in the further development of this sector. The results revealed that:

1) During the last decade, the total volume of discharged wastewater in Latvia has slightly decreased from 186,9 up to 176,6 million m^3 per year. In addition, water consumption is not currently a concern as it is among the lowest in the EU.
2) Removal efficiency of nutrients in wastewater increases every year, thus preventing eutrophication in surface waters and the Baltic Sea.
3) There is no reuse and recycling of wastewater in Latvia mainly due to the availability of sufficient water resources. Nevertheless, there are good practice examples of stormwater, process, and cooling water reuse in the country.
4) With an upward trend the main solutions for sewage sludge utilization are field fertilization in agriculture (28%) and composting (20%) while a still large amount of sludge is placed in temporary storage.

In order to accelerate circularity in the wastewater sector in Latvia and other EU countries, firstly change in the policy documents would be necessary starting with Urban Waste Water Treatment Directive (UWWTD). EC is already planning significant and necessary changes in UWWTD: 1) to expand the scope of the Directive to cover all urban agglomerations above 1,000 p.e. (in Latvia incl. more than 70 WWTP); 2) to further and set a more strict limit for nutrient releases; 3) treatment of N and P will be applied to all larger facilities also above 10,000 p.e. as well as 4) stricter changes to be set in the settlement of decentralized wastewater facilities (European Commission, 2022b).

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OIL SPILLS DETECTION BY MEANS OF INFRARED IMAGES AND WATER QUALITY DATA USING MACHINE LEARNING

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Abstract
The paper presents the results of the research on oil spill detection using machine learning methods such as Support Vector Machine (SVM) for classification of infrared images and Logistic regression for water quality parameters. This paper focuses on real time detection of oil spills using infrared images and water quality data obtained by RPA equipped with multi-sensor payload. The developed Naïve Bayes (NB), SVM and Logistic regression classification models for prediction of oil spill have been successfully tested in real experiment conditions. All developed classification models were tuned using grid search method and main tuning parameters to determine the optimal parameters. The proposed complex algorithm for identification of oil spills using infrared images and water quality parameters is evaluated by experiments in real environment conditions. The proposed algorithm is based on the binary SVM and NB classification of infrared images and the classification of water quality parameters using the machine learning method logistic regression allows to rapidly and with high accuracy identify any oil pollution of water. Proposed complex algorithm achieves higher accuracy and efficiency; moreover, the developed machine learning models will further reduce the probability of human error and save man-hours of work.
Key words: RPA, machine leaning, SVM, oil spill.

Introduction

Oil pollution as a result of oil transportation activities and accidental oil spills is the main factor that influences water quality in an area contaminated by oil. This paper focuses on real time detection of oil spills using infrared images and water quality data obtained by RPA equipped with a multi-sensor payload. Operational monitoring of large sea aquatorium areas with the aim of detecting oil pollution is now carried out using various technical devices – satellites, seagoing vessels and various aircraft (Zavtkevics & Urbaha, 2022). Taking into account that oil spills cannot be completely eliminated, the main objective is to develop multi-sensor RPA payloads for more efficient and sustainable water monitoring and management in line with the WFD 2000/60/EC requirements (Zavtkevics & Urbaha, 2022). The main objective of the paper is to consider the problem of oil spill detection using machine learning methods such as Support Vector Machine (SVM) for classification of infrared images and logistic regression for water quality parameters. Taking into consideration the complexity of monitoring with RPA equipped with an infrared camera and water quality sensors, it would be feasible to develop a complex algorithm for identification of oil spills using infrared images and water quality parameters. Moreover, performance of machine learning models and complex algorithm for identification of oil spills need to be evaluated by experiments in real environment conditions.

Materials and Methods

Oil, which is optically thick, absorbs solar radiation and reemits a portion of this radiation as thermal energy, primarily in the 8 to 14 mm region (Urbahs & Zavtkevics, 2017). Remote sensing using an RPA equipped with an infrared camera can detect thin oil film temperature that due to the contrast may appear different than the surrounding water both during the day and night. For oil spill detection, an image clustering is required, since the image of the water surface in the case of an oil spill is not homogeneous, and it is necessary to identify the oil slick as a separate object (Xing *et al*., 2015). Infrared images of water surface allow using different processing techniques for machine learning to define oil slicks and films. The main reason of creating the dataset by experiments in laboratory was the necessity to develop an innovative oil spill detection system based on machine learning techniques using infrared images of oil spills. A sufficient number of training samples and their representativeness are critical for image classifications (Hubert-Moy *et al*., 2001). Experiments for creating a data set were conducted out of the laboratory on sunny days under the real environment conditions according to experiment settings. Oil and water temperatures were measured using the infrared thermography system, and infrared images were taken in the real time. Infrared images were processed using segmentation, and pixel values were extracted as features (He *et al*., 2015). Processed data were used for creating a data set in csv format using developed python software. On the first step, method's K means was proposed for segmentation of an RPA infrared image for using to segment object of interest such as oil slick from water surface background. In the dedicated case of oil slick detection on water surface, the main objective is to select abnormally measurable features

to a group and collect other features to another group (Al-Ruzouq *et al*., 2020). Because of the high efficiency of the K means algorithm, it is widely used in the clustering of large-scale data (Capó, Pérez, & Lozano, 2017). This approach allows to segment an image into the following categories: oil slick and clean water to simplify the image and visualize oil slick's sectors using labelling for future processing for determination of oil spill border coordinates. For achieving maximum efficiency of K means method, optimal number of clusters K, into which data set will be clustered, was determined using Elbow method. The Elbow method was implemented using Python integrated development environment and indicated that K=4 is the optimal number of clusters for infrared images data set. K means is quantization simple method that is optimal for initial data analysis of an unlabelled real data set obtained during experiments. On the second step, two machine learning classification methods were used for classification: NB and SVM.

Two stage approach for infrared images of oil spill analysis with probability machine learning method using data set of an oil spill is more precise because NB classification is a probabilistic algorithm. On the second step, the NB method was used to predict classification from pixel values based on the training data set, created by classification model. It is likely that data obtained using remote sensing for oil spill detection was distributed according to the Gaussian probability density. For a reliable and efficient classification of oil slicks on water aquatorium, surface and probably oil pollution spills are required to implement probabilistic classification methods after clustering an image. NB model was developed for the classification of pixels and implemented for oil spill prediction using an experiment data set with infrared images. NB is based on Bayes theorem, but it defines that all features are independent. It is considered that NB classifiers, which make the simplifying assumption that the features are independent of each other, given the label (Duda & Hart, 1973). Therefore, advantages of NB classification are simple models that can achieve high level of accuracy. The implementation of Naïve Bayes is a simple algorithm used in the machine learning based on assumption that variables in the data set are not correlated. Correlation coefficient of variables is zero. For increased performance, simplification and increased accuracy, a data set is split into two random and independent subsets. First subset will be used for training of a model and second for evaluation and testing of performance of classifier model on real online data that were not applied for training of a model. For optimal oil slick detection on the second stage using NB classification, a training data set was created in real experimental conditions.

SVM is a reliable machine learning classification method for binary classification when classification labels in the data set are known (De Kerf *et al*., 2020). The data set developed in the laboratory by experiments in real conditions consists of different oil types labelled infrared images according to performing procedure. The main advantage of using SVM in an oil pollution detection missions is effective processing of high amount of data from different sensors of multi-sensor payloads. SVM finds a hyperplane that is a hyperplane in a feature space induced by a kernel K (the kernel defines a dot product in that space (Wahba, 1990)). The advantage of using SVM methods for oil spill detection is reliability to perform dividing data into two classes and possibility to create a model on small data sets. Pixel values as features were extracted to create a data set labelled with assumption that there are only two classes and further applied in the developed classification SVM model. For implementation of the developed SVM model, infrared oil pollution images, created according to the experiment procedure, these were reshaped to a two-dimensional array and three colour values (RGB). The data set A used in binary classification is a two-dimensional data set consisting of n points with assumption that there are only two classes yi $\in$ {+1,−1}, where yi is class label of data. The liner model was formulated by equation (1).

$$y_n [w^T x_i + b] \begin{cases} \geq 0 \text{ if oil spill detected} \\ < 0 \text{ if oil spill not detected} \end{cases} \quad (1)$$

where w^T is a weight vector;
T is size of training data set;
w_i is input vector;
b is bias.

In case of water contamination by oil, as a result of chemical and physical processes, the complex water quality parameters change. Measurement of complex water quality parameters in real time will provide the detection of oil spill and water quality parameters in the area of the oil spill as well as the degree of pollution. As a criterion for the quality of water in the oil spill area, physical and chemical parameters that correlate with oil pollution and can be used for classification, are taken for detection of an oil spill. The proposed method for classification of an oil spill is based on the concept of electrical conductivity of oil. Deviation of water conductivity from standard range could indicate water pollution

from oil products. In the oil spill zone, conductivity of water reduces from standard value due to lower conductivity of oil.

The electrical conductivity of water is a physical parameter by which oil pollution of water can be estimated. The level of dissolved oxygen that is the chemical parameter, is effected by oil sheen, that reduces oxygen diffusion process through air water surfaces rate. The oil layer directly can also cause the dissolved oxygen level in the water to become low due to the obstruction of the diffusion process from the air (Ifelebuegu *et al*., 2017). In the oil spill area, pH critical chemical parameter of eco system is considered acidic due to presence of heavy metals from oil. The lower pH in zones 1 and 2 could be attributed to either the presence of heavy metals from the oil spills or mainly from humic acid which resulted from the decomposition of forest materials in the river (Beadle, 1974). The experiments conducted in the laboratory confirmed the existence of the above mentioned dependences. Physical and chemical parameter changes have been observed conducting experiments in the laboratory in real conditions according to the experiment protocol. Logistic regression (LR) analysis is widely regarded as the statistic of choice for situations in which the occurrence of a binary outcome is to be predicted from one or more independent variables (Hosmer & Lemeshow, 2000). The mathematical formulation of logistic regression model for the oil pollution detection is proposed as a binary classification problem with the following predictor variables: pH, electrical conductivity, dissolved oxygen and dependent variable Y that can take the values 1 or 0. Taking into account the small dimensions off the data set, non-linearity, minimal number of sampling points and high volume of water quality data in the oil spill area a logistic regression model was developed to improve efficiency of monitoring. The deviation of quality parameters from standard seasonal values is a sign of oil pollution and a criterion for assessing the threat to the ecosystem in the area of oil pollution. The objective is analysing three parameters, such as conductivity pH, DO correlated with oil spill; therefore, a number of features taken is three.

In the developed complex machine learning algorithm (Figure 1), first, IR images segmentation using K means method is performed to identify segments with possible features of an oil spill from water surface background.

Using water quality parameters algorithm to detect oil pollution uses machine learning logistic regression using the developed model. At the final stage of the proposed algorithm, accuracy of classification results of the IR image and water quality parameters are evaluated.

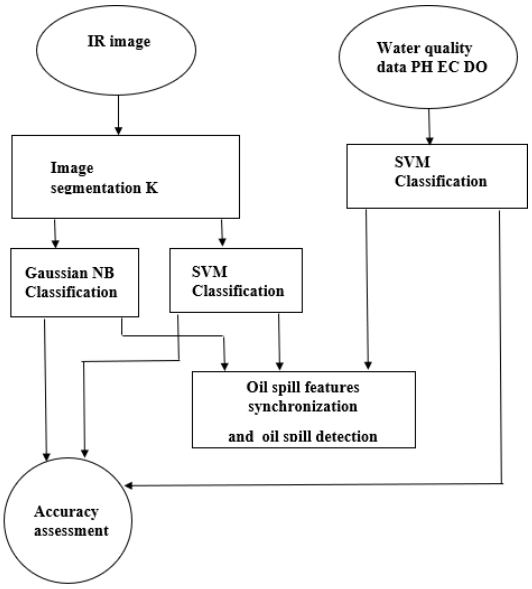

Figure 1. The developed complex machine learning algorithm.

Results and Discussion

The developed NB, SVM and logistic regression algorithms were run using Python environment. The NB and SVM model validation has been performed using the datasets that have been divided into training subset 70% and testing subset 30%. NB and SVM algorithms were used for IR image classification and detection of an oil spill. The logistic regression algorithm was used for the water quality parameters classification and prediction of an oil spill. The logistic regression algorithm validation has been performed using water quality dataset that has been divided into training subset 70% and testing subset 30%. In the oil spill experiment in the real environmental conditions, findings of NB, SVM and logistic regression were recorded and analyzed to estimate the performance of each developed classification model. The developed classifier tools were tuned according to appropriate procedures and parameters to achieve high accuracy results. A series of developed model runs was carried out using grid search approach to determine optimal parameters of SVM, NB and logistic regression for optimization performance. The developed NB and SVM oil spill classification models have been successfully tested in real experiment conditions in the laboratory using thermal camera images for classification of oil spill in a glass tank. In both NB and SVM models, image processing was started with K-means clustering. Afterwards, clusters of images were processed separately by NB and SVM models. The IR image of a controlled oil spill in the laboratory after segmentation was processed by NB model using

the data set, which was created to test model. Figure 2 demonstrates the result of processing using the developed NB model.

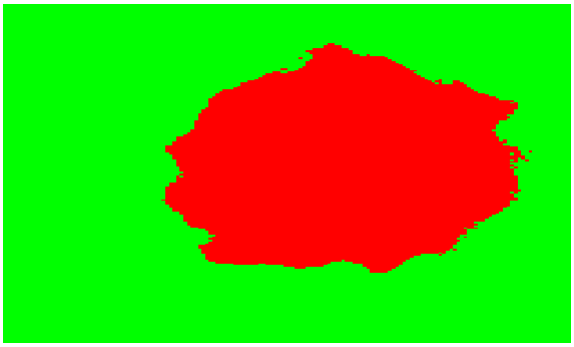

Figure 2. Result of processing using the developed NB model.

After processing using binary classification method, we have received resulting image with two classes: oil and water. It is likely that binary classification gives reliable results that can be used for determination of the oil slick border. When the RPA finds some areas of the border of an oil slick, these coordinates can be used to calculate the probability of spreading (Urbahs & Zavtkevics, 2020).

The IR image which was used for the NB model was processed by the SVM model using the data set which was created to test the model. Figure 3 shows the result of processing using the developed SVM model. After processing using the SVM method, we have received the resulting image with two classes: oil and water. It can be seen that the SVM model gives reliable results that can be used for detection of the oil slick border.

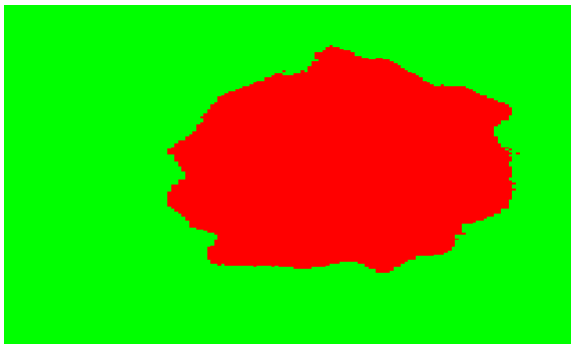

Figure 3. Result of processing using the developed SVM model.

It can be seen that oil spill has been correctly classified using the developed SVM and NB model; however, there is a small difference between the SVM and NB results. It is expected that there are differences between resulting images obtained after classification by two independent methods, as the NB is a generative model, while the SVM is a discrimination model.

To perform evaluation of accuracy and testing of the proposed model, IR images of engine and hydraulic oil slicks were created according to the experiment protocol in the real environmental conditions. The initial preprocessing of IR images for the NB and SVM methods was performed using the K means method for segmentation of oil. Based on the analysis of the training and test data sets, as the main parameter RBF kernel of the SVM method was selected, and the classification of infrared oil spill images was performed using it. For the machine learning SVM method, the accuracy of the classification results for IR images of engine and hydraulic oil slicks are presented in Table 1. The grid search using various pairs of penalty parameter C and hyperparameter gamma was conducted with the objective to define values with the best accuracy of the cross validation. The results of the experiments allow to derive the following dependencies: the best results of accuracy are obtained by C 150 with a gamma from 0.1 to 100. Taking into account the absence of recommendations on the choice gamma, the optimal value of gamma for model was set 1/n where n is the sample size.

Based on the analysis of the training and test data sets, as the main parameter variances smoothing of the NB method was selected, and the classification of infrared oil spill images was performed using it. For the machine learning NB method, the accuracy of the classification results for IR images of engine and hydraulic oil slicks are presented in Table 2. Variances smoothing is using float value provided to calculate the largest variances of each feature and adding it to the stability calculation variance. The results of the experiments allow to derive the following dependencies: it is likely that the best results of accuracy are obtained by variances smoothing 1e-9. Variance smoothing is used to improve model stability by adding a portion of largest variances for each feature to variances. Variance smoothing 1e-9 will be used to increase model stability. Based on accuracy assessment, it is determined that SVM method has better results than NB Gaussian classification method. It should be pointed out that the performance of the SVM is better in comparison with NB, as NB is a probabilistic machine learning method.

The logistic regression model of water quality data was run using hydraulic oil and engine oil spills modulated in plastic containers in the lab according to the experiment in the real conditions. For the machine learning logistic regression method, the accuracy of the classification of oil spill using parameters such as conductivity, dissolved oxygen, pH of engine and hydraulic oil slicks results are presented in Table 3.

Table 1

The accuracy of the classification of results for IR images using SVM method

Penalty parameter (C)	Hyperparameter gamma				
	0.1	1	10	50	100
0.1	95.4545455	95.4545455	95.4545455	95.4545455	95.4545455
1	95.4545455	95.4545455	95.4545455	95.4545455	95.4545455
10	95.4545455	95.4545455	95.4545455	95.4545455	95.4545455
50	95.7118353	95.7118353	95.7118353	95.7118353	95.7118353
100	95.7118353	95.883362	95.883362	96.054885	95.7118353
150	96.1406518	96.1406518	96.1406518	96.1406518	96.1406518

The grid search using various of C known as a 'hyperparameter', and regularizations and l1; l2 was conducted with the objective to define values with the best accuracy of the cross validation. The results of the experiments and grid search allow to derive the following dependencies: the best results of accuracy are obtained by C 100 with a regularization l1; taking into consideration the unavailability of recommendations on the choice of regularizations, the optimal value of regularization for model was set to 11. Due to the fact that the data set was created by real experiments reflecting real water quality data in the oil spill area, the optimal value of the parameter C was set to 100 as to define the data set data is more important.

Table 2

The accuracy of the classification of results for IR images using NB method

Variances smoothing	2e-9	1e-9
Accuracy	93.22	93.4

Table 3

The accuracy of the classification of oil spill using parameters such as conductivity, dissolved oxygen, pH

	Hyperparameter (C)				
	0.01	0.1	1	10	100
Regularization (l1)	97.299509	99.714379	99.924669	99.973017	99.978368
Regularization (l2)	97.188976	99.5494215	99.851346	99.945659	99.975567

Accuracy of the proposed complex algorithm was evaluated by an evaluating metric that takes into account the number of true oil spill detections in relation to the total size of experiment data set formulated in the equation (1).

The accuracy of the proposed complex algorithm for oil spill detection that includes SVM, NB developed models and logistic regression model with data set of defined water quality parameters was evaluated using experimental data set by evaluating metric that takes into account the number of true oil spill detections in relation to the total size of experiment data set formulated in the equation (2).

$$A=TD/N \quad (2)$$

where A is accuracy;
TD is true oil spill detection number;
N is size of experiment data set.

The accuracy of the proposed complex algorithm

is 99.5%; that is a significant value and allows to decrease false detections. It is likely that the extracted information about oil spill by the pixel values as features using SVM model has a clear distinction between oil slick and water. It can be seen that after pre-processing using K means clustering and classification based on the developed SVM model, the resulting image has a clear boundary of the oil spill.

Use of the logistic regression method for water quality parameters is reliable and efficient for detection.

The comparison of accuracy between the SVM model, NB model and logistic regression model allows to conclude that all the developed algorithms have sufficient performance; however, the logistic regression has better accuracy. Each classifier and logistic regression function was tuned using a grid search method and main tuning parameters to determine the optimal parameters of developed classification models.

Logistic regression is one of machine learning classification methods that uses logistic function for prediction of a categorical dependent variable which predicts two maximum values (0 or 1). Therefore, logistic regression function as a binary classification method can be implemented to determine probability of oil spill using the set of independent variables such as water quality parameters.

The state of a water ecosystem during monitoring of oil spills using RPA with multi-sensor payload is determined by many properties such as infrared image of the surface and water quality indicators. The proposed algorithm is based on the binary classification of infrared images and the classification of water quality parameters using the machine learning method logistic regression; the machine learning method allows to identify any oil pollution of water.

During the monitoring, using RPA equipped with thermal camera and water quality sensors, the value of the maximum deviations of water quality parameters and preprocessed infrared images classified by SVM and NB are used to determine the separation of clean water and oil slick. Using the proposed complex algorithm using for monitoring of oil spills RPA, taking into account that currently data collection of oil spill and water quality in the spill area are collected manually and require a lot of human resources, will significantly decrease labor cost of monitoring. The proposed complex algorithm allows to perform data analysis more efficiently; moreover, the developed machine learning models will further replace the manual work of the graphical information systems operators, reduce the probability of human error and save man-hours of work.

Conclusions

The proposed complex algorithm using thermal camera images and water quality parameters obtained by RPA is reliable and allows to detect oil spills in real time. The oil pollution monitoring using RPA requires a qualitative analysis using an IR camera and quotative analysis such as pH, conductivity; therefore, developed complex oil pollution detection algorithm will increase reliability and detection accuracy. The developed NB and SVM oil spill classification models have successfully been tested in real experiment conditions in the laboratory using thermal camera images. The logistic regression model of water quality data was run using hydraulic oil and engine oil spills modulated in plastic containers in the laboratory according to the experiment in the real conditions and demonstrated higher accuracy in comparison with SVM and NB models. Each classifier and logistic regression function were tuned using a grid search method and main tuning parameters to determine the optimal parameters of the developed classification models. The proposed algorithm is based on the binary SVM and NB classification of infrared images, and the classification of water quality parameters using the machine learning method logistic regression allows to rapidly and with high accuracy identify any oil pollution of water. The proposed complex algorithm achieves higher accuracy and efficiency; moreover, the developed machine learning models will further reduce the probability of human error and save man-hours of work. The present research has demonstrated that after experiments and grid search, optimal parameters of the developed models were determined and the detection accuracy of complex algorithm achieved 99.5%.

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PostDoc Latvia | NATIONAL DEVELOPMENT PLAN 2020 | EUROPEAN UNION European Regional Development Fund
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WATER STABLE ISOTOPES AS DRINKING WATER QUALITY INDICATOR IN DUG WELLS OF EASTERN LATVIA

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Abstract

Stable isotope ratios of water (δ^2H and $\delta^{18}O$) are important indicators which describe hydrological processes in the environment. These parameters allow to analyse structure, status, migration of pollutants and processes of the groundwater system. Groundwater from dug wells is widely used as a drinking water source highlighting the importance of investigation of water quality and its possible flows and sources. Despite available centralized water systems, there are still wide territories where dug wells are the main source of drinking water supply. Dug wells are recharged from shallow groundwaters which makes them more vulnerable to anthropogenic contamination. Therefore, quality monitoring and estimation of anthropogenic influences are of importance. Quality requirements of drinking water do not provide measurements of stable isotope ratios in drinking water, but the combination of those elements can be valuable for the characterization of impacts on groundwater quality. The aim of this study was to survey 64 dug wells in Eastern Latvia and analyse water quality together with measurements of stable isotope ratios. Measurements were performed twice, i.e., autumn and spring to track water sources in wells and describe the extent of possible impacts. This approach can indicate the magnitude of local factor impacts on drinking water quality. Surveyed wells provide high differences in analysed parameters, for example, nitrate concentrations in autumn varies from 0.44 to 108.26 mg L^{-1}. Also, other detected parameters are variable; therefore, tracking water flow with stable isotope values gives better insight into the water quality of the studied region.

Key words: stable isotope ratio, drinking water, quality, dug wells.

Introduction

A significant source of drinking water is water supply from wells, especially in the countryside where centralized water supply possibilities are economically and technologically not feasible (Swistock *et al*., 2013; Adelakan *et al*., 2010; Fontenot, 2013). For water supply dug wells (excavated large diameter well, relatively shallow) as well as drilled wells (boreholes) can be used. The depth of drinking water wells depends on the geological structure of the well installation site and the distance to water-saturated layers, usually in Baltic countries it is not more than 20 m and thus water quality in such wells can easily be affected by anthropogenic contamination as well as other factors affecting groundwater level and quality, including climate change. Water from wells is used as a drinking water source worldwide (Klavins *et al*., 2016; Swistock *et al*., 2013; Adelakan *et al*., 2010). However, water quality control of these individual water supply facilities is not as intensive as it is for centralised water supply systems. On the other hand, water quality in wells can be used as a tool to characterise groundwater quality, groundwater flow patterns, intensity of anthropogenic pollution and other processes directly affecting groundwater quality. Several surveys have demonstrated high vulnerability of groundwater quality in wells, and elevated concentrations of contaminants (Han *et al*., 2016; Kitterød *et al*., 2022; Jadeja *et al*., 2022). Commonly high concentrations of nutrients like nitrogen compounds, phosphates, and pesticides have been found coming from agricultural applications of agrochemicals in agricultural areas, but microbiological contamination has been found from multiple human or animal faecal sources influenced by on-site specific factors (Khatri et al., 2015; O'Dwyer *et al*., 2018). Another major group of substances are of natural origin, such as inorganic substances, but also trace elements, such as heavy metals or arsenic seems to be a general problem affecting water quality in dug wells as well as boreholes (Wongsasuluk *et al*., 2014; Bai *et al*., 2022). Considering the vulnerability of water quality in wells, it is important to continue the search for new water quality characterisation tools to better understand drinking water contamination sources and processes affecting water quality.

A versatile tool for groundwater characterisation stable hydrogen (δ^2H) and oxygen ($\delta^{18}O$) isotope ratio analysis can be considered, which is a tool widely used for the characterisation of groundwaters (Hunt *et al*., 2005; Bowen *et al*., 2007; West *et al*., 2014). Stable isotope ratios are conservative at low temperature of groundwater, but they change (isotopical fractionation) in groundwaters due to inflows of atmospheric precipitation or surface waters. Thus, $^{18}O/^{16}O$ and $^2H/^1H$ ratios can be used to

identify the source and residence time of groundwater flow (Al-Kubaisi *et al*., 2022; Massmann *et al*., 2008; Darling *et al*., 2003) as well as to identify possible contamination sources.

The aim of this study was to investigate water quality in wells used as drinking water source in Eastern Latvia and analyse water composition together with measurements of light stable isotope ratios.

Materials and Methods

The studied area is located in Eastern Latvia (Figure 1), it is of glaciogenic origin and mostly consists of till sediments in the highlands. In lowlands without glaciolimnic sediments also peat sediments can be found. Differences in sediment origin and their composition with site-specific factors, including location, amount of precipitation and infiltration speed are the main factors responsible for the natural composition of shallow groundwaters. The average annual temperature is 4-6 °C with max average temperature in July (~17.5 °C) and minimal in February (~ -5.5 °C). Long-term precipitation rates vary from 550 to 650 mm per year; however, in the study period 535 mm in 2020 and 526 mm in 2021 were recorded. With respect to water recharge rates, an important aspect is the actual precipitation rates in seasons of interest, respectively in autumn 2020 from September to the end of the year there was 162 mm of precipitation, but in 2021 from January to April 61 mm. In 2021, predominant snow accumulation (14 cm) was recorded until the 21st of February when rapid melting happened, and all snow was thawed by the 26th of February.

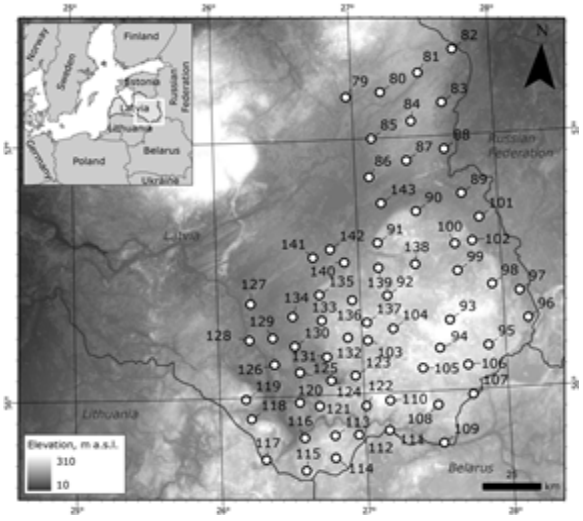

Figure 1. Location of sampling points in Eastern Latvia.

Water analysis

Water samples from wells were collected in two 1 L plastic bottles for water and stable isotope analysis and were placed at 4 °C. For the detection of phosphate ions ascorbic acid method was used, chlorine content was determined using titration, sulphate contents were determined using the turbidity method, and other nutrients were determined by spectrophotometric methods using Hach DR3800 Spectrophotometer and Hach-Lange reagents. For the turbidity HANNA HI88703 Turbidity Meter was used, and for pH and conductivity HANNA HI 2210 pH meter and HANNA HI 9932 Microprocessor Conductivity Meters were used, respectively. Macro components and trace elements were measured using an inductively coupled plasma spectrometer − ThermoScientific ICP spectrometer iCAP 7000 series.

Stable isotope ratio measurements

Stable isotope ratios of hydrogen and oxygen in water were analyzed in the Laboratory of Environmental Dating at the University of Latvia (Faculty of Geography and Earth Sciences). Isotope ratios are expressed in standard δ-notation relative to the Vienna Standard Mean Ocean Water (Craig, 1961). Both isotope ratios of hydrogen and oxygen were measured using the cavity ring-down laser spectroscopy method (Brand *et al*., 2009) with a Picarro L2120-i Isotopic Water Analyzer. The reproducibility of stable isotope measurements was less than ± 0.1‰ for $\delta^{18}O$ and ± 1‰ for $\delta^{2}H$. To assure the quality of water sampling and processing in the laboratory, internationally accepted procedures elaborated by the IAEA (Aggarwal *et al*., 2007) were followed. The laboratory has successfully participated in worldwide open proficiency tests on the determination of stable isotopes in water organised by the IAEA in 2016 and 2020 (Wassenaar *et al*., 2018).

Data analysis

Multivariate correlation, Principal Component analysis (PCA) and cluster analysis (Ward's minimum clustering method) were done using SAS JMP ® data discovery software version 17.0.

Results and Discussion

Dug wells are fed by precipitation and their infiltrate into groundwaters. Temperate climate groundwater recharge is biased towards late winter/early spring (Nygren *et al*., 2020). In the precipitation isotope ratios data are available at the IAEA/GNIP (Global Network of Isotopes in Precipitation) database. The three closest stations to the study area are Riga, Tartu and Minsk (IAEA, WMO, 2022). Considering that more recent precipitation samples are collected in station Riga, it was further chosen to represent precipitation input values.

The notion of d-excess (deuterium excess) is a

convenient way to illustrate the deviation of water isotope observation from the GMWL, calculated as d-excess = $\delta^2H - 8*\delta^{18}O$ (Craig, 1961) (Figures 2; 3), indicating the deviation of the δ^2H ‰ and $\delta^{18}O$ ‰. The weighted d-excess for local precipitation at the Riga station was 11.2‰ (Babre *et al*., 2016). The least squares fit (LSF) regression lines between two isotope ratios for the period: 2016−2022 are 9.84 $\delta^{18}O$‰ -69.8 δ^2H‰ (VSMOW).

The background isoscape for $\delta^{18}O$ in groundwater was interpolated from direct observations by Raidla et al. (2016). It varies from − 10.8 to − 11.5‰. The average of 10 direct $\delta^{18}O$ groundwater observations (Babre *et al*., 2016; Raidla *et al*., 2016) in the study area is –11.34‰ ± 0.19‰ standard deviations (SD). Direct observations are consistent with interpolated values of the isoscape. The interpolated groundwater isoscape is spatially continuous; therefore, in this study, it is used as a reference instead of individual direct observation. The mean of 7 direct δ^2H groundwater observations (Babre *et al*., 2016; Raidla *et al*., 2016) is − 78.9% ± 2.2% SD. The linear regression line between observed $\delta^{18}O$ and δ^2H has a slope of 12 ± 3 SD and an intercept of 55 ± 36 SD; note the high uncertainty. Moreover, the modelled global precipitation map (Terzer *et al*., 2013) shows that the modelled precipitation's $\delta^{18}O$ in the BAB is only slightly depleted (less than 0.5‰) with respect to the isotopic composition of shallow groundwater in the region. At the same time, our results show a difference of up to 2‰. The isotopic composition of shallow groundwater in the BAB area is depleted with respect to mean weighted annual values of local precipitation (Babre *et al*., 2016; Raidla *et al*., 2016).

The results of collected 64 samples repeated during two sampling campaigns are compiled in Table 1. Average values for all analysed samples are -10.41 $\delta^{18}O$‰ (SD 0.93) and -73.52 δ^2H‰ (SD 7.19) respectively. There are differences in the mean values for the sampling season. As expected, the mean values in the samples collected in the autumn were slightly enriched due to the more enriched isotopic input signal from the precipitation. Therefore, mean values of autumn sampling are -10.07 $\delta^{18}O$‰ (SD 0.75) and -70.78 δ^2H‰ (SD 5.88) and slightly lower spring values, i.e., -10.75 $\delta^{18}O$‰ (SD 0.97) and -76.27 (SD 7.37) δ^2H‰. Deuterium excess is less distinct and reflects the direct recharge of precipitation with the expectance of individual samples that show more pronounced evaporation during a particular season.

The stable isotope ratio range of all samples and both sampling campaigns are 5.40 ‰ for $\delta^{18}O$ and 43.52‰ for δ^2H. The difference is lower if compared to a single sampling site. Wells with a higher error between sampling timing reflect less mixed annual signal, therefore, have more seasonal recharge. This difference is noticeable in sampling sites No. 83, 87, 97, 101, 108, 128 and 133 where exceed 3‰ $\delta^{18}O$ indicating less mixed annual signal as well as higher vulnerability to contamination and groundwater droughts.

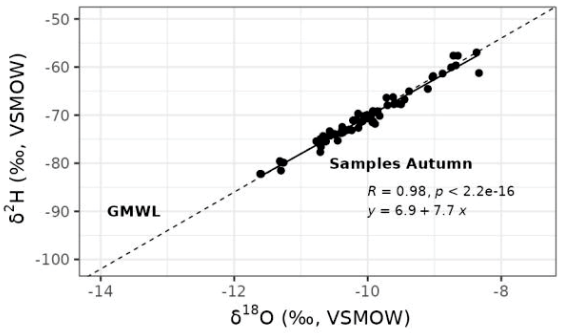

Figure 2. Water stable isotopes and regression line (filled) for samples collected in the autumn campaign with the Global Meteoric Water Line by a dashed line (Craig, 1961).

Dug well No. 101 has higher d-excess values indicating evaporation during the recharge in its origin source before autumn sampling, meanwhile, in well No. 103 has a more evaporative signal during the spring sampling. Regarding more stable isotopic signal, wells No. 82, 86, 91, 94, 95, 96, 105, 106, 111, 115, 117, 124, 126, 131 and 138−140 have almost undetectable differences in the isotopic signal between sampling campaigns, regarding both analyzed stable isotopes. These wells are considered to have more retained groundwater recharge, better mixing, longer residence times and less pronounced annual groundwater level fluctuations. However, long-term monitoring is necessary to unmistakably deduce groundwater seasonal and annual recharge for particular sites.

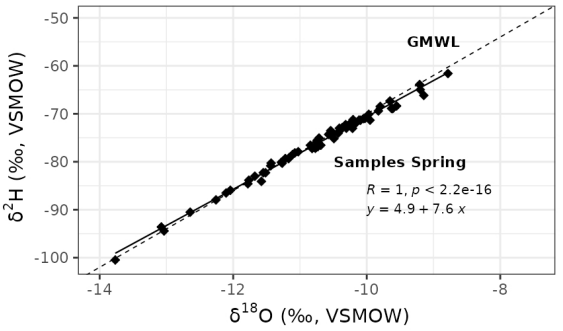

Figure 3. Water stable isotopes and regression line (filled) for samples collected during the spring campaign with the Global Meteoric Water Line by a dashed line (Craig, 1961).

The depth of studied water wells (groundwater table) in Eastern Latvia varies from 0 m to 6.5 m while the average depth is only 2.5 m. Water wells are installed mainly for water supply; however, other human activities are present in this area which can affect overall water quality. Anthropogenic activities with agricultural applications are mainly responsible for elevated amount of nutrients in groundwaters and in studied area in some wells nitrate ions exceed even 100 mg L^{-1}. In 9 over 64 wells, phosphate concentration was detected in significant amount reaching more than 1 mg L^{-1}. Despite high concentrations in the autumn season, in spring some of those parameters showed even higher values. Overall, the hardness of water in the wells of this area can be characterized as hard and very hard with only a few exceptions with soft water. Other parameters show that in Eastern Latvia wells with high water quality, that are safe for use, can be found; however, in around 15% of the studied wells some of the parameters show elevated values, for example, ammonia, nitrites, nitrates, phosphates, iron, colour, and turbidity. In 2 wells elevated sodium and chlorine content was detected which can be the result of human activities and is not coming from natural sources and their natural fluctuation in Latvia (Retike *et al*., 2016).

Table 1

Variability of analysed parameters in dug wells in Eastern Latvia

Parameters		Autumn 2020	Spring 2021
Hydrochemical parameters	NO_2-, mg L^{-1}	0.01–0.68	0.01–0.37
	NO_3-, mg L^{-1}	0.44–108.26	1.77–222.24
	PO_4^{-3}, mg L^{-1}	0.03–2.72	0.06–3.93
	NH_4^+, mg L^{-1}	0.11–2.72	0.06–0.73
	Si, mg L^{-1}	2.61–21.23	4.76–18.39
	SO_4^{-2}, mg L^{-1}	1.00–42.00	1.00–37.00
	Colour, Pt Co scale	1.00–115.00	1.00–92.00
	Conductivity, µS cm^{-1}	96.10–2127.00	6.32–1974.00
	pH	6.98–8.42	6.77–8.11
	Turbidity, NTU	0.07–5.71	0.10–12.70
	COD, mg L^{-1}	7.27–69.20	N/A
	Cl^-, mg L^{-1}	3.55–254.86	2.84–180.10
	HCO_3-, mg L^{-1}	40.26–1022.36	42.70–1008.94
	Total hardness, mg eq L^{-1}	1.43–11.17	1.74–16.23
Isotopes	$\delta^{18}O$‰, VSMOW	-11.31– -8.37	-13.77– -8.78
	δ^2H‰, VSMOW	-82.23– -56.96	-100.48– -61.60
	Deuterium excess, ‰ VSMOW	6.86–12.11	7.00–11.17
Macro-components	Ca, mg L^{-1}	7.53–159.58	7.53–159.57
	Fe, mg L^{-1}	0.007–0.52	0.007–0.50
	Mg, mg L^{-1}	2.00–107.03	2.00–90.66
	Zn, mg L^{-1}	0.005–0.62	0.005–0.61

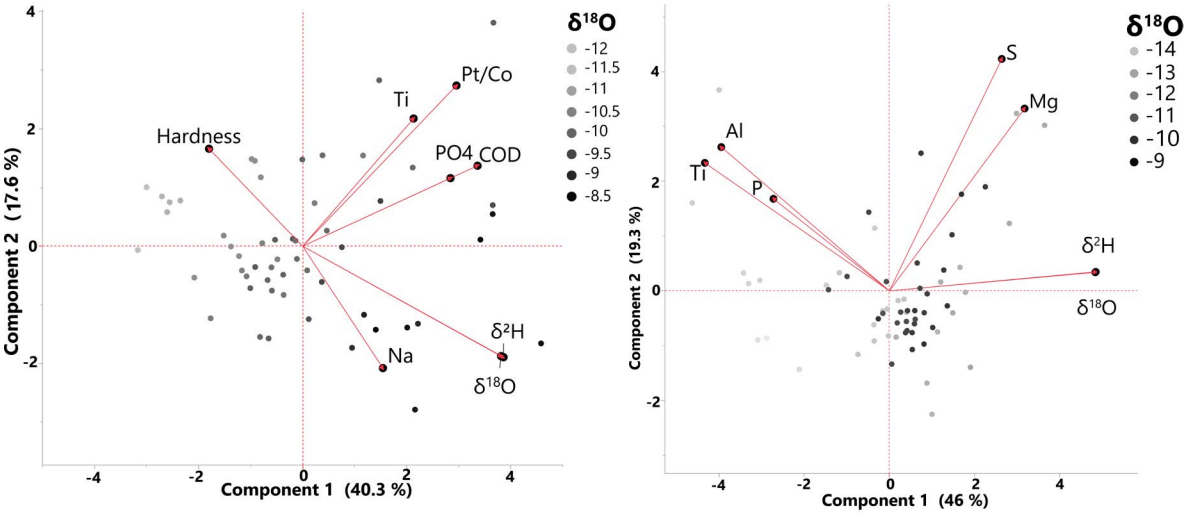

Figure 4. Principal component analysis of isotopes and hydrochemical parameters in autumn 2020 (left) and spring 2021 (right).

To track potential correlations between studied hydrochemical parameters and stable isotopes, principal component analysis (PCA) were performed.

The principal component analysis (Figure 4) matrix was not indicating a significant correlation of isotopes with analyzed hydrochemical parameters. The strongest relationship was recorded in autumn with such parameters as chemical oxygen demand (COD), phosphates, total hardness, Na, Ti and colour. Those parameters indicate major differences between relief forms with noticeable higher values for lowland, therefore, corresponding to actual differences also in isotope data.

Samples collected in spring also did not show any correlation with the measured parameters. High variability and dispersion of data was recorded which is due to the presence of snow melting water, and high variability of individual parameters between studied wells (Table 1). Only phosphorus had a detectable correlation as indicated by the PCA results from spring 2021 (Figure 4). These results can be affected by anthropogenic activities while other parameters can be influenced by both natural and anthropogenic factors and particularly in the spring when visible impact from snow thawing and soil infiltrate in groundwaters can be seen, which very well corresponds with trace elements and their concentration in snow (Pilecka *et al*., 2017) and soil media in other studies (Vincevica-Gaile *et al*., 2013).

Due to the fact that individual correlations between other studied parameters could be found, the data was analyzed using cluster analysis in order to characterize potential patterns of water quality with isotope measurements.

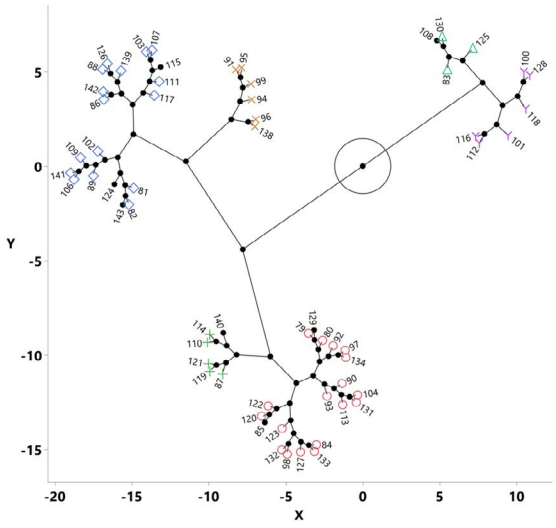

Figure 5. Constellation plot of the measured $\delta^{18}O$ and $\delta^{2}H$ in the autumn season of 2020 showing clustering of the sampled wells (No. 79−143) according to Ward's method. X and Y represent the distance overcome at each cluster joint from the origin (0;0).

Cluster analysis (Figures 5; 6) in both seasons grouped water wells into three major groups although the wells are only partially grouped between sampling seasons. In comparison to PCA analysis which showed a correlation with several parameters in water, found clusters correspond to major findings with isotope measurements in the autumn season. For example, wells No. 82, 86, 91, 94, 95, 96, 105, 106, 111, 115, 117, 124, 126, 131 and 138-140 have almost undetectable differences in the isotopic signal between sampling campaigns in the autumn season. However, these wells are grouped in one particular

cluster although in spring those wells are distributed within 2 clusters. This group of wells have a similar pattern with their location in the highland, with a tendency for average water turbidity and relatively high hardness.

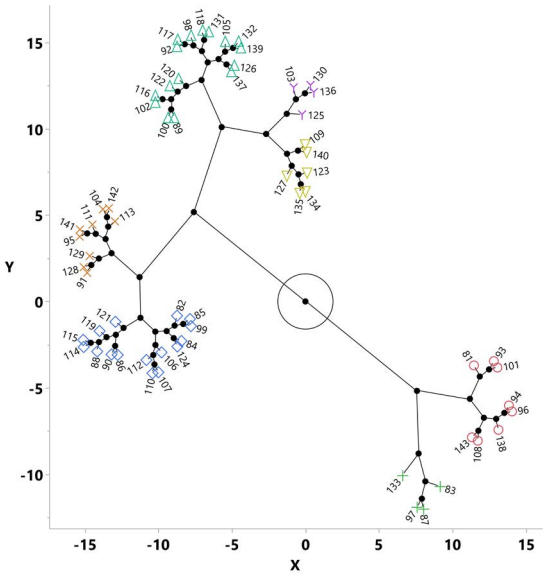

Figure 6. Constellation plot of the measured $\delta^{18}O$ and $\delta^{2}H$ in the spring season of 2021 showing clustering of the sampled wells (No. 79−143) according to Ward's method. X and Y represent the distance overcome at each cluster joint from the origin (0;0).

Other group of wells (83, 87, 97, 101, 108, 128 and 133) which due to their higher seasonal water recharge can be concluded as more vulnerable to potential contamination of groundwater made detectable distribution in cluster analysis (Figures 5; 6). Respectively in the autumn season, those wells are located in two other clusters while in the spring season, they dominantly made one cluster. In the spring season, the other two clusters grouped all other studied wells, thus indicating differences between wells and their potential vulnerability. These grouped wells by isotope data and cluster analysis detected as vulnerable ones, have similar patterns to other hydrochemical parameters in the autumn season showing a noticeable amount of phosphates, relatively high colour and COD. This group of wells are located in lower terrain with a high groundwater table and wells also contain microbiological pollution.

Wells with higher water recharge rate in spring have some differences from autumn indicating that values of colour and phosphates are comparable in both seasons, but in spring noticeably increases turbidity and has significantly smaller total hardness and amount of hydrocarbonates due to intense recharge of snow melting water. These results correspond to findings in other studies (Kalvans *et al*., 2020) and changes in tested parameters without infiltration indicate also potentially direct surface water flow in water wells during intense precipitation or snow melting. In such areas, water wells with proper isolation against surface water infiltration should be equipped. Although in highland individual differences between water wells are noticeable, isotope data and depth of groundwater level demonstrate more stable water recharge rates.

Local conditions with location in relief and groundwater recharge patterns may play an important role in overall water quality and therefore indicate potential risks to meeting criteria for water quality standards. This phenomenon demonstrates correspondence with findings in PCA analysis and a strong correlation with individual ions from such sources as snow and soil. Moreover, the influence of intense water recharge in these wells also impact their water quality from anthropogenic activities can play an important role, because these sampling sites dominantly are in urban areas, near farms or agricultural areas.

Conclusions

Studied dug wells have high individual variability on analyzed parameters, thus making it difficult to apply statistical analysis and find convincing patterns. Nevertheless, there are visible differences between water quality parameters in wells located in different terrain as more vulnerable to anthropogenic contamination indicating wells in lowlands. PCA analysis indicates several parameters which correspond to isotope values and their seasonal fluctuations, but do not prove the potential of isotope values as the main tool for characterizing shallow groundwater quality. A significantly better overview described cluster analysis by grouping wells by their major differences, thus indicating areas with higher potential risk for water contamination and the usefulness of including stable isotope analysis for characterization of water quality aspects.

Acknowledgements

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HYDROXY GAS AS AN ADDITIVE FOR IMPROVEMENT OF EXHAUST EMISSIONS OF INTERNAL COMBUSTION ENGINES – A REVIEW

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Abstract
Lowering emissions expelled from internal combustion engines has been the focus of researchers worldwide. Adding hydroxy gas to current internal combustion engines can be an effective way of lowering CO_2, CO, HC and particle emissions, as well as improve combustion. Because of this, a review of previously conducted research on the addition of hydroxy gas to different internal combustion engines has been produced. During this review, it was concluded that addition of hydroxy gas can be an effective way of lowering fuel consumption and CO, CO_2 and HC emissions in petrol engines, as well as fuel consumption and CO and HC emissions in diesel engines.
Key words: Hydrogen, Hydroxy, Emissions, Exhaust gases, Internal combustion engine.

Introduction

Worldwide, the total amount of motor vehicles is constantly increasing. According to the International Energy Outlook 2021, liquid fuels such as petroleum fuel remain as the largest energy source (Energy Information Administration, 2021). International Energy Outlook 2019 has projected that liquid fuel consumption is expected to increase by approximately 50% between 2019 and 2050 (Energy Information Administration, 2019). Fossil fuels are the main fuels used in the automotive sector, both in personal vehicles and industrial machinery. The biggest drawbacks of these fuels are the large amounts of toxic components in the exhaust. Besides of that the source of fossil fuels, crude oil, is being depleted at a fast pace. Since the demand of energy is constantly increasing, but the source of this energy is depleting rapidly, the use of alternative and renewable energy sources is required.

A good alternative to traditional fossil fuels is hydrogen gas. It contains zero carbon, making it a clean burning fuel. Additionally, it has a high combustion efficiency (Ma *et al.*, 2007). Hydrogen gas can be generated from various sources, such as water, coal, biomass, and fossil fuels. Hydrogen fuel is renewable, and it is an efficient and clean fuel that can be used for multiple applications, mainly as an additive or substitute for fossil fuels. However, the usage of hydrogen gas in vehicles can be challenging because of the difficulty of storing hydrogen gas in its liquid state at low temperatures or in its gaseous state at high pressure. Moreover, any damage caused to such systems can have disastrous consequences as hydrogen gas is highly flammable. Because of these safety concerns, researchers are proposing the use of a different form of hydrogen gas that can be created on-board of the vehicle, such as hydroxy gas, also known as Brown's gas.

Hydroxy or HHO gas consists of a mix of hydrogen and oxygen with a stoichiometric ratio of 2:1. HHO gas is mainly produced via water electrolysis (Newborough & Cooley, 2021). It has been used as a fuel additive in various researches using both petrol and diesel engines. Researchers have found that using HHO gas as an additive in regular internal combustion engines has resulted in a 10% increase in thermal efficiency, up to 34% decrease in fuel consumption and a reduced concentration of nitrogen oxides (NO_x), carbon monoxide (CO) and hydrocarbon (HC) emissions in petrol engines (El-Kassaby *et al.*, 2016) and 41% reduction of particle emissions, 13.5% reduction of CO emissions and 5% reduction of HC emissions in diesel engines (Bari *et al.*, 2022; Yilmaz *et al.*, 2010).

Materials and Methods

A monographic research method has been used in this research, in order to summarize and analyze the impact of adding hydroxy gas to internal combustion engines in order to reduce toxic emissions. This research combines scientific literature from various journals and authors. Articles from scientific journals published from 2007 to 2023 were used, while more recent research was favored. The use of research that was recent and contained the use of dry cell hydroxy generators was favored, as this method is better suited for use in automotive applications. Multiple articles were analyzed, and articles that contained similarly conducted research were selected for the review.

Results and Discussion

Hydroxy gas

Hydroxy gas is extracted from water by splitting water into two molecules of hydrogen and one molecule of oxygen via the process of electrolysis. The process is caried out in an electrolytic cell. Hydroxy gas has a low density of 0.5378 $kg \cdot m^{-3}$. That means, hydroxy gas is lighter than air, and in open environment it will rapidly disperse (Paparao & Murugan, 2021).

The comparison between hydroxy gas and other gaseous fuels can be seen in Table 1. Based on the data in Table 1 it can be concluded that hydroxy gas can be used as a gaseous fuel in internal combustion

engines in a wide array of air-fuel ratios. As it contains hydrogen, it also requires less energy to be ignited. Since hydrogen has high diffusivity, hydroxy gas can mix well in the air-fuel mixture, resulting in a uniform mixture. A major drawback for hydroxy gas is that it has a low quenching distance, which creates a large possibility for backfire. And finally, since hydroxyl gas contains hydrogen, it has higher flame speeds, that require a safer engine operation to avoid damage.

Hydroxy generators

The easiest way to produce hydroxy gas on-board a vehicle is by electrolysis of water mixed with an electrolyte, for example sulfuric acid (H_2SO_4), potassium hydroxide (KOH) or sodium hydroxide (NaOH).

Table 1

Comparison between gaseous fuels (Paparao & Murugan, 2021)

Properties	Hydroxy	Hydrogen	Methane	Propane	Butane	Biogas
Chemical Formula	HHO	H2	CH4	C3H8	C4H10	-
Density ($kg \cdot m^{-3}$) at 16 °C and 1.01 bar	0.5	0.1	0.7	0.5	2.5	0.7-0.9
Molecular weight	12.0	2.0	16.0	44.1	58.1	16.6
Lower heating value ($MJ \cdot kg^{-1}$)	13.2	119.9	47.1	45.6	45.3	23
Higher heating value ($MJ \cdot kg^{-1}$)	25.9	142.2	52.2	50.36	49.1	-
Flame Velocity ($cm \cdot s^{-1}$)	265-325	265-325	42	46	87	20
Diffusivity in air ($cm^2 \cdot s^{-1}$)	0.6	0.6	0.3	-	-	-
Stoichiometric Air-Fuel Ratio	-	34.3	17.2	15.7	15.5	17
Octane Number	-	130+	100	105	92	130
Motor Octane Number (MON)	-	-	120	97	-	-
Auto-ignition temperature (°C)	-	585	565	490	287	650
Flash Point (°C)	-	-253	-188	-104	-60	>230
Boiling Point (°C)	-	-253	-161.5	-42	-0.5	-
Melting Point (°C)	-	-259	-182	-188	-135	--
Flammability limits (Volume % in air)	4-95	4-75	5-15	2.1-10.1	-	-

The gas can be produced via a dry cell HHO gas generator, principles of which are shown in Figure 1, or wet cell hydroxy generators, shown in Figure 2.

As seen in Figure 1, the water and electrolyte mixture is filled into the tank. The mixture then fills up the HHO generator. Power is supplied to the generator from the vehicle battery, and the process of electrolysis begins. The gas, containing both hydroxy and water/electrolyte vapors is then transported back to the tank, where vaporized water and electrolyte mixes back into the liquid water/electrolyte mixture, but the hydroxy gas rises to the top and is expelled from the tank. This gas is ready to be injected into the engine.

In the case of wet cell hydroxy generators, the cathode and anode are submerged in the tank containing the water and electrolyte mixture, and power is supplied to them from the battery. The HHO gas emitting from the electrolysis process rises above the water level, and then is ready for injection into the engine.

When compared, the dry cell generator has a smaller volume, so a smaller amount of water and electrolyte mixture is needed for the reaction to happen. However, using wet cells, the electrical connections are submerged in the water and electrolyte mixture, reducing the time it takes for the connections to corrode (Shah *et al.*, 2018).

Overall, comparing both generators, the dry cell generator would be more acceptable for the use in automotive applications, as the tank for water and electrolyte mixture can be stored separately and the generator itself and the whole assembly can be better integrated in the vehicle.

As seen in Table 2, the addition of hydroxy gas in engines can be an effective way for reduction of CO, HC and NOx emissions, and decreasing the fuel consumption in petrol engines and smoke opacity in diesel engines.

However, to achieve optimal results, the modification of engine control parameters is necessary, mainly the modification of fuel delivery.

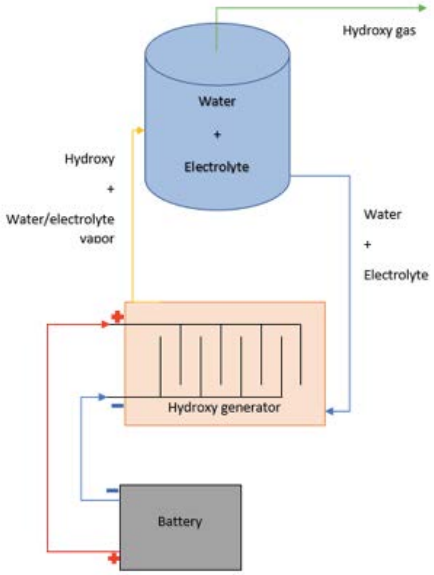

Figure 1. Operation of a dry cell hydroxy generator.

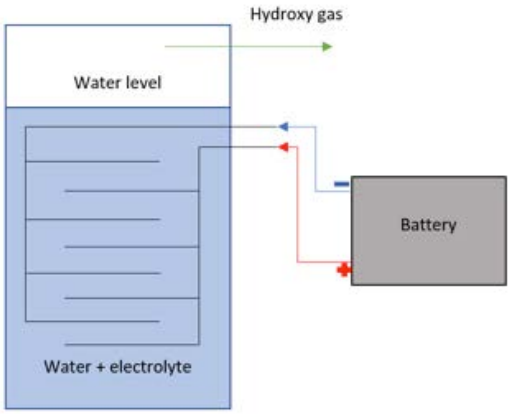

Figure 2. Operation of a wet cell hydroxy generator.

Results of adding hydroxy gas to internal combustion engines

Table 2

Results of adding hydroxy to engines

Author	Vehicle/engine used	Fuels used	Results obtained
Mohamed M. EL-Kassaby (El-Kassaby *et al.*, 2016)	Skoda Felicia 1.3l GLXi	Petrol Petrol + HHO gas	10% increase in thermal efficiency 34% decrease in fuel consumption 15% reduction in NO_x emissions 18% decrease in CO emissions 14% decrease in HC emissions
František Synak (Synák *et al*., 2021)	Skoda Felicia 1.3 MPI	Petrol LPG Petrol + HHO gas LPG + HHO gas	No effect on CO concentration Slight increase in HC concentration When driving on petrol, no effect on CO_2, O_2 and NO_x. On LPG and HHO gas, CO_2 concentration increased.
	Skoda Fabia 2 1.4 MPI	Petrol LPG Petrol + HHO gas LPG + HHO gas	Adding HHO gas to both petrol and LPG resulted in slight decrease in CO concentration.
	Kia Ceed 1.6 CVVT	Petrol E85 Petrol + HHO gas E85 + HHO gas	Adding HHO gas resulted in slight decrease of engine power and torque. Specific fuel consumption increased after adding HHO gas. When used with E85, the addition of HHO gas did not result in changes to engine power and torque.
	Skoda Felicia 1.9D	Diesel Diesel + HHO gas	Engine power and torque were not affected. Increase in NO_x levels from 8 ppm to 29 ppm. Slight reduction in smoke opacity.
	Kia Sportage 1.6 CRDI	Diesel Diesel + HHO gas	Slight decrease in engine power and torque. Slight increase in HC from 8 ppm to 11 ppm. 14.46% reduction in CO_2 emissions. CO and NO_x levels are unchanged.

Continuation of the Table 2

Zhe Zhao (Zhao *et al.*, 2022)	VW EA888 engine	Petrol Petrol + HHO gas	With λ = 1, CO emissions decrease by 18%. With λ = 1.1, CO emissions decrease by 91.67%. With λ = 1.4, CO emissions decrease by 92.38%. With λ = 1, HC emissions decrease by 17.18%. With λ = 1.1, HC emissions decrease by 20.52%. With λ = 1.4, HC emissions decrease by 32.8%. NO emissions increase when th mixture is lean (λ = 1.1 and λ = 1.4).
Sa'ed A. Musmar (Musmar & Al-Rousan, 2011)	Honda G200 0.7l single cylinder engine	Petrol Petrol + HHO gas	Increase in thermal efficiency with HHO gas added. Decrease in specific fuel consumption with HHO gas added. 50% reduction in NO emissions 20% reduction in CO emissions 54% reduction in NO_x emissions
Saiful Bari (Bari *et al.*, 2022)	Cummins 6BT5.9-G2 engine	Diesel Diesel + HHO gas	Average 41% reduction in particle matter No impact on performance parameters No significant reduction in CO_2 emissions CO emissions were reduced by 5.5%, 3.4% and 2.32% (at 0.42 LPM, 0.84 LPM and 1.25 LPM hydroxy addition). No significant change in NO_x emissions.
Ali Can Yilmaz (Yilmaz *et al.*, 2010)	3567 cm^3 4-cylinder direct-injection diesel engine	Diesel Diesel + HHO gas	19.1% Increase in engine power 14% reduction in specific fuel consumption is achieved 5% reduction in HC emissions 13.5% reduction in CO emissions
Jorge M. Rodriguez Matienzo (Rodríguez Matienzo, 2018)	LISTER PETTER LPW2 engine	Diesel Diesel + HHO gas	3.81% increase in engine power 2.79% increase in engine torque At low and medium load, brake specific fuel consumption is reduced in a range of 2.66% to 9.29%. Lower vibration levels that indicate smoother combustion.
Mohamed F. Al-Dawody (Al-Dawody *et al.*, 2023)	Kirloskar TAF-1 0.553 l diesel engine	Diesel Diesel + 10% HHO gas	9% to16% increase in brake power (from 1500 to 3500 RPM) 31.5% increase in thermal efficiency 20% reduction in fuel consumption Decrease in NOx emissions
Mohammad Sabeghi (Sabeghi *et al.*, 2022)	8CRZ 2800 cm^3 diesel engine	Diesel Diesel + HHO gas	66% reduction in CO emissions 33% reduction in CO_2 emissions 38% decrease in HC emissions 11% decrease in NO_x emissions
Piotr Jaklinski (Jakliński & Czarnigowski, 2020)	Fiat Cinquecento 170A.000	Petrol Petrol + HHO gas	1% increase in NO_x emissions 24% reduction in HC emissions 34% increase in CO emissions
	Renault Twingo 1149 cm^3	Petrol Petrol + HHO gas	17% reduction in NO_x emissions 45% reduction in HC emissions 20% reduction in CO emissions
	Opel Corsa 1398 cm^3	Petrol Petrol + HHO gas	50% reduction in NO_x emissions 35% reduction in HC emissions No change in CO emissions
	Skoda Octavia 1896 cm^3	Diesel Diesel + HHO gas	10% increase in NO_x emissions 80% increase in HC emissions 95% decrease in CO emissions
	Opel Combo 1248 cm^3	Diesel Diesel + HHO gas	100% increase in NO_x emissions 37% decrease in HC emissions No change in CO emissions

Comparing results, it can be observed, that in cases where the fuel delivery system has been left unmodified, the obtained improvements are significantly reduced.

Hydroxy gas contains hydrogen that is a type of fuel by itself. Therefore leaving an engine unmodified and adding hydroxy gas could result in an overall increase in fuel delivery without leaving significant decrease in emissions, fuel consumption or smoke opacity.

Adding hydroxy gas to the air-fuel mixture can reduce specific fuel consumption, thanks to the additional oxygen contained in hydroxy gas. This results in enhanced combustion efficiency and lower fuel consumption. Hydroxy gas also provides a more homogenous mixture with air and dissolves better with the fuel-air mixture which further increases efficiency of combustion (Aydin & Kenanoğlu, 2018).

Multiple researchers claimed that the addition of hydroxy gas resulted in reduced vibration and smoother work of the test engines. This is due to the fact that hydrogen has a very high flame speed that positively affects the combustion process. Hydrogen has a high auto-ignition temperature, which means the main fuel is ignited first, and that ignites the hydrogen gas that then ignites the remaining unburnt fuel, resulting in smoother and more complete combustion.

Exhaust gas emissions

Consumption of fossil fuels creates a large number of harmful and toxic pollutants that are one of the main causes of global warming. These pollutants include carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), particulate matter (PM).

The consumption of 1 liter of petrol in an internal combustion engine creates at least 2.28 kg of carbon dioxide. In diesel engines, at least 2.76 kg of CO_2 is emitted from each liter of diesel fuel (Pinto & Oliver-Hoyo, 2008). Carbon monoxide is produced from partial oxidation of carbon. CO production is higher if the engine is in poor technical condition, there is limited oxygen or if the engine has not reached proper working temperature. Nitrogen oxides are created in high pressure and high temperature conditions, especially if the air-fuel mixture is lean. Nitrogen oxides include nitrous oxide (N_2O), that depletes the ozone layer and is toxic, nitrogen oxide (NO) that is responsible for the creation of smog and acid rains and nitrogen dioxide (NO_2) that is irritating and also causes smog. Particulate matter is produced in cases of local oxygen deficiency, resulting in free carbon molecules that connect with free hydrocarbons and form larger particles. Particulate matter can cause respiratory diseases in humans (Synák *et al.*, 2021).

The use of hydroxy gas additive can be used to improve emissions, resulting in a decrease in smog formation, decrease in greenhouse gas emissions and slow down global warming.

Adding hydroxy gas to diesel engines can result in an increase in NO_x emissions, because the added hydrogen increases the total amount of fuel and energy. The combustion speed is increased, and so is the temperature and pressure inside the cylinder, which results in an increase in NO_x emissions. In petrol engines, at low load conditions the addition of hydroxy gas does not increase the temperature significantly, so no major changes in NO_x emissions can be observed (Jakliński & Czarnigowski, 2020). If the fuel management system is adjusted for the added hydrogen and the air/fuel mixture is made leaner, NOx emissions can be reduced.

CO and CO_2 emissions are byproducts of combustion, resulting from the oxidizing of carbon present in the fuel. Hydroxy gas does not contain carbon, which causes the reduction in CO and CO_2 emissions. Additionally, the addition of hydroxy gas makes the air-fuel mixture burn faster and more completely, resulting in further reduction in CO and CO_2 reduction (Yilmaz *et al.*, 2010).

At higher engine rotation speeds, the reduction of HC emissions becomes less visible. The time, intake valves are kept open, is becoming shorter, so sufficient amount of air cannot be supplied to the engine. This results in a decrease in combustion efficiency and lower improvements in HC emissions (Aydin & Kenanoğlu, 2018).

Diesel engines contain particle matter emissions, that are comprised of carbon soot particles. They are created inside the cylinder during combustion in fuel rich areas. Adding hydroxy gas adds oxygen that helps in combustion of soot particles in fuel rich areas, as well as hydrogen that increases the temperature of combustion and accelerates the oxidation of particle matter, resulting in an increased amount of CO_2 emissions (Bari *et al.*, 2022). Since hydroxy gas does not contain carbon, the overall amount of CO_2emissions still remains lower when compared to traditional petrol or diesel combustion without added hydroxy gas.

Conclusions

The following conclusions can be drawn from the analysis of addition of hydroxy gas to internal combustion engines:

1. Addition of hydroxy gas can be an effective way of lowering fuel consumption and CO, CO_2 and HC emissions in petrol engines.
2. Addition of hydroxy gas can be an effective way of lowering fuel consumption and CO and HC emissions in diesel engines, as well as a reduction in smoke opacity.
3. When used in diesel engines, the addition of

hydroxy gas could increase NO_x emissions.
4. Specific fuel consumption can be reduced via the addition of hydroxy gas.
5. Thermal efficiency of both petrol and diesel engines can be improved via the addition of hydroxy gas.
6. Smoother combustion can be observed with the addition of hydroxy gas.

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IMPROVING INTRUSION DETECTION INTELLIGENCE BY OPEN DATA USAGE

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Abstract
Cyberattacks have become a regular part of network activity. To mitigate the risks from possible threats, organisations have implemented firewalls and intrusion detection systems, which can help stop network attacks. The problem is that often the accuracy of these systems is not effective enough. Another part of network security is security information and management platforms. These systems are more advanced versions of Threat Intelligence Platforms, because it is possible to make in-depth analyses of real-time events in a network. This research paper proposes improving intrusion detection system functionality using Open-Source Intelligence. Anomaly-based intrusion detection systems often generate alerts, but these alerts require deeper analysis to understand whether it is a real attack or just a false alarm. By making Open-Source Intelligence requests and evaluating extra information, it is possible to make more precise rules to stop attacks against network infrastructure. Open-Source Intelligence requests are generated directly from the intrusion detection system or with Python scripts based on the organisation's infrastructure profile. The proposed architecture was experimentally tested by automating Open-Source Intelligence requests and intrusion detection rule generation by Python scripts.
Key words: Threat intelligence, intrusion detection, cybersecurity.

Introduction

Nowadays, information system faces a wide range of threats and cyberattacks. With COVID-19 and the Russian invasion of Ukraine, hackers and other malicious actors have become even more active than before. Latvian Information Technology Security Incident Response Institution has stated in its report that malicious activity has grown multiple times (CERT.LV, 2022).

At the same time, network bandwidth has grown exponentially and devices are becoming more and more portable. It brings great opportunities to business, but it also makes threat actors even more dangerous. IBM Threat Intelligence Index (IBM, 2017) shows that hacktivism and destructive malware have grown dramatically – a 100% increase in hijacking attempts, a 62% increase in phishing attacks using spear phishing attachments, a 21% increase in backdoors deployed, etc.

Simply analysing packet per packet or file by file is not enough and cybersecurity professionals must use more sophisticated tactics and implement more and more intelligence in their tools. The problem nowadays is that information collection simply for knowledge base also is not effective, because then information can become noise. It is important to collect information with context and when it is needed.

The most effective instrument for attack mitigation is intrusion detection systems (IDS) which can identify attack behaviour. These systems generally are classified into two groups: Misuse-based detection systems and Anomaly-based detection systems. Misuse-based detection is based on patterns or strings that correspond to a known attack or threat, but Anomaly-based detection monitors deviation from the normal behaviour of network connections or other activities in systems (Liao *et al.*, 2013). These systems have been developed already several years and a lot of research has been done to improve their effectiveness and detection algorithms as well (Lata & Singh, 2022; Nuaimi *et al.*, 2023). All this research concentrates on the implementation of algorithms and detection accuracy. The situation with Misuse-based systems is quite simple. If packets match certain rules or defined patterns, then an alarm is announced. In this case, research focuses on system performance and search algorithms which could check rules as fast as possible. Another situation is with Anomaly-based systems. These systems do not search for an exact match but for a deviation from normal. That is why alarms often require for deeper research. Alarms like Hight Total Traffic, Suspect Data Flow or Hight Concern Index can be a hacker attack activity, but at the same time, it can be a normal user who does something different from everyday activities. The number of alarms also depends on threshold boundaries in the system. There would be a possibility to rise system intelligence from different knowledge sources which are publicly available on the internet, like MITRE Cybersecurity vulnerabilities catalogue (MITRE.org, 2023) or Google Hacking Database (OffSec, 2023). But in current research, IDS systems are not focusing on this potential but more concentrating on machine learning and algorithm improvement.

That does not mean that cybersecurity does not use the possibilities of intelligence analysis. In fact, there are separate movements of cybercrime intelligence called Threat intelligence platforms (TIP) which concentrate on proactive measures of computer and network security and incident response (Cascavilla *et al.*, 2021). These systems are based on intelligence traditional steps – planning, collection, processing, analysis, dissemination and evaluation. Such a process is often used in Security Operation Centers (SOC) where

analysts try to analyse incidents by collecting various information from the internet. Basically, it works with Source Intelligence (OSINT), for improving the analytical quality of TIP data and trying to find indicators of compromise (IOC), to show possible indicators that the system can be compromised (Costa-Gazcon, 2021). There are possible benefits that can bring data enrichment via OSINT sources, like blacklisted IP recognition, exploit activity detection, attack planning recognition via Natural language processing, create detection rules based on open data.

In both cases there is the possibility of false positive information – in IDS it can be false alerts about attacks and in TIP gathered OSINT information can be nothing more than disinformation. That is why the important part is not just an extraction of information, but also the evaluation of data source trust and relevance with events in real infrastructure.

This paper tries to evaluate possibilities to improve IDS detection quality by the usage of TIP intelligence possibilities and OSINT data integration for attack detection. The research paper describes various data sources for information security improvement and how information from these sources can be extracted and integrated into intrusion detection systems in automated way. There is other research done for evaluation of OSINT in intrusion detection (Shannon, Pournouri, & Ibbotson, 2021), but previous research more concentrates on algorithmic improvement of systems, but not so much on system architecture and contextual extraction of OSINT feeds.

By proposing intellectual IDS architecture, the author tries to provide possibilities to improve data source quality assessment, and data exchange between systems and shows deployment possibilities of system over real attack scenarios.

Materials and Methods

Testing lab environment intelligent intrusion detection inspired by the HELK platform (Rodriguez, 2020) this is an open source threat hunting platform which works more like a Security information and event management (SIEM) tool. But in this case, to collect information from various OSINT sources, SpiderFoot project was installed, which can be combined with the so-called ELK stack (Elastic, 2022) consisting of Elasticsearch, Logstash and Kibana. Elasticsearch is a database engine for data collection, Logstach is for log integration in Elasticsearch, and Kibana is for data visualization.

Each OSINT source needs to be parsed to harmonize, categorize incoming data and prepare data so that it can be defined as IOC of some specific event. OSINT sources are categorized by the following categories:

- abused IP – IP addresses which are blacklisted by security organizations and reported as malicious;
- early warnings – OSINT feeds about possible attacks. It can be text feeds from hacker forums or social networks about possible attacks or zero-day vulnerabilities;
- threat patterns – specific properties or features of some exploit or attack pattern, it can be used to describe this threat in IDS rules;
- attack patterns – these can be information from vulnerability and exploit databases about known misconfigurations, and possible requests against the network;
- vulnerability warnings – based on existing infrastructure, it can be alarms about Common vulnerabilities of relevant application versions, and possible exploits of certain software versions;
- abusive content – it can be some content which should not be used in an organization's network, like spam, disinformation feeds, pornography, etc.

As shown in Figure 1, during the generation of IOC, it is necessary to avoid duplicates, because threats can be recognized already before or multiple sources can generate the same IOC. If duplicates are not found, they can be stored in a database.

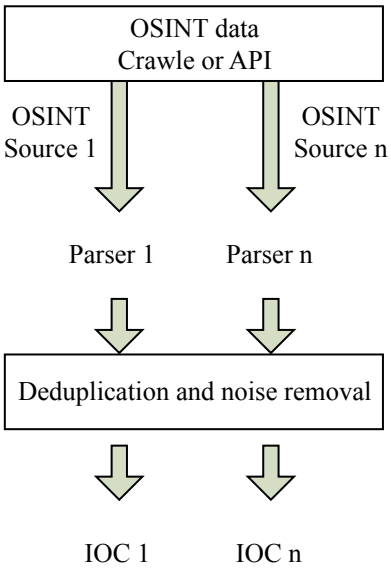

Figure 1. OSINT data collection process.

An open-source intrusion detection system Suricata IDS (OISF, 2020) was chosen for this research. Suricata outperforms other open-source IDS like Suricata and Zeek due to better exploitation of underlaying hardware. Suricata IDS architecture can be seen in Figure 2, most important part is detection engine because it provides possibility to split detection process in multiple threads, so it can bring advantage in multicore environments.

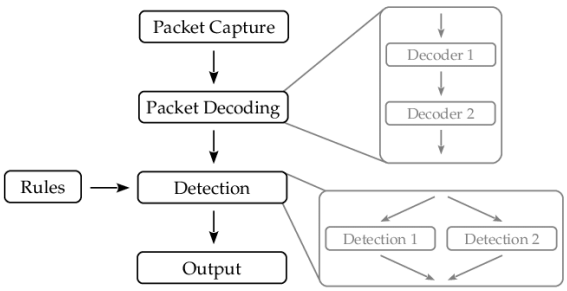

Figure 2. Suricata IDS architecture (Prenosil & Hammoudeh, 2017).

Suricata IDS provide possibility to make scripts for complex matching and even gain efficiency by combining multiple rules into one script (Waleed, Jamali & Masood, 2022). This IDS has its own rules dataset for possible attack detection for application-layer requests and better hardware acceleration can be very useful if proposed architecture will be implemented in production environment where network speed is much faster.

The base idea behind cooperation between OSINT and IDS is that Suricata alerts about suspicious activity can be triggers for OSINT requests to collect extra information about IP addresses, activity topics, suspicious files and other relevant information which has been noticed in network flow. It is necessary to convert IOC data to the Suricata rule, so that it can be used for intrusion detection. But simply converting all OSINT indicators would not be effective, it would generate too many rules and also would require too much time to check these rules that is why it would be necessary to understand whether these generated IOCs correlate with infrastructure attributes or data flows. There are several possibilities to check the similarity between values in IOCs (Leskovec *et al.*, 2014), but in this case, Locality-Sensitive Hashing will be used, which can compress large values into small signatures and preserve the expected similarity between two pairs. The Apache Spark is used to calculate event similarity and related event grouping.

By such computation it can be calculated if vulnerability X can be used in the infrastructure of company Y. This can help analysts to avoid analysis of unrelated events, for example, IDS should not check against vulnerabilities of MikroTik Routers if there are no such communication devices in the organization's network. There could be some sources in which IOC could be used straight without checking its relevance, for example, if we check the Abused IP database and some IP has been reported as malicious IP with 100% confidence, then it must be blocked without specific analytics behind it. But then such IP must be blocked in the firewall, not in the IDS system.

An important part of OSINT data relevance checking and relevance evaluation is the company profile which collects the main features of an organization and its infrastructure and indicators of possible threat vectors. The company profile consists of multiple parts:

- domain indicators – industry of business – financial or healthcare, private or governmental agency, clients of organizations, partners, or other high-level description indicators;
- infrastructure – server OS, switches, firewalls, IDS, proxy servers, VPN gateways and other nodes for information storage, accessibility, and intercommunication;
- applications – web servers, SMTP services, Mail servers, web applications, FTP services and other systems which are used in daily work and processing organization data;
- endpoints – these could be workstations, laptops, printers, mobile phones, some IoT devices, or VoIP devices;
- cloud services – cloud storage services, software as service applications, and online applications which are used by organization staff.

There were included multiple well know OSINT sources parts, some of which are shown in Table 1, but information about the rest of the sources can be found in IntelMQ documentation.

Table 1

OSINT Source examples

OSINT source	URL
Exploit Database	https://www.exploit-db.com/
Abused IP abuse.ch	https://abuse.ch/
AlienVault OTX Reputation list	https://otx.alienvault.com/
Malware Panels Tracker	http://benkow.cc/export.php
Darkreading.com	https://www.darkreading.com/
Cybersecurity vulnerabilities	https://www.cve.org/
Threat sharing platform	https://www.misp-project.org/
BitcoinAbuse	https://www.bitcoinabuse.com/
AdGuard DNS	https://adguard.com/en/welcome.html
HackerTarget	https://hackertarget.com/

Based on the organization profile and its assets, possible attack vectors can be generated. Asser features can help evaluate IOC relevance and its possibility to generate an IDS rule for infrastructure protection. Attack vectors may depend on infrastructure, but they can be – phishing, recognizance, malware, ransomware, compromised credentials, misconfiguration, and potential vulnerabilities.

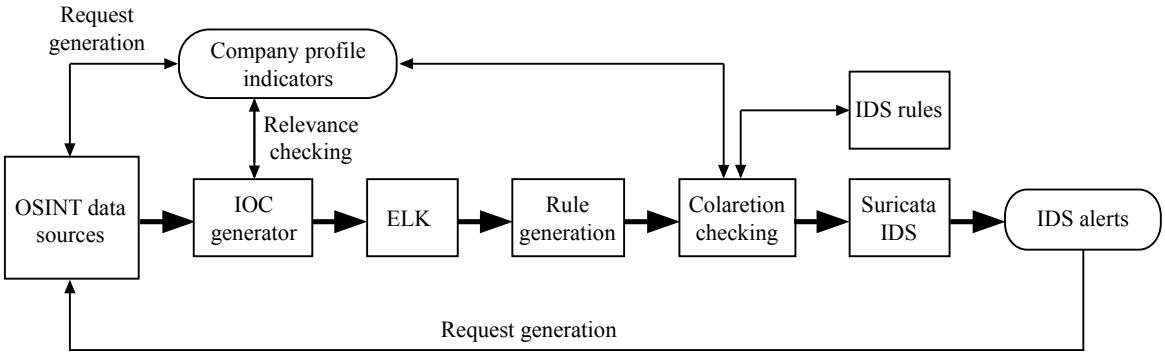

Figure 3. Intelligent IDS with OSINT capabilities.

Potential threat vector enumeration is an essential part of intelligence teams' work to provide better attack mitigation steps and recommendations.

The architecture of the system can be seen in Figure 3. IntelMQ threat intelligence platform has been installed on Kali Linux (OffSec, 2021) which is an open-source distribution for Penetration testing. The system was made on a VirtualBox machine with 8 GB RAM and 2 processor cores and 40 GB of HDD. For OSINT feed classification, it was decided to use Security Incident Taxonomy which was created by ENISA and TF-CSIRT and approved on 26 September 2018 (TF-CSIRT, 2018).

Open source database Reidis Output bot (IntelMQ community, 2023) was used to feed IntelMQ messages in the ELK. MinHash LSH also supports Redis (Zhu, 2021) which goes together with chosen similarity algorithm for this research. The similarity between events can be computed by Python:

```
from pyspark.ml.feature import MinHashLSH
from pyspark.mi.linalg import Vectors
from pyspark.sql.function import col

mh=MinHashLSH(inputCol='features', outpuCol='hashes', numHashTables=10)
model = mh.fit(result)

r=model.aproxSimilarityJoin (result, result, 0.3, distCol='JaccardDistance').cache()
```

The threshold of similarity can be set from 0 to 1, where 0 would be an exact match, but 1 would be different values. After finding similarities between events, it is possible to make a grouping of these events and put them in joint tables having records about similarity which can be quickly extracted during event checking.

For testing reason, .pcap files from the real network environment have been used. Those files have been provided by Latvian governmental institutions with an agreement that the organization name and network sensitive information cannot be exposed. Network flow files have been taken from Cisco Network Analytics software and are stored because of their suspicious activity, so there are a lot of suspicious IPs with Hight concern index (Cisco, 2017).

Results and Discussion

Table 2 shows a summary of experimental results. During a 5-day period of network flow .pcap files 1048 IP addresses were approved as abused and malicious. Also, 23 domains were recognized as malicious.

In the IDS system, these addresses performed activities like port scanning, recognizance, and ping scanning which in normal situations would not be a reason for address blocking. In this case, abused IPs were written in a separate .csv file which was configured as a blacklisted source for the organization's Palo Alto firewall. It is hard to say that communications were related to certain countries, because traffic was communing not just from countries like China, Russia, and Bulgaria, but also from European countries like Germany and Netherlands.

Table 2

OSINT feed results in IDS system

OSINT activity	Count
Blacklisted IP addresses	1048
Blacklisted domain names	23
Whitelisted IP addresses	128
Vulnerabilities alerts	36
Attack alerts	0

In this case, also 128 addresses were related to services or organizations which approve that they do not provide a threat to the organization. Mostly they were cloud services of several updates or services which extracted data from organizations' API services. Due to a large amount of data or large count of requests, these addresses were marked as suspicious, but their activity objective was not malicious.

It was also possible to extract 36 OSINT feeds about potential vulnerabilities which are announced in open databases and connected with organization-used services. It was discovered that some OSINT sources already provide API interfaces for Suricata rule generation like AlienVault OTX Suricata rule generator. In the case of certain exploit announcements and their connection with organization recognition, a specific rule was generated to be sure that IDS will recognize malicious content if it reaches the network. Python script was used to convert OSINT feeds from JSON to Suricata rules.

Trying to detect DoS attacks or hacking announcement feeds, the research failed to get positive match for certain organisation.

This research is still ongoing to improve the rule generation process and OSINT request targeting. Result numbers are quite small because research has not been done on real networks, but with selected .pcap flows. Threshold should be set for which category events OSINT requests must be generated, otherwise it would generate too much traffic and could cause more noise than benefit in an attack with threat actors.

Conclusions

This research demonstrates the possibility to improve IDS system rules with OSINT data. OSINT requests are based on contextual information of organization infrastructure and IDS alerts. Such an approach can be very useful for Anomaly-based IDS which analyses unusual activities in the network and could be useful to extract extra information about communication parties. Especially it can be used for suspicious IP address recognition and blocking by putting these addresses in a firewall blocking list. Experimental results show that OSINT data can be used for extra rule generation in IDS systems and help to prevent suspicious threat actors before analysts make the decision whether alarm is suspicious or not.

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CAREER DEVELOPMENT FOR ENHANCING EMPLOYABILITY OF STUDENTS AS PROSPECTIVE SPECIALISTS IN THE UNIVERSITY EDUCATIONAL ENVIRONMENT

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Abstract
Universities play an important role in providing a wide range of services and connecting all stakeholders, such as employers, alumni, and other community members to prepare students for future employment, establish networking with labour market representatives, assist them in integrating into the labour market, and develop students' as potential specialists' employability skills, thereby fostering their career development in the university educational environment. The aim of this study is to analyse the career related theories and propose a career development model for economics and business-focused universities. The following research methods were used: desk study, analysis and evaluation of scientific literature (theoretical research method); reflection of personal experience (empirical research method). The theoretical research emphasised modern career-related theories and resulted in a proposal for a career development model for a university. A mandatory course that formally prepares students as prospective specialists for employment and internship, exposure to the labour market via internship, networking events, and mental support provided by qualified psychologists, university teachers as part of an academic advising programme and alumni organized in the form of an alumni mentorship programme, are the main pillars of the proposed career development model.
Key words: career services, career development, counselling, employability.

Introduction

Individuals' career paths have changed within time due to various factors such as increased automation and machine learning, the rise of the gig economy, global competition, and reforms to labour markets and government policy. Having a number of jobs during a lifetime is now widely expected for the majority of the labour market (Bridgstock, 2019; Bridgstock, Grant-Imaru, & McAlpine, 2019) and long-term employment relations have become quite a rare phenomenon. Together with the change of individuals' career paths, career counselling goals and methods have also changed over the last 50 years in response to the increased employment uncertainty, industrialization, mass education, and the possibility of full employment (Evangelista, 2015).

The shift in careers led to the transformation of career counselling from an occasional into continuous process. While previously career counselling was in place when a student or recent graduate entered the labour market, or when a company shut down and its employees had to find new employment places (Evangelista, 2015), now career counselling helps people of all ages manage their careers and make the best possible choices in terms of education, training, and employment by promoting reflection about the individual's strengths and weaknesses, matching those with the individual's plans and goals, and with the current situation of the labour market (UNESCO …, 2019). It also plays a significant role in terms of inclusion, increasing the chances of people from disadvantaged groups (National Forum …, 2022). In addition to that change, universities have become part of the knowledge triangle, the goal of which is to bring together the worlds of academia, industry, and research, putting an emphasis on entrepreneurship and innovation (European Institute …, 2022). As a result, the role of universities also changes, emphasising the need of strengthening connections with the labour market and collaborating to achieve common goals, such as preparing students for employment and developing students' employability skills as prospective specialists (*Katane & Troskova*, 2023).

The aim of this study is to analyse the career related theories, and propose a career development model for economics and business-focused universities.

Materials and Methods

The topic of career counselling is relevant among different researchers which is proved by a number of publications (Evangelista, 2015; Lara & Vess, 2014; Pryor & Bright, 2022; Savickas, 2005; Stuart, 2014).

The theoretical study highlighted the key concepts about how and why individuals make career decisions (Savickas, 2005; Pryor & Brights, 2022). If, in accordance with the construction theory (Lara & Vess, 2014; Savickas, 2012; Savickas *et al.*, 2009), the life trajectory and life design have been discussed, then the career theory of chaos emphasises the importance of complexity, change, and chaos (Pryor & Bright, 2003). So individuals as dynamic and complex dynamic systems seek survival and purpose. Now it is suggested to accept and prepare for the uncertainty of everyday life in the context of career management (Pryor & Bright, 2022).

In addition to academic and research activities, universities participate in the knowledge triangle, which connects research, education, and innovation,

and one of the universities' responsibilities is to link students and researchers with the labour market (Unger & Polt, 2017).

Desk study, analysis and evaluation of scientific literature (theoretical research method), as well as reflection of personal experience (empirical research method) were used in the current study.

Results and Discussion

By analysing the current career management models at various universities, considering the career related theories, and given the author's experience, a career development model for business and economics-focused universities has been proposed.

Before moving on to the key career related theories and the proposed career development model, it is essential to begin with the definition of a career notion. In this article a career is viewed as a sequence of work experiences that an individual has during the working life, whether at one company or different ones (Greenhaus, Callanan, & Godshalk, 2018).

One of the widespread career related theories, career construction theory (Savickas, 2005), explains why and how individuals choose certain jobs. The theory offers a framework for understanding occupational behaviour across the lifespan and tools for career counsellors to use in directing clients into fulfilling jobs. It takes into consideration the diverse, developmental, and dynamic perspectives of vocational behaviour which enable researchers and counsellors to examine how individuals build careers through the application of life themes to integrate self-organisation of personality and self-extension of career adaptability into a self-defining whole that motivates to work, guides occupational choice, and designs vocational adjustment. The theory investigates the essence of vocational personality types and people's diverse preferences, involves the study of how individuals adapt to the difficulties of vocational training, job transitions, and traumas and brings to the subject of how and why the themes of an individual's personal life affect their professional decisions.

In a number of publications, further discussion of life trajectory and life design has been addressed (Lara & Vess, 2014; Savickas, 2012; Savickas *et al.*, 2009). Life design interventions involve clients reflecting on how they use their strengths and skills to build their lives and meet their needs. In order to build careers that express a client's self-concept, clients reflect on themselves, receive feedback, and imagine possible selves. As part of the process of constructing careers that express the clients' self-concepts, reflection on self, receiving feedback, and imagining possible selves are integrated. The five presuppositions of life-design counselling are ecological contexts, complex dynamics, nonlinear casualties, multiple subjective realities, and dynamical modelling (Savickas, 2005; 2011; 2012).

Another holistic approach to careers is presented in the chaos theory of careers (Pryor & Bright, 2003) that emphasises complexity, change, and chance. Individuals are complex and dynamic systems that seek both survival as well as meaning and purpose, according to this theory. A career counsellor's role in this regard is to encourage individuals to pursue their life goals and meaning by teaching them how to understand their diversity and complexity. Accepting and remaining open to new possibilities is crucial which has been discussed in the recent research (Pryor & Bright, 2022) and which suggests people to accept that uncertainty is now a part of everyday life and that wealth, power, or experience can guarantee protection from it. According to the theory, individuals should instead be aware of, and able to adjust to and prepare for, real-world uncertainty, at least in the context of career management.

Another term that is often used by researchers is career management, the most essential part of which can be viewed from either the individual's or the company's point of view, is adopting a proactive approach to managing an individual's own career (Stuart, 2014). By developing self-management skills and taking a proactive approach, individuals can identify the areas where some actions and support are needed and areas where they progress well.

The notion of adaptability was observed in M. Savickas's (Savickas, 2005) research, in which the adaptive individual is defined as an individual who is concerned about his/her vocational future, increasing personal control over his/her vocational future, displaying curiosity by exploring possible selves and future scenarios, and increasing confidence in his/her aspirations. Increasing a client's career adaptability is a key goal of career counselling.

In accordance with another theory, the social cognitive career theory (Lent, Brown, & Hackett, 2002; Stajkovic & Stajkovic, 2019), self-efficacy beliefs, outcome expectations, and goals are three factors that are significant for educational and vocational interest development, choice making, and performance attainment. An individual's self-efficacy relates to an individual's personal ideas about his or her ability to undertake specific actions or courses of action. Individuals are more likely to get engaged with, pursue, and succeed at tasks for which they have high levels of self-efficacy. Self-efficacy beliefs are changeable and are derived from four basic sources of information: personal performance successes, subjective experiences, social persuasion, and physiological and emotional conditions. Outcome expectations are views about the consequences or results of specific behaviours. Personal goals are

viewed as intents to organise and direct one's behaviour in the absence of immediate positive feedback and despite unavoidable negative consequences. People tend to choose goals that are fit to their perceptions of their own skills and the consequences they anticipate from pursuing a certain course of action.

Returning to the changes in career development, they initially in many countries first started with helping people figure out what courses to study or which professions they wanted to pursue and included the assistance for young people that is centred on preparing them to make informed decisions about further education or entry into the workforce (Evangelista, 2015). Career counselling as a part of career development is still quite often viewed as something occasional and needed in such cases when a student graduates and moves on to the labour market, or when a company closes, and its employees have to find new jobs.

Due to the constant changes in the labour market, now career counselling is viewed as a continuous process that assists people of all ages in managing their careers and making the most suitable choices in terms of education, training, and employment by encouraging self-reflection about their own strengths and weaknesses and matching them to their plans and goals, as well as matching this information with the real circumstances of the labour market (UNESCO …, 2019). In addition to that, career counselling facilitates economic and social inclusion of people from various backgrounds and helps them reach their full potential and get employed (National Forum …, 2022). Because of the necessity of an individual's skills to remain marketable and competitive in the labour market and avoid unemployment, more individuals are investing their own money and spare time in developing various skills, and they seek out career counsellors on a regular basis to identify the best ways for developing their skills (Evangelista, 2015). Career counselling is carried out in close connection with other services such as education and training, which could include regular meetings to discuss professional development, weekly support meetings for those looking for work, carrying out job search activities, and mediating on behalf of members of disadvantaged groups (Evangelista, 2015).

In relation to providing career related services, career development models are introduced in universities that play a significant role in providing services to ensure students' as prospective specialists' readiness for employment and their integration into the labour market (Staiculescu, Lacatu, & Richiteanu Nastace, 2015). Career guidance, career fairs, workshops, internships, career resources, assessment, academic advising, career courses for credit, and many other services are now all part of the modern career development offered by universities in collaboration with external members like alumni, enterprises and other members of the community (Hayden & Ledwith, 2014).

The career management model in universities is a structured model that incorporates a number of services that assist students build employability skills, prepare for future careers, and at the same time, on an institutional level, help the university retain talents (Achenreiner *et al.*, 2019).

The author's proposed career development model (Figure 1) for business and economics-focused universities includes five components: a mandatory course in which students gain theoretical knowledge and prepare for future internships and employment; a mandatory internship in which students put their theoretical knowledge into practice; events organised in collaboration with employers and alumni; advising and mentorship programs; and psychological support and career counselling services.

One of the main components of the career development model is related to the preparation of students as prospective specialists for the internship and future employment and is a credit-based course for all students. Before starting an internship at companies, students need to be well-prepared and receive necessary support from the university, which could be done by integrating workshops on career-entry 'or' career design into their curricula, where possible measures regarding how to proactively and effectively shape students' labour market entry are presented (Ebner, Selenko, & Soucek, 2021). This idea is also supported by other researchers (Bridgstock & Hearn, 2012; Hayden & Ledwith, 2014; Reardon *et al.*, 2022) and is close to the author's views that a mandatory course has to be designed to prepare students as prospective specialists for the labour market. Throughout the course, students prepare their resumes and cover letters, engage in and arrange mock interviews, learn how to conduct professional communication with employers and co-workers, and develop their leadership abilities. The course has to be credit-based and is a part of a mandatory curriculum because the employability skills trained during this course are essential for all student groups.

After the first and second year of study, students do internships at real enterprises where they are exposed to the labour market and apply their theoretical knowledge to practice. Credit-based internship is one of the key components of career services at universities since all stakeholders, beginning with university students, employers and universities, benefit from them. For students, internships give a possibility to be exposed to the labour market, apply their theoretical knowledge to practice, thus improving their employability skills (Kapareliotis,

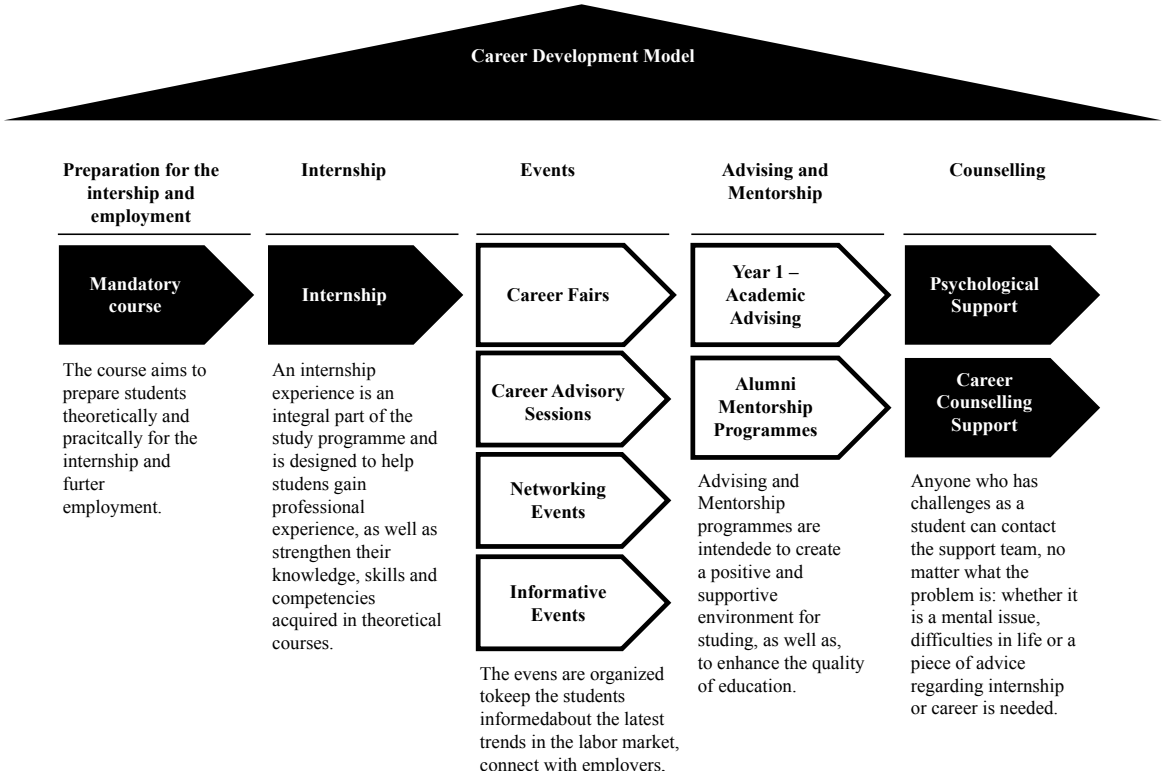

Figure 1. Career Development Model in a University Educational Environment.

Voutsina, & Patsiotis, 2019). In addition to that, doing the internship can reduce fears and uncertainty about future employment (Ebner, Selenko, & Soucek, 2021). During internships, employers can screen interns and see whether they are suitable for open positions. Universities, in addition to providing students with a possibility to apply the knowledge and skills gained during theoretical studies into practice and acquire specific skill sets required by the job market. Organising internships for students helps maintain closer connection between universities and the labour market (Kapareliotis, Voutsina, & Patsiotis, 2019). In the proposed model, even though the internship is credit-based, students are allowed to choose an internship of their choice and preference and will need to find a placement themselves, thus developing their presentation skills (Katane & Troskova, 2023) and the ability to approach employers in a professional way.

In order to establish connections with the labour market representatives, to create a professional network and also secure an internship or employment placement, various workshops and events, such as career fairs, are organised in cooperation with employers and alumni. Slightly changing the definition stated by S. Batistic and A. Tymon (Batistic & Tymon, 2017), in this case, networking is a process of establishing and maintaining personal and professional connections with a group of employers or alumni in order to generate a bank of resources, such as contacts, information, and support.

Continuing the topic of networking, an alumni mentorship programme is organised for second- and third-year students. In accordance with the study (Guccione & Hutchinson, 2021), mentoring is widely used in different universities in career related contexts and provides individuals from various backgrounds to establish professional connections, go through difficult situations and challenges with the support of a mentor, expand their horizons, and discover what works best for them. Mentoring can be viewed as coaching conversation combined with additional information, advice, or guidance based on the mentor's expertise (Guccione & Hutchinson, 2021) or a process when a person of superior rank guides an entry-level individual (Savage, Karp, & Logue, 2004). Alumni mentoring is a program designed to promote students' confidence and encouragement and improve their learning experience (Preethy & Smitha, 2023) by providing support and helping reduce stress caused by the lack of skills and motivation and issues in socializing with peers. Mentoring programs, both formal and informal, are used in university and professional environments to assist students and new professionals grow personally and professionally (Skrzypek *et al.*, 2019) and establish professional contacts used for networking (Preethy & Smitha, 2023). Alumni mentoring improves students' perceptions of graduate employability, their overall student experience, and their willingness to become mentors to future students (Dollinger, Arkoudis, &

Marangell, 2019). The participation in the alumni mentorship programme is voluntary and is based on students' as prospective specialists' initiative. Besides all the above-mentioned advantages, students have a possibility to develop their leadership skills (Katane & Troskova, 2023) as the programme is expected to be student-driven.

While second- and third-year students can be engaged with the alumni mentorship programme, for the first-year students it is mandatory to attend individual academic advising sessions four times per year and discuss students' academic performance and challenges of the academic process with a university teacher. Academic Advising helps organise a smoother transition from schools to universities and keep student retention. Although university teachers do not organise direct career counselling, they influence a lot on students' as prospective specialists' career choice. During academic advising sessions, students set academic, career, and life goals (Allen & Smith, 2008). An important factor is belonging to the community, which advisors play a large part in developing (Tinto, 2016). Students are able to build connections with supportive representatives of the university, interpret their experiences, and make well-considered choices when receiving advice. Putting together different learning experiences is a crucial step in building a unique academic identity (McGill, 2021).

Because of the growth in mental health issues that people are currently facing (World mental..., 2022), individual psychological help is offered and appears to be an important component of the career development program. Psychological readiness is also a component of the competitiveness of a specialist, indicated in one of the previous studies (Katane & Troskova, 2020).

In addition to the previously mentioned services, it is quite essential to provide support to students as prospective specialists with career counselling support, especially needed when students, despite their acquired knowledge and abilities, may become frustrated with the present labour market's uncertainties or the variety of available options or if the case of disadvantaged group representatives are involved (Evangelista, 2015; Savickas, 2005).

Conclusions

1. In the last 50 years, there has been a significant shift in the focus of both career paths and career counselling, moving from the temporary to the long-term, as individuals now take a more active role in managing their careers. Through the development of self-management skills and by applying a proactive approach, professionals can point out the areas in which individuals need additional help and the ones in which they progress well.
2. Primary aims of career counselling is to find fulfilling work and help clients become more adaptable in their chosen profession. In addition to that, a career counsellor's job is to help people see the complexity and variety in their own lives so that they can pursue the things that matter to them.
3. In accordance with the career theory of chaos, complexity, change, and chaos are emphasised. People are ever-evolving systems that look for not only the means to their own survival but also some higher meaning in life.
4. Three factors that are significant for educational and vocational interest development are choice making, and performance attainment are self-efficacy beliefs, outcome expectations, and goals.
5. The proposed career development model comprises the mandatory course that formally prepares students as prospective specialists for employment and internship, exposure to labour market in the form of internship, networking events, including alumni mentorship programme, and mental support provided by qualified psychologists and university teachers as a part of academic advising programme.

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FACTORS INFLUENCING STUDENT INITIATIVE IN EFFECTIVE MATHEMATICS STUDIES AT UNIVERSITIES

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Abstract
One of the most important problems of modern education is low achievement in STEM (Science, Technology, Engineering and Mathematics) subjects. Poor performance in mathematics is a serious problem in many countries. In order to improve the effectiveness of mathematics studies, it is more important to improve such key factors as students' learning self–efficacy and learning initiative. This study is devoted to students' learning initiative and the factors influencing it. It is the insufficiency of students' regular learning initiative in the study process that is the basis of the fact that students are not sufficiently prepared for the final exam. Based on the research results of the scientific literature, a questionnaire was created that investigated the students' learning initiative and factors that could improve it – attitude towards mathematics studies, motivation, as well as emotional factors that are often related to Causal attributions. The research was conducted at Latvia University of Life Sciences and Technologies, surveying students of various specialties and various courses. Fisher's exact test of independence is used to determine whether there is a significant relationship between two categorical variables – the respective factors and performance on the math completion test. The results show that one of the main causes is a low self–assessment of mathematics competence, which in turn affects motivation and attitude towards mathematics studies and slows down learning initiative.
Key words: effective mathematics studies, students' learning initiative, attitude, motivation.

Introduction

Mathematics studies in universities play an increasingly important role not only in engineering, but also in social science education, such as in such interdisciplinary fields as mathematical linguistics, quantitative sociology, etc. (Xiang, Wan, & Zhou, 2019). At the same time, it is no secret that mathematics studies are becoming more and more difficult both in secondary schools and universities. For example, the average grade in mathematics in Latvian secondary education centralized exams is improving (2019 – 32.7%, 2020 – 35.4%, 2021 – 36.3%, and 2022 – 37.6%) (State test, 2022, State test, 2020); however, it is insufficient. At universities, especially engineering study programs, student dropout is critical – around 40% in the United States (Hanson, 2022), in Latin America – around 50% (Ferreyra *et al.*, 2017), in the European Union – around 30% (Grove, 2014), including Latvia – as much as 48% (OECD, 2022). One of the reasons is the low success in exact subjects.

The results show that learning mathematics is not particularly effective. How to evaluate **learning effectiveness**? One of the most popular is The Kirkpatrick model, which consists of four levels (Kirkpatrick Model, 2022):

- **Reaction** (have the learners found the training relevant, engaging, useful);
- **Learning** (has knowledge, skills, attitude improved, according to the program);
- **Behavior** (whether behavioral changes can be observed, whether the learners have applied what they have learned);
- **Results** (whether objectives were achieved).

Not less important is the question: how to improve learning efficiency? The most important factors that would improve learning efficiency are learning self–efficacy, learning cognition, learning initiative. At the same time, we cannot ignore such factors as students' attitude towards learning, learning environment and teacher's support. **Self–efficacy** has developed since A. Bandura's work in 1977. Self–efficacy refers to an individual's belief in his capacity to perform the relevant behavior necessary to achieve a certain goal (Bandura, 1988; 1994) and has a great importance in the learning process, which was especially relevant during the COVID–19 period, when distance learning took place (Ahmadipour, 2022). Self–efficacy is influenced by: emotions, attitudes, digital literacy, expected result, previous experience, motivation, satisfaction (Backs, 2017). **Cognitive learning** is an active type of learning and is characterized by the ability of the brain's mental processes to absorb and retain information through experiences, feelings and thoughts (Learning Theories, 2022). A very important factor in improving learning efficiency is the student's learning initiative, which in turn depends on the students' attitude towards learning, motivation, the learning environment and the teacher's support.

The above referred to effective learning in general. Mathematics studies at the university are influenced not only by factors acquired in secondary education (basic knowledge, general competence, ability to learn in general, attitude towards school in general), but also by the emotional attitude towards these factors. These factors could be improved if there was more student learning initiative. Experience shows that success in mathematics could be much better if:

- students showed more **initiative** during the study

process than at the end of the semester;
- students changed their passive **attitude** towards learning mathematics, which is largely dependent on **motivation**;
- students were aware of the influence of the **learning environment**;
- made **efforts** to eliminate obstacles that hinder an effective study process.

The aim of this study is to identify factors that could increase students' **initiative** in learning, which in turn would improve the effectiveness of learning mathematics at universities.

Objectives of the study are:
1) to find out the students' **attitude, goal** and **involvement** in the mathematics study process and its relationship with the results in mathematics;
2) to investigate the influence of the **emotional factor** on learning **initiative** and **attitude** towards learning mathematics;
3) to investigate the relationship between students' learning performance motivation and **emotional factor** and **attitude** towards learning mathematics.

Many studies were and are being conducted on the factors that influence the attitude towards learning various subjects, especially towards those subjects which are difficult to learn. As an example, the main factors influencing **the attitude** towards foreign language learning are often mentioned: (i) The learner's personality context (self–confidence, risk–taking, anxiety), (ii) The educational context (learning situation, teacher, learning materials); (iii) Social context (students' parents, students' peer groups, community), as well as other factors, such as the students' gender, age, etc. (Gettie, 2020).

As the determining factors for students' attitude towards learning, studies also mention: ways of thinking about learning, awareness of the goal of learning (Anghelache, 2013), which would stimulate personal involvement in the learning process (initiative) and the development of personal performance.

However, Wenden (Wenden, 1991) offered a broad definition of the concept of attitudes. He states that the concept of attitude includes three components:
- the cognitive component, which consists of beliefs and ideas or opinions about the object of attitude;
- the affective component, which refers to feelings and emotions towards the object, 'like' or 'dislike', 'with' or 'against';
- the behavioral component, which refers to human actions or behavioral intentions towards an object.

But the most important thing is that attitude is learned, not innate or genetically endowed (Gardner, 1985). Although attitudes tend to persist, experience can change them.

The **emotional factor** plays a relatively large role in the attitude towards learning mathematics. It is essential for students to be aware of their emotions and build emotional skills. The promotion of emotional skills is essential (Mayer, Salovey, & Caruso, 2020): (i) emotional perception; (ii) emotional integration; (iii) emotional understanding and (iiii) emotional management.

The emotional factor often correlates with **achievement motivation** and attitude toward learning mathematics. Achievement motivation can be defined as an individual's ability to work to achieve the highest level of performance (Jankielewicz, 2022). It includes both thoughts and feelings related to motivated behavior. The desire to understand the causes of one's performance, to attribute responsibility to something, forms the causal attributions. **Causal attributions** have emotional consequences that lead to our subsequent feelings – whether we feel good, bad, or indifferent about our success or failure. The type of causal attribution made will affect the student's reaction to the situation (Sytsma, 2019). Internal and external factors also play an important role in motivation (Ornelas, 2023).

Causal attributions can be classified according to three criteria (Weiner, 1985; Graham & Weiner, 1996) (Figure 1):
- Locus of control – which can be internal (ability or motivation) or external (success or task difficulty).
- Stability – which can be stable (ability or task difficulty) or unstable (motivation or luck).
- Controllability – whether successes and failures are controllable or not.

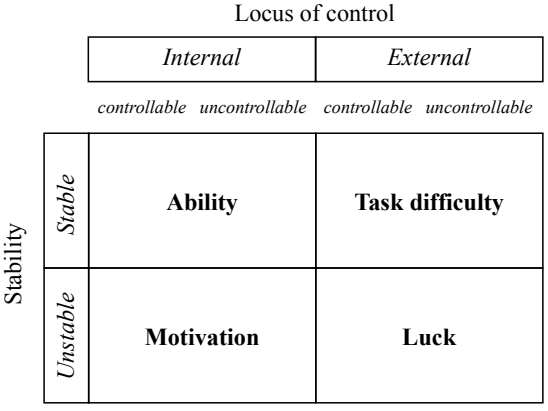

Figure 1. Attributions for Success and Failure.

Materials and Methods

In order to develop a research methodology on factors that would promote student initiative in the learning process, a study of scientific literature and documents was carried out. Based on the obtained results, a questionnaire with closed questions was created. The survey was conducted at the Latvia

University of Life Sciences and Technologies (LBTU), inviting students from various specialties to fill out an electronic questionnaire 'Factors Affecting Mathematics Studies' online. It consisted of questions about the respondents and their competences in mathematics. Study sample is 116 LBTU students from Faculty of Information Technologies, Faculty of Engineering and Faculty of Food Technology. 52% of them were first year students, 39% second year students and 9% third year students. By gender, 67% were male and 33% female, which is related to the work of the authors of the study mostly with engineering students, where most students are male. The questionnaire included questions related to the student's goal to study at LBTU, the goal to study mathematics, the evaluation of his/her competence in mathematics, as well as the evaluation of his/her attitude and involvement in mathematics studies. Based on the above, an emotional factor plays a huge role in students' involvement in mathematics studies, as well as motivation, so questions about students' emotional attitude and related attributions for success and failure were developed.

Tests of independence are used to determine whether there is a significant relationship between two categorical variables. Since some values in the contingency table in the case of obtained data are less than 5, Fisher's exact test was used in this study. Statistical analysis of results was performed using R Statistical Software (version 4.2.2, R Foundation for Statistical Computing, Vienna, Austria).

Results and Discussion

As the results of the final exams of mathematics courses show that the results in mathematics are not high enough, especially for students of engineering specialties. The involvement of students in the learning process, regular work during the semester, and the ability to manage time are very important in the process of studying mathematics. If the homework is not handed in on time, the last night is spent trying to prepare for tests, then the results are often poor.

In order to characterize students' **learning initiative** – regular involvement in the process of learning mathematics, the questionnaire includes questions about how the student solves problems when faced with difficult tasks in homework (Figure 2).

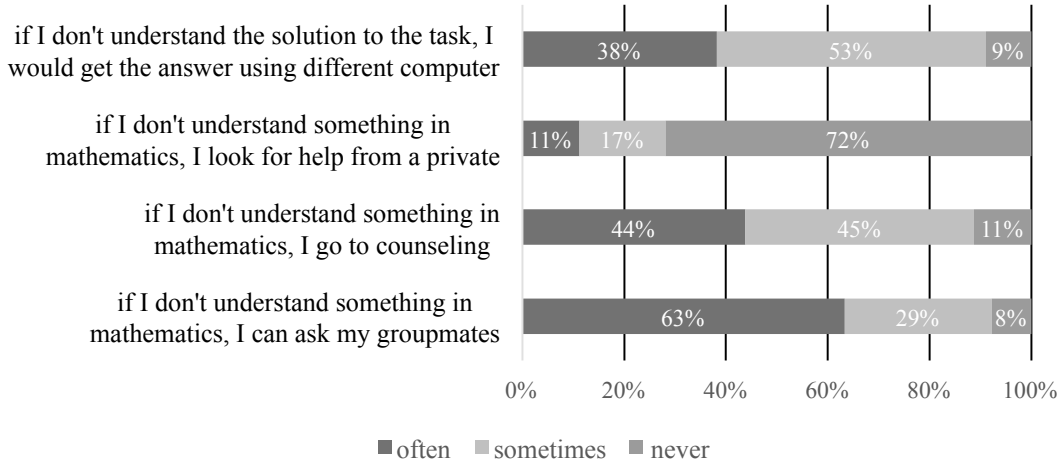

Figure 2. Student initiative in independently solving difficult tasks in mathematics.

Studies show that students more often use the 'easiest way' to solve their problems – to ask for advice from groupmates (63% – 'often'), instead of attending consultations (44% – 'often'), where the help of better quality from the teacher is possible. It is surprising that small percentage of the surveyed students use various mathematics computer programs (38%– 'often'), which are of high quality and where the solution is even explained in some of them (such as 'Symbolab Math Solver – Step by Step calculator', available https://www.symbolab.com). Students' initiative in the regular learning process is also manifested in the ability to **systematize** their knowledge, to create their own formula list in time, so that they can more fully engage in practical work in the audience. In response to the question 'When calculating homework in mathematics, do you systematize your own knowledge?', 62% of respondents answered 'often' and only 4% chose the answer 'never'. On the other hand, when answering the question 'Do you create your own list of formulas?', the majority of students (63%) chose the option 'created before the test', while 21% of students noted that they do not create their own list of formulas at all.

Of course, learning mathematics is not easy for everyone, and one of the reasons is insufficient prior

knowledge, which was not acquired in secondary educational institutions. Therefore, learning requires **effort** and **takes time.**

Evaluating the time required for learning mathematics, more than half of the survey participants (52%) chose the option 'I spend an average amount of time solving tasks', only 10% believe that 'mathematics is easy, so I don't need much time to learn subjects', but 38% chose the answer option 'when solving tasks, I make a lot of effort, devote a lot of time to them' (Figure 3).

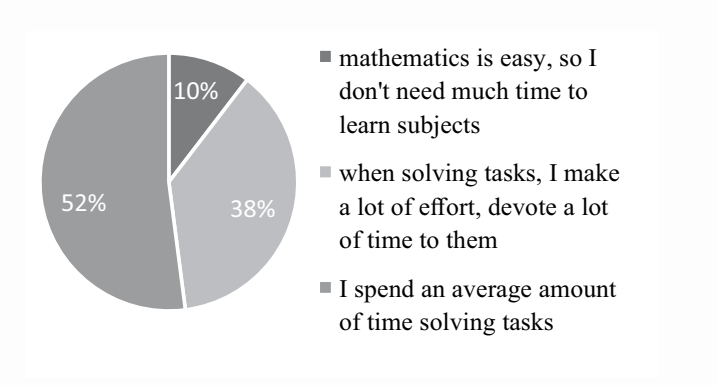

Figure 3. Time required for learning mathematics.

48% of survey participants often feel helpless when solving math problems, 42% find solving math problems interesting, and 10% feel confident.

In order to increase students' learning initiative, first of all, students' attitude towards the study process, or **motivation** to study at LBTU, should be assessed (Figure 4).

When answering the question about what motivates them to study, students had the opportunity to choose one of seven answers and the possibility to write another option. 18% of respondents chose 'it was my own choice' as the only option from the options offered, 10% chose 'career and good salary opportunities in the future' as the only option, 4% chose 'like the chosen specialty', 3% 'recommended by parents' and 2% 'recommended by friends', the rest of the respondents mentioned several reasons for studying the chosen specialty at LBTU. From the results of the survey, it can be concluded that the respondents' motivation to study was more often 'it was their own choice' and 'career and good salary opportunities in the future', so a reasonable question arises, why the student with a weak basic knowledge of mathematics chose the relevant specialty knowing

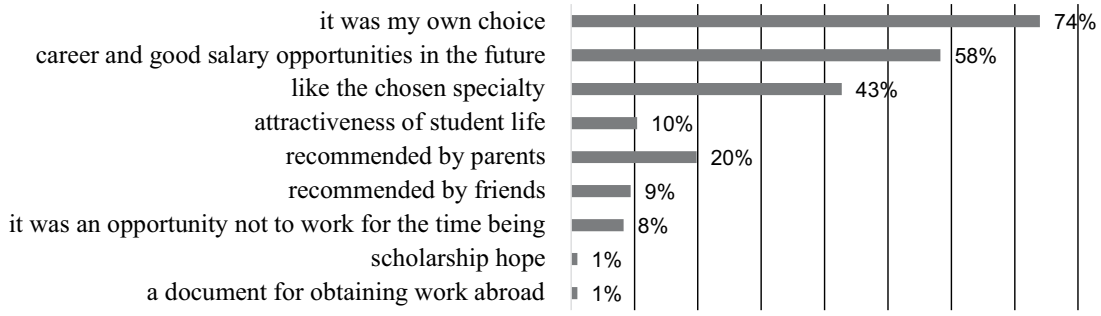

Figure 4. Motivation of students to study at LBTU.

that the program contains higher mathematics.

When starting to study mathematics, students begin to question the necessity of studying this subject even at the first failure. Students often do not see where they will use calculations in higher mathematics, because mathematics is in the first years and students have not mastered special subjects yet.

The survey participants were asked to answer which **mathematics learning goal** is most important personally to them. Three answer options were offered ('get a passing grade', 'get the best possible result', 'get knowledge that can be used in learning other study courses') and students could write other option themselves (Figure 5).

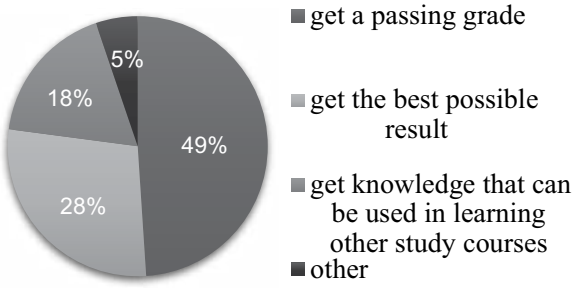

Figure 5. Students' motivation to study mathematics.

As other option, students wrote, for example, the following 'to improve thinking skills', 'to gain knowledge and understand the application for further life', 'I like solving math problems and thinking along'. Using Fisher's exact test, the hypothesis about the relationship between students' study goals and average grades was tested. Let's define the null hypothesis H0: there is no relationship between the student study goal and the student grade and the following alternative hypothesis H1: the student study goal and student grade are related variables. The result of test is $p= 0.0005<0.05$, which proves that there is a relationship between the student's study goal and the student's average grade in mathematics. 82% of students with the goal of 'getting a passing grade' have an average grade between 4 and 6. 85% of students with the goal of 'getting the best possible grade' are between grades 7 and 10.

The study also looked at the relationships between students' goals to study mathematics, attendance at counselling and the final grade in mathematics.

Applying the Fisher's exact test, it was found that for students whose main goal of learning mathematics is to get a passing grade, there is a relationship between the average grade and the attendance of counselling ($p=0.046$). Survey data shows that 86% of these students attend counselling.

For the students with the main goal of teaching mathematics 'to get knowledge that can be used in learning other study courses', there is also a relationship between the average grade and attendance at counselling ($p=0.039$). Survey data shows that only 5% of these students never attend counselling.

Using Fisher's exact test, a relationship between student's evaluation and counselling attendance was not demonstrated for students with a goal 'get the best possible result', but survey results show that 90% of these students attend counselling.

Being aware of your motivation to study mathematics, you should have a positive attitude towards the usefulness of studies. Evaluating their **attitude** towards mathematics studies, 64% of students evaluated it positively, 4% evaluated it negatively. The remaining 38% are problematic – for whom the **attitude** is neutral, but apparently not enough to increase the study initiative.

On the other hand, the attitude towards mathematics studies is also influenced by the students' self–assessment of competence. The results show that the **self–assessment** of mathematics **competence** is relatively low. Only 31% agreed with the statement 'I also understand more difficult tasks in mathematics class and tests do not cause me problems'. 26% of students admit that they simply do not understand how to solve math problems, 59% – admitted that they sometimes do not understand. The last statement is a too low self–assessment, because students have just passed the final exam in mathematics in secondary educational institutions.

Fisher's exact test of independence was performed to assess the relationship between student's attitude towards the mathematics study process at LBTU and his or her average grade in mathematics at university. Let's define the null hypothesis H0: there is no relationship between student's attitude towards the mathematics study process at LBTU and the student's average grade in mathematics, the alternative hypothesis H1: student's attitude towards the mathematics study process at LBTU and the obtained average grade are related variables. The result of Fisher's exact test is $p= 0.726>0.05$. In this case a high p–value indicates that our evidence is not strong enough to indicate the existence of a relationship between these two quantitative variables. But if the same null hypothesis is considered for students whose motivation factor for studies was a career and good salary opportunities in the future, it turns out that $p=0.0015<0.05$. It can be concluded that for this group of students, the attitude towards the mathematics study process at LBTU depends on the obtained average grade. Similarly, for students whose motivation factor for studies was their parents' recommendation where $p=0.007<0.05$.

Often the emotional factor, such as anxiety, affects the study process and test results. The participants

of the survey evaluated the emotional factors in the process of studying mathematics, choosing 'often', 'sometimes' and 'never' to evaluate the following statements: 'I worry that math lessons will be difficult', 'I worry that the test will be difficult', 'excitement during the test reduces my task–solving abilities' (Figure 6). Almost half of the surveyed students admit that they often worry that the test will be difficult. The relationship between the statement 'I worry that math lessons will be difficult' and the average grade and between the statement 'I worry that the test will be difficult' and the average grade was not found using Fisher's exact test of independence ($p=0.104>0.05$ and $p=0.500>0.05$ respectively).

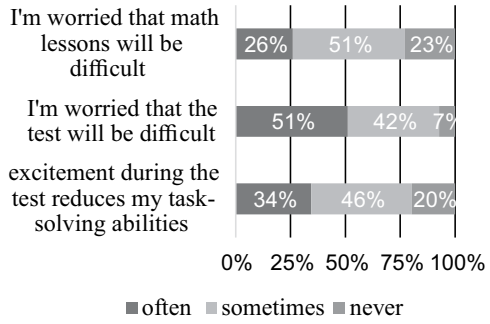

Figure 6. Emotional factors in the process of studying mathematics.

Students' answers to the questions, which were created based on the three criteria of Causal Attributes (Weiner, 1986; Graham & Weiner, 1996), are shown in Figure 7. Respondents were asked to rate with 'disagree', 'partially agree' and 'agree' several reasons why the mathematics test was not written as well as expected (Figure 7 for options and answer choices).

According to Causal attributions theory, the statement 'I haven't had time to study at all lately' ('agree' and 'partly agree' 56%) indicates controllable luck, while the statement 'I was just unlucky this time' ('agree' and 'partly agree' 67% of students), and indicates uncontrollable luck. In both cases, where the success factor dominates, there is minimal expectation of success and little desire to engage in the further learning process.

The statement 'There was an event the day before and I was too tired' ('agree' and 'partly agree' 28%) indicates a controllable effort, while the statement 'I have to study late at night and I can't learn the course well' ('agree' and 'partly agree' 73%) – already to uncontrollable effort. Deliberate lack of effort can increase guilt and heighten expectations of success when engaging in achievement–prone tasks.

It is worse when failures are attributed to lack of ability. The statement 'My head simply does not accept numbers and calculations' ('agree' and 'partly agree' 61%) indicates an uncontrollable lack of ability although the statement 'I am too lazy to properly prepare for test' ('agree' and 'partly agree' 64%) indicates a lack of controllable abilities. Practice shows that it is difficult to overcome laziness, and if it does succeed, it often turns out that it is no longer capable. In this case, there is shame, the expectation of success is reduced, and there is a reluctance to engage in tasks in which achievement is even possible.

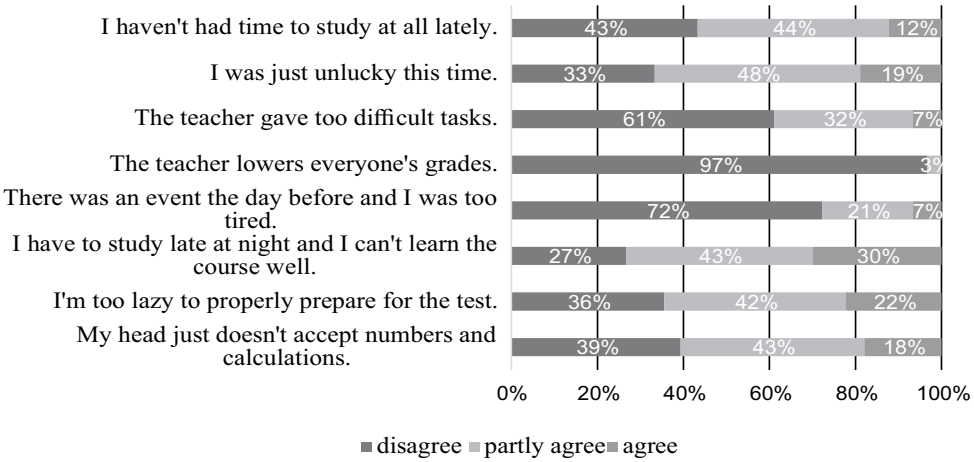

Figure 7. Attributions for Success and Failure.

One of the objectives of our study is to investigate the relationship between emotional factor and attitude towards learning mathematics. Using Fisher's exact test, the relationship between the student's attitude towards mathematics studies and the emotional factor was found in two cases: between 'how a student feels when solving math tasks' and the student's attitude towards mathematics studies ($p=0.012<0.05$) and between 'I worry that the test will be difficult' and the student's attitude ($p=0.007<0.05$).

Analysing the obtained data on the motivation of the students' learning performance and attitude towards mathematics studies, as well as on the motivation of the performance and the emotional factor, in seven cases the relationship of two qualitative variables was found using Fisher's exact test (Table 1).

Table 1

Cases when a relationship was found using Fisher's exact test

There is a relationship between	p–value
1. attitudes towards mathematics studies and 'the teacher gave too difficult tasks in the test', so it was not possible to write it as intended	0.004
2. how a student feels when solving math problems and 'my head just doesn't accept numbers and calculations', so it was not possible to write it as intended	0.008
3. how students feel when they solve math problems and 'the teacher gave too difficult task', so it was not possible to write it as intended	0.020
4. how students feel about solving math problems and 'I'm worried that math lessons will be difficult'	0.013
5. 'the teacher gave too difficult tasks in the test, so it was not possible to write it as intended, and 'I'm worried that math lessons will be difficult'	0.028
6. 'I haven't had time for studies at all lately, so I didn't manage to write the test as planned' and 'I'm worried that math lessons will be difficult'	0.027
7. 'I haven't had time for studies at all lately, so I didn't manage to write the test as planned' and 'I'm worried that the test will be difficult'	0.039

Conclusions

1. The results show that students' initiative and involvement in the study process and regular work during the semester increase the effectiveness of mathematics studies.
2. Students initiative in mathematics studies is influenced by such factors as study goals and attitude towards the learning process, understanding of the necessity of mathematics both in being able to perform calculations of various processes and in the development of cognitive processes.
3. Although almost half of the surveyed students admitted that they often worry that the test will be difficult, the relationship between the anxiety in studying mathematics and the average grade was not found.
4. Applying Causal attribution theory to research on student failure in mathematics studies, a disturbing fact is that 61% of students underestimate their ability in mathematics, while 64% admit that they are too lazy to prepare properly. Unfortunately, even unwritten several tests are not enough incentive to overcome your laziness.
5. The relationship between students' learning performance motivation and emotional factor and attitude towards learning mathematics was found in several cases using Fisher's exact test.
6. In order to improve students' attitude towards mathematics studies and motivation, to increase students' self–assessment of mathematics competence:
   – a major role must be taken by the lecturer who chooses not only optimal teaching methods and the organization of the study process, but also provides effective support.
   – the social learning environment in the student group should be improved, helping to form group work even when learning outside of the classroom.

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DIGITIZATION OF HIGHER EDUCATION IN UKRAINE: ORGANIZATIONAL AND APPLIED ASPECTS

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Abstract
Today in Ukraine, a digital transformation of the educational system of higher education is taking place at a rapid pace, in which information and communication technologies are not becoming an additional 'load' in learning, but an integral part of a comprehensive educational process, which increases its efficiency. At the same time, there are a number of challenges, including such specific ones as unprovoked military aggression, which complicates the process of entry of higher education in Ukraine into the global educational digital environment. To assess the significance of the digitalization of the educational systemof higher education in Ukraine in specific conditions, to analyze the attitude of the teaching staff and students to online education, to establish technical means of participation in the educational process, to determine the advantages and disadvantages of distance learning through the prism of the experience of teaching staff and students, we used three main methods: the survey method, the method of analysis and synthesis, the graphical method. As a result of the study, the authors revealed the general concept of digitalization and its educational dimension; identified the main challenges faced by higher education institutions in the digital environment; determined the impact and scale of military aggression by the Russian Federation on the activities of Ukrainian universities; establishedthe features of training in the digital environment by institutions of the higher education of Ukraine.
Key words: digitalization, higher education in Ukraine, educational system, digital environment, teaching staff, students.

Introduction

Digitalization is a product of the fourth industrial revolution, which is characterized by the active, rapid introduction of new innovative technologies that bring changes to all spheres of human life. New technologies give birth to others, primarily digital technologies, introducing them into the economy, culture, politics, public sector and education. This trend, caused by the global COVID-19 pandemic and catalyzed in Ukraine by unprovoked military aggression by the Russian Federation, has accelerated the pace of reforming the higher education system, determining the primary need to reorient the educational process to functioning in a digital environment.

Institutions of higher education that want to remain relevant and competitive in the 21st century are turning to digital technologies to improve the quality and accessibility of the educational process, to achieve new educational results harmonized with the requirements of the modern digital society.

As a result of the digital revolution, the very concept of higher education has undergone radical changes, starting with system-forming provisions. Therefore, responding to the challenges of digital modernity, higher education institutions around the world are accelerating the digital transformation of their activities caused by the fourth industrial revolution,which led to the emergence of a new educational and technological dimension: global, dynamic, competitive, in which they should develop.

The purpose of the study is to assess the importance of digitalization of the educational system of higher education in Ukraine, to establish the attitude of teaching staff and students to online learning, to determine its advantages and disadvantages through the prism of the experience of teachers and students in the context of a sudden transition to distance learning, staying in it for a long period and the impact on the educational process of such a specific factor as military aggression.

The objectives of the study are:

1. To reveal the general concept of digitalization and its educational dimension.
2. Identify the main challenges faced by higher education institutions in the digital environment.
3. To determine the impact and scale of the military aggression by the Russian Federation on the activities of higher education institutions in Ukraine and the formation of the educational process by them.
4. To establish the attitude of teaching staff and students to online learning, technical means of participation in the educational process, the advantages and disadvantages of digitalization of the educational system of higher education for respondents.

Materials and Methods

To assess the level of digitization of higher education in Ukraine, in the specific conditions of its course and determination of its advantages and

disadvantages through the prism of the experience of teaching staff and students in the context of a sudden transition to distance learning and staying in it for a long period, we used three main methods: the survey method, the method of analysis and synthesis and the graphic method. The study was conducted in Ukraine. Mykolaiv National Agrarian University, located in Mykolaiv (hereinafter referred to as the 'MNAU'), became the basis of the study. In the system of higher education institutions of Ukraine, MNAU has specialization in the field of agricultural technologies, technology of production and processing of animal husbandry products, standardization and biotechnology with corresponding expansion in engineering and energy, economic, management spheres (Official site of Mykolaiv National Agrarian University, 2023). The respondents were representatives of the teaching staff and students of this institution of higher education. The conducted survey sheds light on the attitude of the teaching staff and students, as the main actors, to the educational process in higher education in the conditions of total digitalization.

The electronic questionnaire (which was a Google form) was distributed among MNAU teachers and students of two levels of higher education –'bachelor' and 'master', through the information system of the university. The survey has been conducted from September 2022 to December 2022 inclusive. The authors received 120 questionnaires, among which 80 represented the opinion of student respondents, 40 questionnaires – the opinion of respondents from the teaching environment.

Respondents commented on issues related to the following areas:

1. Attitudes to distance learning.
2. The presence of digital devices that ensuresthe connection of respondents to the Internet environment in order to participate in the educational process.
3. Evaluation of online education in the following subcategories: efficiency of information and communication technologies, including the Internet, software security; the impact of digital learning on the level of acquisition of theoretical knowledge and acquisition of practical skills; assessment of online educational communication.
4. Assessment of positive and negative features of the educational process in the digital environment.

When processing experimental data, methods of mathematical statistics (statistical methods) were used. They are used in descriptive statistics (grouping, tabulation, graphical expression and quantification of data), theory of experimental planning (identification and verification of causal relationships between variables). The general population during the research was: students and teachers of Mykolaiv National Agrarian University. Sample: students of the fourth and fifth years, PhDs and doctors of science. Calculations were performed directly by the authors of the study.

Results and Discussion

Digitalization as a global trend

In recent years, digitization has become an important phenomenon that attracts the attention of both researchers and practitioners. At the macro level, digitalization refers to the changes that institutions and society as a whole undergo as a result of the use of new digital technologies. Vial (2019) analyzed more than twenty definitions of the term 'digitalization' and proposed to define it as a process aimed at improving an object by initiating significant changes in its properties through a combination of information, computing, communication and connectivity technology.

We agree with Curaj, Deca, Pricopie (2018), that digitalization is a series of deep and coordinated changes in culture, workforce and technology that create new educational and operating models and transform the institution's business model, strategic directions and value positions. Thus, it is not only about the quality of changes or technologies, it is related to the fact that technologies and digitalization are becoming a basic necessity for society (Curaj, Deca, & Pricopie, 2018).

In recent years, universities around the world have actively begun to create a digital learning environment that allows students not only to acquire the knowledge and skills needed in their respective subject areas, but also the necessary tools to make a difference (Russo & Mueller, 2013). The COVID-19 pandemic accelerated this process four years ago.

According to Rampelt *et al.* (2019), digitalization affects all activities of higher education institutions. It permeates all processes, places, formats and purposes of teaching, learning, research and work in higher education. Digitization includes the development of new infrastructures and the expansion of the use of digital media and technologies used for teaching and learning, research, support services, administration and communication, as well as for the needs of students and staff in developing their own digital skills for use in the labor market.

Higher education institutions should set clear and specific goals for their digitalization in their management strategies. Universities must have a strategic vision that will allow them to join forces to implement digital initiatives, take advantage of the enormous potential of the field of educational technologies, and offer revolutionary educational opportunities to new generations of students from anywhere in the world. For this, it is important to have professional leadership and a professional

management team that can confidently implement the plans (Rodrigues, 2017).

Distance learning tools, online tools of social networks, open educational resources, massive open online courses, complex learning management systems, etc. are considered as innovations that contribute to equal educational opportunities for all, access to quality educational content and support of lifelong learning (Saykili, 2019).

Digitization of the educational process of higher education institutions: a study from Ukraine

Higher education in Ukraine is represented by institutions of such types as university, academy, institute, college.

The legislation of Ukraine on higher education is based on Constitution of Ukraine and consists of Laws of Ukraine 'On education', 'On Scientific and Scientific-Technical Activity', this Law and other statutory instruments, international agreements in Ukraine concluded in accordance with the procedure established by law.

According to the law, higher education is a set of systematized knowledge, abilities and practical skills, ways of thinking, professional, worldview and civic qualities, moral and ethical values, other competencies acquired in a higher education institution (scientific institution) in the relevant field of knowledge according to a certain qualification at the levels of higher education, which in terms of complexity are higher than the level of complete general secondary education (On higher education, 2014).

The greatest challenge of today, which has surpassed the pandemic in terms of its consequences for Ukrainian institutions of higher education, is the unprovoked military aggression launched against Ukraine by the Russian Federation. This problem is especially relevant for universities that are located close to the war zone or were located in the occupied territories and were forced to move to another regions of Ukraine.

Innovations related to the active use of digital tools (first of all, distance learning) have been present in higher education for a long time, but due to pandemic and then the war, it has never had such a large audience as in the 2022–2023 academic year.

Open Russian aggression against Ukraine, which resulted in the beginning of the war on February 24, 2022, caused significant material damage to the education sector, including higher education. According to the information of the Ministry of Education of Ukraine (hereinafter referred to as the 'Ministry'), as of August 1, 2022, 9 colleges out of 606 existing and 7 universities out of 275 were completely destroyed, 71 colleges and 49 universities were partially damaged. The share of destroyed institutions of higher education as of January 1, 2023 is 3.27%, but with the continuation of hostilities, the number of ruined real estate of higher education institutions will constantly grow. In the regional context, such damages affected institutions of higher education in 14 regions of Ukraine out of 24. Chernihiv region suffered the greatest losses (66.7% of the total number of universities, institutes and academies of various forms of ownership in the region), Kharkiv region (47.8%), Mykolaiv region (37.5%), Donetsk region (33.3%), Zaporizhzhia region (21.4%). Note that in the last two and a half months of 2022, the number of damaged colleges and higher education institutions (together with post-graduate education institutions) increased from 99 to 120, or 1.2 times (Education of Ukraine under military conditions, 2022).

The impact of the war is catastrophic for all spheres of social life in Ukraine, including higher education. Digital innovations in this situation are a means and a tool for mitigating the consequences of war for all participants in the educational process. Therefore, the Ministry of Education and Science of Ukraine makes maximum efforts to ensure the continuity of education in Ukraine, providing access to knowledge and the opportunity to learn to every participant in the educational process. In the conditions of martial law, the ability to organize distance learning through digital technologies and solutions is of critical importance; therefore, the Ministry immediately (already at the beginning of March 2024) launched active work to attract the largest possible number of international partners, Ukrainian organizations and representatives of the business sector to support the digital education in Ukraine. Thanks to the previous experience of organizing distance learning in Ukraine during the pandemic, the work did not have to start from scratch, the creation and modernization of digital content was continued.

The attention of international donors is focused on the development and provision of access to top content for domestic universities. To date, an agreement has been reached with the leaders of the online education market – the Coursera, Udemy and edX platforms – to provide free access to a wide range of courses for Ukrainian students. As part of supporting Ukrainian education, Coursera and Udemy have opened more than 12,000 free online courses for applicants of vocational pre-university and higher education of Ukraine with the possibility of obtaining a certificate of their completion. As of August 1, 2022, more than 22,000 Ukrainian students have already registered on the Coursera platform, having completed almost 30,000 courses.

From the first weeks of the war, the website 'Education at Risk' was launched with an online map of Ukraine, which shows the number of destroyed or damaged schools, kindergartens, universities.

The International Renaissance Foundation also joined to help universities in the development of digital learning and the development of educational digital services, which contributed to the creation of a team to support and promote distance learning among higher education institutions. Together with the Ministry of Education and Science, the foundation team is working on the technical component of supporting universities in terms of access to various platforms, holding webinars for higher education representatives responsible for the digital component of education. In collaboration with Tech ToTheRescue, the team is developing a web portal to collect information about the possibilities of using online platforms, as well as successful examples of the use and adaptation of content by Ukrainian universities in the learning process.

Success in the era of digitalization in higher education can only be achieved through institutional conviction in the need to use the momentum of the digital revolution and the strong commitment of students, teachers, researchers, staff and managers. This process involves the growth of digital infrastructure, the development of the skills of academic staff to use digital methods in teaching and improving the digital skills of their students, as well as other important challenges, among which, we emphasize knowledge leadership, pedagogical and learning changes (Kaputa, Loučanová, & Tejerina-Gaite, 2022).

The results of the survey of the teaching staff and students of Mykolaiv National Agrarian University.

The qualitative characteristics of the respondents, including their gender composition, the level of higher education obtained by students, and the qualitative composition of teachers who provide the educational process, are given in Table 1.

Table 1

Qualitative characteristics of MNAU respondents-representatives who took part in the study

Study level				Teaching staff			
Bachelor		Master		Candidates of Sciences		Doctors of Science	
women, %	men, %	women, %	men, %	women, %	men, %	women, %	men, %
83.72	16.28	50.94	49.06	63.85	36.15	42.37	57.63

Women made up about two-thirds of the sample of 120 respondents (Table 1). Among teaching staff, there are 76.6% more women than men, among those teachers who have the scientific degree 'Candidate of Sciences'. Men have a numerical advantage of 36.01% among teachers with a Doctor of Science degree. Students of bachelor programs were represented in the sample by a larger share compared to students of master programs.

Mykolaiv National Agrarian University is in a state of active online education for the fourth year, starting with the second semester of the 2019–2020 academic year, when the emergence of the COVID-19 pandemic caused a sharp change in the format of education from face-to-face to distance learning. While developing the study, we were interested in how teachers and students perceived online learning after the first year of practical experience of distance learning (2019–2020 academic year) and after the fourth year of distance learning (2022–2023 academic year). The evaluation of this criterion was carried out from a gender point of view, which, in our opinion, in addition to the professional reaction, made it possible to highlight the psychological state and emotional background of the respondents in which they were in the specified period.

The evaluation of the questionnaire data made it possible to establish that the level of support for the practical application of distance learning among students was high from the 2019–2020 academic year: 80.1% – among female respondents, 93.2% – among male respondents.

Over four academic years, this level has not changed much among male students, but has significantly increased among female students (up to 96.4%) in the 2022–2023 academic year.

This is due to the number of students who, in connection with the beginning of Russia's military aggression, were forced to go abroad or are internally displaced persons. The number of such students, according to various estimates, for the city of Mykolaiv, which is a front-line city that was under daily shelling for almost 9 months, is approximately 84%. Among the students who have moved, the lion's share is made up of female students, since the male students are persons subject to conscription.

Among the teaching staff, the level of support for the use of distance learning was low in the 2019–2020 academic year: only 7.6% of female teachers and 13.3% of male teachers positively perceived the total use of this form of education. At the same time, during four years, the level of support for teachers has been constantly growing, practically increasing its positive indicators by 2 times per academic year. The biggest jump in the reassessment of the role of distance learning in a positive direction occurred among female

teachers (from 7.6% to 93.0%) in the second semester of the 2021–2022 academic year, when a large part of them had to leave Mykolaiv in March 2022 year, when there were fierce battles for the city.

In terms of technical support, laptops are the digital devices most often used by students to participate in the educational process (58.8%), followed by smartphones (37.6%), the share of other devices was 3.6%.

It is possible to conclude that the most demanded hardware for the participation of teachers in the educational process is a laptop (58.8%), the same as among students. 14.1% of respondents – teachers used a smartphone, and 2.4% – other gadgets. Among the surveyed respondents,there were such teachers who indicated the parallel use of two gadgets at the same time as an additional answer option.

Very few MNAU students and teachers had problems with online learning due to the lack of digital equipment suitable to connect to the learning process and perform duties. This statement applies to the respondents.The most common problems were poor quality of the Internet connection or failure on the respondents' digital devices.

The final part of the study in the Google form offered to respondents was devoted to determining the advantages and disadvantages of digitalization of the educational process. Its results are presented below.

Table 2

Advantages of digitalization of the educational process in higher education according to the opinion of respondents – MNAU students, %

Category	Bachelor	Master
Adequate security of software for online learning	64.2	82.1
Training in comfortable conditions	78.9	61.2
Quick collection of necessary information, easy nature of its analysis and systematization	86.3	89.5
Ability to learn how to select information and evaluate it critically	67.3	88.1
Development of new knowledge and skills, their application based on previous experience	59.0	90.0
Faster communication and the possibility to work creatively and communicate with foreign students and teachers	62.4	84.8
Balance between digital and real communication	17.2	32.7
Less material costs in distance learning compared to face-to-face learning	96.0	93.8
More time for social contacts through the Internet	91.3	87.4

Source: developed by the authors (Vindača, 2020).

Respondents among students consider the security of the software of the platforms used one of the main advantages of implementing learning in a digital environment. At the same time, master students have more confidence in software for online learning (82.1%) than bachelor students (64.2%). The technical solution of online learning at MNAU is provided by a combination of the capabilities of the Moodle learning management system for the implementation of an asynchronous knowledge acquisition mode and video conference software products (Google Meet, Zoom) to work in real time format. An important step for the university was the implementation of the policy of creating and providing a unified electronic communication space. The launch of the Moodle e-learning platform at MNAU took place in 2012, and would not have been possible without the quality management of this process, in particular with regard to the professional and psychological support of the teaching staff on the way to the digitalization of the educational process, which was provided by a multi-vector system of training and development of digital competences of teachers and students.

The vast majority of respondents–students highly appreciated the ability to collect the necessary information quickly, the easy nature of its analysis and systematization. For masters, the opportunity to develop new knowledge and skills is extremely important – 90.0% of respondents, at the same time, bachelors thought little of this advantage – 59.0%.

Also, the possibility of communication and creative cooperation with foreign students and teachers was more important for masters (84.8%) than for bachelors (62.4%) (Table2).

Important indicators of the positivity of innovative changes in the educational environment for students were the possibility of reducing material costs with distance learning compared to face-to-face learning(on average – 95.0% for bachelors and masters); the opportunity to study in comfortable conditions (on average – 70.1% for bachelors and masters); the possibility of increasing time for social contacts through the Internet (on average – 89.3% for bachelors and masters). Students adequately identified the possibility of a balance between digital and real communication as the least tangible advantage for themselves, since both bachelors (17.2%) and masters (32.7%) understand that achieving harmony between the time spent in the digital environment and the time of communication in the real world is very difficult.

Table 3

Disadvantages of digitization of the educational process in higher education according to respondents–MNAU students, %

Category	Bachelor	Master
Failures in the operation of information and communication technologies, including the Internet	100.0	100.0
Inability to have the necessary technical support for quality participation in online learning	23.4	9.1
Inability to create an appropriate space for discussion, as in the case of face-to-face teaching during lectures and seminars	46.2	68.9
Lack of personal communication with teachers, which is necessary for explaining the curriculum	73.6	51.7
Lack of personal communication with fellow students	89.1	80.1
Specific individual psychological traits that cause a student problems with online learning	9.4	4.7

Source: developed by the authors (Vindača, 2020).

Both bachelors (100%) and masters (100%) attributed failures in the operation of information and communication technologies, including the Internet, to the most problematic negative consequence of digitalization of the educational process. This problem turned out to be extremely acute and sensitive for both students and teachers against the background of massive missile attacks on the energy infrastructure of Ukraine carried out by the Russian Federation. They began on October 10, 2022, take place daily throughout the territory of Ukraine and will continue until the end of Russian military aggression. This makes the educational process unstable and dependent on the presence of the Internet, an air warning signal and electricity.

The question of real communication with fellow students is sensitive for students (89.1% – for respondents-bachelors, 80.1% – for respondents-masters) (Table3), since the war led not only to the large-scale introduction of distance learning, but also to the departure of more than 256 thousand students from Ukraine, and their internal movement to safer regions in an unknown number, especially from such large front-line cities as Kharkiv, Mykolaiv, Zaporizhzhia, Sumy, Chernihiv, Kherson (Education of Ukraine under military conditions, 2022). Also, among the most negative consequences of digitization of the educational process, students noted the lack of personal communication with teachers (on average – 62.6% for bachelors and masters) and the lack of appropriate space for discussing educational material (on average – 57.5%). An analysis of the questionnaires among the interviewed representatives of the MNAU faculty made it possible to determine that the most significant advantage of the digitalization of the educational process at the university is the unlimited resources for implementing distance learning (94.5% for Candidates of Science, 88.2% for Doctors of Science).

Table 4

The advantages of digitalization of the educational process in higher education according to the opinion of the respondents – MNAU teaching staff, %

Category	Candidates of Science	Doctors of Science
Adequate security of software for online learning	73.4	81.6
Training in comfortable conditions	86.2	89.8
Quick collection of necessary information, optimization of its classification, structuring, analysis and systematization	93.6	91.3
Increasing the level of technological competence	85.5	87.3
Connection of theory and practice	68.2	47.1
The possibility of cooperation and communication with foreign colleagues	70.8	90.6
Individual approach to learning	92.6	89.5
Unlimited resources for the implementation of distance learning	94.5	88.2

Source: developed by the authors (Vindača, 2020).

Also, a significant advantage for the above-mentioned respondents is the high rate of collection of the necessary information, effective tools for its optimization, classification, structuring, analysis and systematization (93.6% for Candidates of Sciences, 91.3% for Doctors of Sciences). Conducting training in comfortable conditions is important for 86.2% of Candidates of Sciences and for 89.8% of Doctors of Sciences. On average, 77.5% of the MNAU teaching staff are involved in the security level of software for online learning. 85.5% of Candidates of Sciences and 87.3% of Doctors of Sciences are looking for an opportunity to improve their technological competence (Table 4).

First place among the negative consequences of the digitalization of the educational process in higher education, according to the teaching staff of MNAU, as well as among the students, are problems and failures in the operation of information and communication technologies and the Internet connection. This was indicated by 100% of all respondents. The same negative impression is caused by the long process of digitizing educational materials, which teachers are forced to carry out mainly outside of working hours. 34.69% of respondents among Candidates of Science and 28.78% among Doctors of Science consider it necessary to improve their level of information and communication competence.

Representatives of the teaching environment noted two problems of a psychological nature: fear of making mistakes when conducting online classes (highly typical for Candidates of Science – 95.1%, and for Doctors of Science – 93.5%); individual rejection of online teaching (10.4% of Candidates of Science, 6.26% of Doctors of Science) (Table 5).

Significant disadvantages of online learning also include the impossibility of creating an appropriate space for discussion, as in the case of face-to-faceteaching at lectures and seminars (on average – 88.6% of respondents); lack of personal communication with students, which is necessary to explain the curriculum (76.6% of respondents).

Given the above, it can be argued that, despite the many opportunities that digital technologies open up for the educational process in higher education in Ukraine, there are also risks associated with their use, namely: the dependence of the educational process on the operation of the Internet network and software; emotional and psychological overload, caused by the duration of the digitization of significant arrays of educational material in teachers, and in students by the assimilation of this material and the lack of communication; limited practical training and the formation of communicative competencies, etc. All these negative aspects are in the active focus of attention of the administration, each of the participants in the educational process, as well as the psychological department of the university. An important tool that allows you to receive feedback from applicants and teaching staff regarding the educational process in a higher education institution are sociological surveys regularly conducted at MNAU using resources such as Google forms, Telegram, Viber, e-mail, etc.

Table 5

Disadvantages of digitalization of the educational process in higher education according to the opinion of the respondents – MNAU teaching staff, %

Category	Candidates of Science	Doctors of Science
Failures in the operation of information and communication technologies, including the Internet	100.0	100.0
Fear of making a mistake	95.1	93.5
Inability to create an appropriate space for discussion, as in the case of face-to-face teaching during lectures and seminars	87.5	89.7
Low level of information and communication competence	34.7	28.8
A long process of digitization of educational materials	100.0	100.0
Lack of personal communication with students, which is necessary for explaining the curriculum	73.3	79.9
Specific individual psychological traits that cause the teacher problems with online teaching	10.4	6.3

Source: developed by the authors using (Vindača, 2020).

Conclusions

The study conducted by the authors allows us to draw the following conclusions:

1. It has been established that digitalization is a series of profound and coordinated changes in culture, workforce and technology that create new educational and operational models and transform the higher education business model, strategic directions and value positions.
2. The main challenges faced by higher education institutions of Ukraine in the digitalization of the educational process are: the lack of modern professional leadership and a professional management team in higher education, which understands the importance of digital transformation of the educational system; formation of a strategic vision for the implementation of digital initiatives; definition in management strategies of clear and specific goals for the digitalization of the educational process at the university; the availability of tools to use the significant potential of the sphere of educational technologies; introduction of mechanisms for the implementation of revolutionary educational opportunities for new generations of students from anywhere in the world. The challenges facing higher education have significantly accelerated the digitalization of the educational process. Large-scale application of educational digital technologies is inevitable for the transformation of higher education. Now competitiveness in the market of educational services is determined precisely by the openness and readiness of an institution of higher education for the new, the ability to adapt and change in a timely manner in accordance with today's realities.
3. The greatest challenge, which has surpassed the pandemic in its consequences, for Ukrainian institutions of higher education is the unprovoked military aggression launched against Ukraine by the Russian Federation. This problem is especially relevant for universities located near the war zone or located in the occupied territories and forced to move to another regions of Ukraine.
4. Open Russian aggression against Ukraine caused significant material losses in the field of higher education. 1.5% of colleges and 2.5% of universities were completely destroyed, 12% of colleges and 17.8% of universities were partially damaged. Regionally, such damage affected institutions of higher education in 14 regions of Ukraine out of 24. The attention of international donors, helping Ukrainian higher education to survive the war and preserve the educational system, is focused on the development and provision of access to top content for domestic universities. To date, an agreement has been reached with the leaders of the online education market – the Coursera, Udemy and edX platforms – to provide free access to a wide range of courses for Ukrainian students.
5. In the course of conducting a survey of the teaching staff and students of MNAU in the context of their assessment of the level of digitization of the university, it was possible to establish the attitude

of the respondents to online learning, technical means of participation in the educational process, the advantages and disadvantages of digitalization of the educational system of the higher school for students and teaching staff.

Mykolaiv National Agrarian University is in a state of active online education for the fourth year, starting from the second semester of the 2019–2020 academic year, when the emergence of the COVID-19 pandemic caused a sharp change in the format of education from face-to-face to distance learning, and until now. Over the course of four academic years, the level of attitude towards distance learning was high among male respondents (both students and teachers), remained almost unchanged among male students and increased among male teachers; but increased significantly both among female students and female teachers in the 2022–2023 academic year, as a significant part of them became displaced persons in the second semester of the 2021–2022 academic year. In terms of technical support, laptops are the digital devices most often used by both students and teachers to participate in the educational process, followed by smartphones and other devices.

6. Among the advantages of digitization of the educational process, respondents attributed: security of software for online learning; quick collection of necessary information, easy nature of its analysis and systematization; the opportunity to learn how to select information and evaluate it critically; development of new knowledge and skills, their application based on previous experience; quick communication and the opportunity to work creatively and communicate with foreign students and teachers; increasing the level of technological competence; connection between theory and practice; individual approach to learning; training in comfortable conditions; lower material costs for distance learning compared to face-to-facelearning; increasing time for social contacts through the Internet.
7. Disadvantages of the digital transformation of the educational environment of the Ukrainian higher school were: failures in the operation of information and communication technologies, including the Internet; impossibility to have the necessary technical support for high-quality participation in online learning; low level of information and communication competence; a long process of digitizing educational materials; the impossibility of creating an appropriate space for discussion, as in the case of face-to-face teaching at lectures and seminars; lack of personal communication with teachers and fellow students; fear of making a mistake; specific individual psychological traits that cause problems with online learning.

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COMPARATIVE STUDY ON THE IMPACT OF COVID-19 ON EMOTIONAL WELL-BEING IN THE WORKPLACE

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Abstract
Individuals' emotional well-being is determined by several factors, including the ability to cope with daily stress and the ability to cope with various daily challenges. Ability of the management to provide favorable psycho-emotional and psychosocial conditions within their team is particularly important. However, managers do not always have the knowledge and skills to lead their teams. For the development of the methodology, a study of the scientific literature on topical issue like healthy workplace was performed. The empirical part of the study is based on the results of the survey conducted Lithuania, Latvia, Estonia and Sweden within the Nordplus project 'Dealing with anxiety during a pandemic to enhance adult well-being' on the impact of Covid-19, as well as the training that would be necessary for the managers of companies or organizations to promote emotional well-being in the workplace. The comparative study was conducted from the perspective of both employees and managers. The results show that the impact of the COVID-19 pandemic on workplace and the well-being of employees was not strong for the respondents, depending mainly on the job position, the size of the organization and country. Managers and employees consider various psychological trainings essential.
Key words: Covid-19, emotional well-being, healthy workplace, pandemic, psychological well-being.

Introduction

COVID-19 pandemic had a significant impact on the working environment. Many companies were forced to introduce remote work arrangements, leading to significant changes in work environment and management practices. Barrero, Bloom, & Steven 2021) mentioned that about 50 percent of paid work hours were conducted from home between April and December 2020, which is ten times more compared to pre-pandemic level. This shift led to an increase in the use of technology and changes in communication and collaboration possibilities. The situation affected life and work of every person: people experiences influence of COVID-19 pandemic on their physical and/or mental health, some of them suffered from fear, anxiety and stress, uncertainty, etc.

The Covid-19 situation has had a negative impact on the individual's work-life balance, resulting in a deterioration of emotional well-being. Remote working, limited socializing opportunities, home schooling, etc. were situations that each of us had to cope with.

If a person feels that he/she is likely to have a negative outcome, he/she may experience higher levels of stress and anxiety. As the stress continues, the person gets stuck in a 'squirrel wheel' where causes and effects get mixed up. Excessive stress leads to somatic and mental weakness, which in turn increases the risk of injury and congestion. Previously familiar and easy life situations become traumatic and require great effort to overcome. It also leads to stress at work, burnout or depression.

Peer support is important in times of emotional stress, and the understanding and ability of the management of a company or institution to provide favorable psycho-emotional and psychosocial conditions within their team is particularly important. However, managers do not always have the knowledge and skills to lead their teams, especially in high emotional risk situations where the main challenge is to reduce anxiety, improve the emotional well-being of employees and ensure a positive psycho-emotional and psychosocial environment in the workplace.

Some actions should be considered in a post-pandemic situation. One of them is to develop a training course for managers of companies and institutions to successfully lead teams, reducing anxiety and improving well-being, and to increase competence to ensure a positive psycho-emotional and psychosocial environment in the workplace. In order to determine the content of this training course, the aims of this study are:

1. Define the components of a healthy workplace;
2. Identify the impact of the COVID-19 pandemic on the workplace;
3. Identify the role of training to increase individual resilience of employees at the workplace considering the views of both workers and employers.

Materials and Methods

To develop the methodology of this study, a study of the scientific literature on topical issues like positive psycho-emotional and psychosocial environment in the workplace was performed.

The survey of managers and employees was conducted in four countries: Lithuania, Latvia, Estonia and Sweden as part of the Nordplus project 'Dealing with anxiety during a pandemic to enhance adult well-being'. The questionnaire is available here: https://forms.gle/R65rPcssmnLmBSKR9.

The questionnaire consisted of three sections:

- Section I: To collect participants' personal and workplace background information;
- Section II: To collect participants' views on the impact of the COVID-19 pandemic on the workplace and the well-being of employees;
- Section III: For the participants to offer their views on receiving training to deal with the impact of the COVID-19 pandemic at workplaces and increase individual resilience.

Section III contained the questions related to a particular topic which can be addressed by training in order to reduce anxiety; enhance the emotional well-being of employees, and insure the healthy psycho-emotional and psychosocial environment at the workplace.

A total of 335 respondents took part in the study. Results include the analysis of impact of the COVID-19 pandemic on the workplace and the role of training to increase individual resilience of employees by country, gender, education level, job position, type and size of organization.

To find out how the COVID pandemic has affected respondents, a set of questions was asked. 260 completed questionnaires were found in the analysis of these responses. Statistical analysis was performed by using chi-square test with a significance level of 0.05.

To analyse the role of training to increase individual resilience of employees, the Kruskal-Wall's test in computer package R is used to evaluate differences between groups based on medians, but pairwise.wilcox test – to evaluate what groups are different. The dataset consists of 321 rows and in this part of the questionnaire, it was necessary to answer three questions, each of which in turn contains several questions (Table 4, Table 5, Table 6) that need to be evaluated: very helpful, somewhat helpful, not very helpful, not at all helpful, difficult to say.

Results and Discussion

Researches show that anxiety of the employees has considerable consequences on the working environment: anxiety has a negative impact on levels of job performance (McCarthy, Trougakos, & Cheng, 2016), decrease productivity (Cheng & McCarthy, 2018), reduce job satisfaction, increase turnover intentions (Thorsteinsson, Brown, & Richards, 2014; Rodell & Judje, 2009), unethical behaviors could occur (Kouchaki & Desai, 2015) which affect relations with colleagues and their overall wellbeing at the workplace. In addition, anxiety can have an impact on physical and mental health of employees, for example, cardiovascular disease (Kristensen, 1996), depression (Jeon & Kim, 2018), etc. Overall, anxiety at workplace can lead to a toxic work environment and high turnaround of the employees. That's why reducing anxiety at the workplace is important and should be taken into consideration by leaders and managers.

The definition of a healthy workplace is closely related to World Health Organization's (WHO) definition of health, such as 'A state of complete physical, mental and social well-being, and not merely the absence of disease', which implies a holistic view on it. Following this definition, the four main areas should be considered while developing a healthy workplace: physical work environment, psychosocial work environment, personal health resources, and enterprise community involvement (Kotrum, 2014).

The physical work environment includes the structure, air, machines, furniture, products, chemicals, materials and processes that are present or that occur in the workplace, and which can affect the physical or mental safety, health and well-being of workers. The elements of the physical work environment can be detected by human or electronic senses. Personal health resources in the workplace include health services, information, resources, opportunities, which are provided at the workplace to support or motivate their efforts to improve or maintain healthy personal lifestyle practices.

The psychosocial work environment includes the organization of work and the organizational culture; the attitudes, values, beliefs and practices that are demonstrated on a daily basis in the enterprise/ organization, and which affect the mental and physical well-being of employees. These are sometimes generally referred to as workplace stressors, which may cause emotional or mental stress to workers.

Enterprise community involvement or business responsibility comprises the activities, expertise and other resources an enterprise engages in or provides to the social and physical community or communities in which it operates; and which affect the physical and mental health, safety and well-being of workers and their families. It includes activities, expertise and resources provided to the immediate local environment, but also the broader global environment.

In Figure 1 all four main areas are presented as well as the examples of possible interventions to improve each of them.

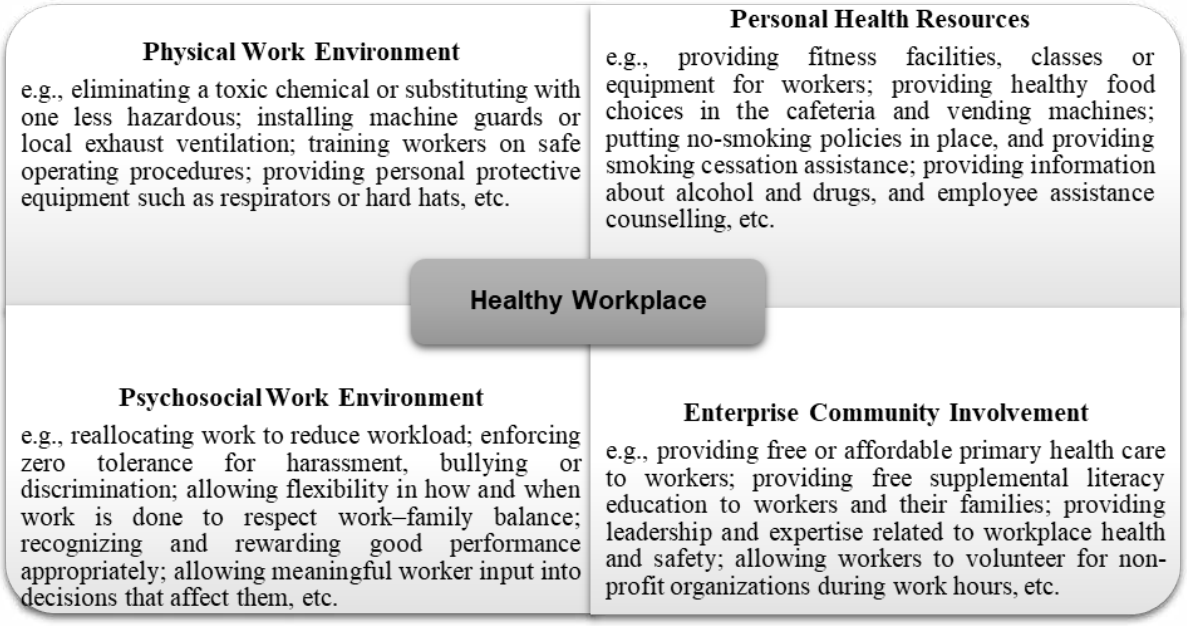

Figure 1. Four main aspects of healthy workplace.
Source: Adapted from Kotrum (2014).

Since the work environment has changed, the leaders of organisations should take more responsibility in insuring healthy psychosocial environment at the workplace and reducing anxiety and enhancing the emotional wellbeing of employees. Research shows that leaders play a critical role in reducing anxiety of the employees and creating and maintaining a healthy psychosocial environment at the workplace. They can create a culture of trust, respect, and inclusion by fostering open communication, providing support and guidance, promoting a sense of belonging among employees, addressing and managing stress factors, eliminating conflicts, and promoting work-life balance. In addition, leaders can develop positive work environment by introducing models of health support strategies (Boott *et al*., 2021) and stress coping practices.

The other issue is how much leaders know about their role in maintaining positive wellbeing of employees at the workplace and how they are prepared to provide this support to their employees.

To better understand the needs of leaders and employees in specific training focusing on particular areas, the questionnaire was designed, based on the above scientific considerations.

First, respondents answered the question on how the pandemic affected them. Table 1 details survey responses. The majority of respondents (41.0%) replied that the COVID-19 pandemic had a moderate impact on their workplace. Only 7.0% of participants mentioned they were not affected by the pandemic on their workplace. This group did not respond to a more detailed questionnaire.

Table 1

Answers to the question ’Regarding the impact of COVID-19 pandemic at your workplace, to what extent do you agree or disagree with the following?’ (%)

No impact at all	Slight impact	Moderate impact	High impact	Difficult to say
6.83	23.29	40.68	24.22	4.97

Analysis of the responses showed that there was no statistically significant difference in the distribution of responses by age, gender, duration of employment in their current position, gender composition of organization.

However, such statistically significant differences were observed when compared by the level of education (chi-squared = 28.51, p-value = 0.0275), job position (chi-squared = 13.67, p-value = 0.0085), type of organization (chi-squared = 25.594, p-value = 0.0123), size of organization (chi-squared = 28.40, p-value = 0.0048), country

(chi-squared = 91.08, p-value = 4.804e-11).

50.0% of Estonian and 20.0% of Lithuanian respondents stated that the pandemic had a moderate impact on their workplace. The largest group of Latvian respondents (35.0%) indicated that they were moderately affected by the pandemic. 45.6% of Swedish respondents and 43.3% of respondents from other countries reported that this had a high impact. Second, respondents answered a more detailed questionnaire on working conditions during the pandemic. Table 2 details survey responses.

Table 2

Answers to the question 'Regarding the impact of COVID-19 pandemic at your workplace, to what extent do you agree or disagree with the following?' (%)

Question	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree	Difficult to say
Q1. My work has become meaningless to me (I have no desire or interest to do this work)	71.81	13.09	10.07	1.01	4.03
Q2. I feel insecure at work, because I have no confidence about the future	51.34	28.52	15.10	2.68	2.35
Q3. My workload has increased significantly	23.49	23.83	28.19	19.80	4.70
Q4. I have less control over my work process and tasks	36.70	27.27	25.59	7.74	2.69
Q5. The conditions of the working environment have deteriorated, they have not been adapted to the changes caused by the pandemic	40.94	26.51	18.79	9.40	4.36
Q6. The goals of the organization where I work, would now need to be clearly defined	29.97	19.87	28.28	10.10	11.78
Q7. Relationships between employees have improved	12.46	25.93	32.32	13.80	15.49
Q8. Relationships with superiors have improved	14.53	24.32	29.05	12.84	19.26
Q9. My role in the organization is now more ambiguous, I have new opportunities for action	19.32	22.03	34.24	13.90	10.51
Q10. My career development is negatively affected (career opportunities are worse than before the pandemic)	44.11	28.62	13.13	8.08	6.06
Q11. My work-life balance is negatively affected, I have less time for home	25.42	26.10	25.08	15.59	7.80

A large proportion of respondents (71.81%) strongly disagreed with the statement 'My work has become meaningless to me (I have no desire or interest to do this work)'. Also, a significant number of respondents also disagreed with the statements 'I feel insecure at work, because I have no confidence about the future' (51.34%), 'The conditions of the working environment have deteriorated, they have not been adapted to the changes caused by the pandemic' (40.94%), 'My career development is negatively affected' (44.11%). It can be seen that there is no strong asymmetry in the distributions of the answers to questions 'The goals of the organization where I work, would now need to be clearly defined' and 'Relationships with superiors have improved'.

Further analysis showed statistically significant differences in responses to all questions except 'My career development is negatively affected' when analyzed by country. The difference in response distributions was also influenced by job position (questions in Table 2 Q2, Q4, Q5, Q6, Q7, Q8), size of organization (questions Q4, Q5, Q6, Q9, Q10, Q11). Gender composition had an impact on the distributions of responses to questions Q2 and Q11, management level – to question Q5, age – to question Q8, education level – to question Q9, length of working experience in the current position – to question Q6.

Finally, the responses to the question 'How much has your psychological well-being been affected by the COVID-19 pandemic?' were analyzed. Table 3 summarizes the distribution of responses.

Table 3

Answers to the question 'How much has your psychological well-being been affected by the COVID-19 pandemic?' (%)

Not at all affected	Slightly affected	Moderately affected	Very affected	Extremely affected	Difficult to say
29.57	40.86	17.94	7.31	0.66	3.65

The data indicated that for a large proportion of respondents the pandemic did not have a significant impact (chi-squared = 38.51, p-value = 0.0077) on psychological well-being. The distributions were statistically significantly different only when analyzing responses by country (Figure 1). It can be noted that a large proportion of respondents from Estonia, Latvia and Sweden indicated that they were not at all affected or slightly affected.

In general, the Impact of the COVID-19 pandemic on workplace and the well-being of employees was not strong for the respondents, depending mainly on the job position, the size of the organization and country. This research has its limitations. Further studies would need to analyze it in more detail to reveal a more complete picture.

The role of training to increase individual resilience of employees was also identified.

The first question 'Regardless of other measures put in place by organisations, the role of training to increase individual resilience and psychological well-being of employees is seen by you as' answered 65 respondents – A priority, 146 – Something needed, 84 – Something to consider, 9 – Not needed at all, and 18 – Difficult to say. Consequently, managers and employees consider various psychological trainings essential.

In the following analysis, we treat the answers separately for managers (134 respondents) and employees (187 respondents). In questionnaire, six questions need to be assessed. (Table 4) Managers answer these questions about their team, while employees answer about themselves. The same options are in Table 5 and in Table 6.

The answers to all questions (Table 4) are statistically different in two groups; it means that managers and employees see different needs for different trainings. Managers consider training more necessary.

Table 4

Kinds of training to reduce anxiety

Q1. Acquire comprehensive knowledge of human health as a whole	Q4. Learn and use different stress management techniques
Q2. Acquire knowledge of how to better take care of oneself	Q5. Learn and use different time management techniques
Q3. Learn and use different relaxation techniques	Q6. Any other training to reduce anxiety

The employees' answers to the questions Q2 (chi-squared = 12.908, p-value = 0.024), Q3 (chi-squared = 20.825, p-value = 0.0008), Q4 (chi-squared = 25.616, p-value = 0.0001), Q5 (chi-squared = 12.404, p-value = 0.029) vary by the level of education. For all four questions people with a vocational school education do not find these questions very helpful compared to people with a university degree (Bachelor`s degree, Master`s degree) who most often answer that these are very helpful or somewhat helpful.

The employees' answers are different in Latvia. There most common answers were not very helpful or not at all helpful. The answers from Lithuania, Estonia, Sweden, and other countries are similar and here the most popular answers are somewhat helpful.

The employees in organization of large size consider these issues much more important than in smaller organizations, specially the Q2 (chi-squared = 10.412, p-value = 0.015) and Q6 (chi-squared = 10.733, p-value = 0.013), where most often are the answer very helpful.

The employees' responses were not statistically significant difference in the distribution of responses by age, gender, duration of employment in their current position, type of organization where they work.

Managers' answers are only different by country for questions Q1 (chi-squared = 32.775, p-value = 0.0000), Q2 (chi-squared = 30.109, p-value = 0.000), Q3 (chi-squared = 31.221, p-value = 0.000), Q4 (chi-squared = 38.293, p-value = 0.0000), Q5 (chi-squared = 34.954, p-value = 0.0000), Q6 (chi-squared = 16.668, p-value = 0.000). Furthermore, here the difference was for Latvian answers, only, where all answer options were present while other countries most often answered 'very helpful'.

Analysis of the managers' responses showed that there was no statistically significant difference in the distribution of responses by age, gender, level of education, duration of employment in their current position, type of organization where they work and organization size.

Managers' and employees' evaluations of emotional well-being are different anyway. For all questions, managers consider them more important than employees. (Table 5). Much more often, managers answer that these questions are very helpful, but employees rather answer that they are somewhat helpful.

The employees' answers to the questions Q2 (chi-squared = 15.569, p-value = 0.008), Q3 (chi-squared = 18.312, p-value = 0.002), Q4 (chi-squared = 23.074, p-value = 0.0003), Q6 (chi-squared = 14.077, p-value = 0.01513) vary by the level of education. Results show that the answers of the respondents who stated that they have acquired vocational education differ from all the others, where they do not consider these issues to be particularly important.

When looking at the employees' answers by the country, there is again difference in all the questions regarding answers given by Latvian people. The distribution of answers is wide while the majority of other countries answers is 'very helpful' or 'somewhat helpful'.

Type of organization (private for profit) the questions Q1 (chi-squared = 29.236, p-value = 0.000), Q4 (chi-squared = 34.777, p-value = 0.000), Q5 (chi-squared = 24.405, p-value = 0.000) are different. People of private companies do not find these questions helpful.

The employees' responses were not statistically significant regarding difference in the distribution of responses by age, gender, duration of employment in their current position and organization size.

Managers' answers are different by education the question Q5 (chi-squared = 16.58, p-value = 0.0023) and Q6 (chi-squared = 10.227, p-value = 0.0367). Respondents who have vocational or master degree education assess these questions as not very helpful.

Table 5

Training for improving emotional well-being

Q1. Acquire knowledge of maintaining a positive attitude towards oneself and others	Q4. Learn ways to boost emotional resilience
Q2. Acquire knowledge of the nature and impact of negative stereotypes and stigmatization	Q5. Learn and apply techniques to increase self-compassion
Q3. Learn communication skills and techniques to better communicate with colleagues	Q6. Some other training to increase emotional well-being, please specify …

When considered the responses of respondents who indicated that they were managers by the country, then the differences are in questions: Q1 (chi-squared = 23.887, p-value = 0.000), Q2 (chi-squared = 14.771, p-value = 0.005), Q3 (chi-squared = 17.578, p-value = 0.001), Q4 (chi-squared = 13.496, p-value = 0.009), Q5 (chi-squared = 15.119, p-value = 0.004). Latvian manager answers differ again and people from other country assess all these questions as very helpful.

The managers' responses were not statistically

significant regarding difference in the distribution of responses by age, gender, duration of employment in their current position, type of organization where they work and organization size.

In Table 6, there are eight questions to assess a healthy psychosocial environment at the workplace.

The answers of employees differ by gender. Men consider all issues more helpful than woman. Also, the answer differs by the education level. Statistically difference is the questions Q1 (chi-squared = 25.208, p-value = 0.0001), Q2 (chi-squared = 19.467, p-value = 0.001), Q3 (chi-squared = 15.632, p-value = 0.007), Q6 (chi-squared = 17.047, p-value = 0.004), Q7 (chi-squared = 17.46, p-value = 0.003) and Q8 (chi-squared = 17.345, p-value = 0.003). People with vocational education do not find these questions helpful. When comparing questions by country, the questions Q1 (chi-squared = 62.945, p-value = 0,000), Q2 (chi-squared = 62.149, p-value = 0,000), Q3 (chi-squared = 37.114, p-value = 0.0000), Q4 (chi-squared = 26.029, p-value = 0.000), Q6 (chi-squared = 49.133, p-value = 0,000), Q7 (chi-squared = 55.025, p-value = 0,000) and Q8 (chi-squared = 18.515, p-value = 0.000) differ. Respondents from Latvia most often choose the option 'not very helpful'. For other countries the answer is 'more helpful'.

The employees' responses were not statistically significant regarding difference in the distribution of responses by age, duration of employment in their current position, type of organization where they work and organization size.

Table 6

Kinds of training to ensure a healthy psychosocial environment at the workplace

Q1. Acquire knowledge of achieving a healthy balance between professional and private life	Q5. Get practical guidance on how to deal with bullying and harassment
Q2. Acquire knowledge of proper workload (when workload is too high, when optimal)	Q6. Acquire knowledge and practical skills for achieving a healthy compromise between professional and private life
Q3. Acquire knowledge of identifying the need for psychological support (counselling), i.e., when it is needed, in what ways it can help, etc.	Q7. Acquire knowledge and practical skills for creating a positive atmosphere at the workplace
Q4. Acquire and use conflict resolution techniques, to learn to resolve conflicts peacefully and effectively	Q8. Some other training to create a healthy psychosocial environment at the workplace, please specify …

The managers' answers vary by the level of age in the following questions: Q1 (chi-squared = 20.639, p-value = 0.002), Q2 (chi-squared = 20.786, p-value = 0.002), Q3 (chi-squared = 23.631, p-value = 0.0006), Q4 (chi-squared = 26.495, p-value = 0.003), Q5 (chi-squared = 29.091, p-value = 0.001) and Q8 (chi-squared = 14.384, p-value = 0.013). For people of age 20 - 29, these questions are much more relevant than for people of age 40 and older.

By the organization type, the managers' answers vary in questions Q1 (chi-squared = 16.655, p-value = 0.0008), Q2 (chi-squared = 23.409, p-value = 0.00003), (Q3 (chi-squared = 8.8809, p-value = 0.031), Q4 (chi-squared = 15.386, p-value = 0.002) and Q6 (chi-squared = 9.0684, p-value = 0.028). Respondents who are working in governmental and public sector appreciate these questions most often as 'very helpful' or 'somewhat helpful' than respondents working for other type of organizations. When comparing answers by the country, then the differences are in questions Q1 (chi-squared = 38.932, p-value = 0.0000), Q2 (chi-squared = 27.148, p-value = 0.000), Q3 (chi-squared = 34.242, p-value = 0.00000), Q4 (chi-squared = 28.936, p-value = 0.000), Q5 (chi-squared = 12.906, p-value = 0.004), Q6 (chi-squared = 21.729, p-value = 0.0002) and Q7 (chi-squared = 14.785, p-value = 0.005). These issues are not so important to Estonian respondents. Most often, they answered 'not very helpful' or 'not at all helpful'. For Latvian, Lithuanian and Swedish respondents these issues are 'very helpful' or 'somewhat helpful'.

The managers' responses were not statistically significant regarding difference in the distribution of responses by gender, education, duration of employment in their current position and organization size.

Conclusions

1. A healthy workplace is characterised by four components: physical work environment, psychosocial work environment, personal health resources, and enterprise community involvement.
2. COVID-19 pandemic impact on the workplace: 50.0% of Estonian and 20.0% of Lithuanian respondents had a moderate impact on their workplace; 35.0% of Latvian respondents

were moderately affected, 45.6% of Swedish respondents and 43.3% of respondents from other countries had a high impact.

3. The majority of respondents (71.8%) feel that the Covid-19 pandemic has not made work meaningless and the desire to work in a job has not diminished, and half of respondents (51.34%) feel secure and confident about their future at work.
4. The survey data show that for the vast majority of respondents, the pandemic has not had a significant impact on their psychological well-being.
5. A fifth of respondents consider training to improve individual resilience and psychological well-being of employees a priority, while almost half consider it necessary.
6. Managers and employees who participated in the survey consider various psychological trainings essential. All the questions the managers' and the employees' have answered are different. The Latvian respondents' answers are different while there is the answer distribution much wider as in other countries. The employees' answers differ by education level. Respondents who have vocational education, for them the training is not very helpful.

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