Global Peatlands Assessment: The State of the World's Peatlands

EVIDENCE FOR ACTION TOWARD THE CONSERVATION, RESTORATION, AND SUSTAINABLE MANAGEMENT OF PEATLANDS

MAIN REPORT

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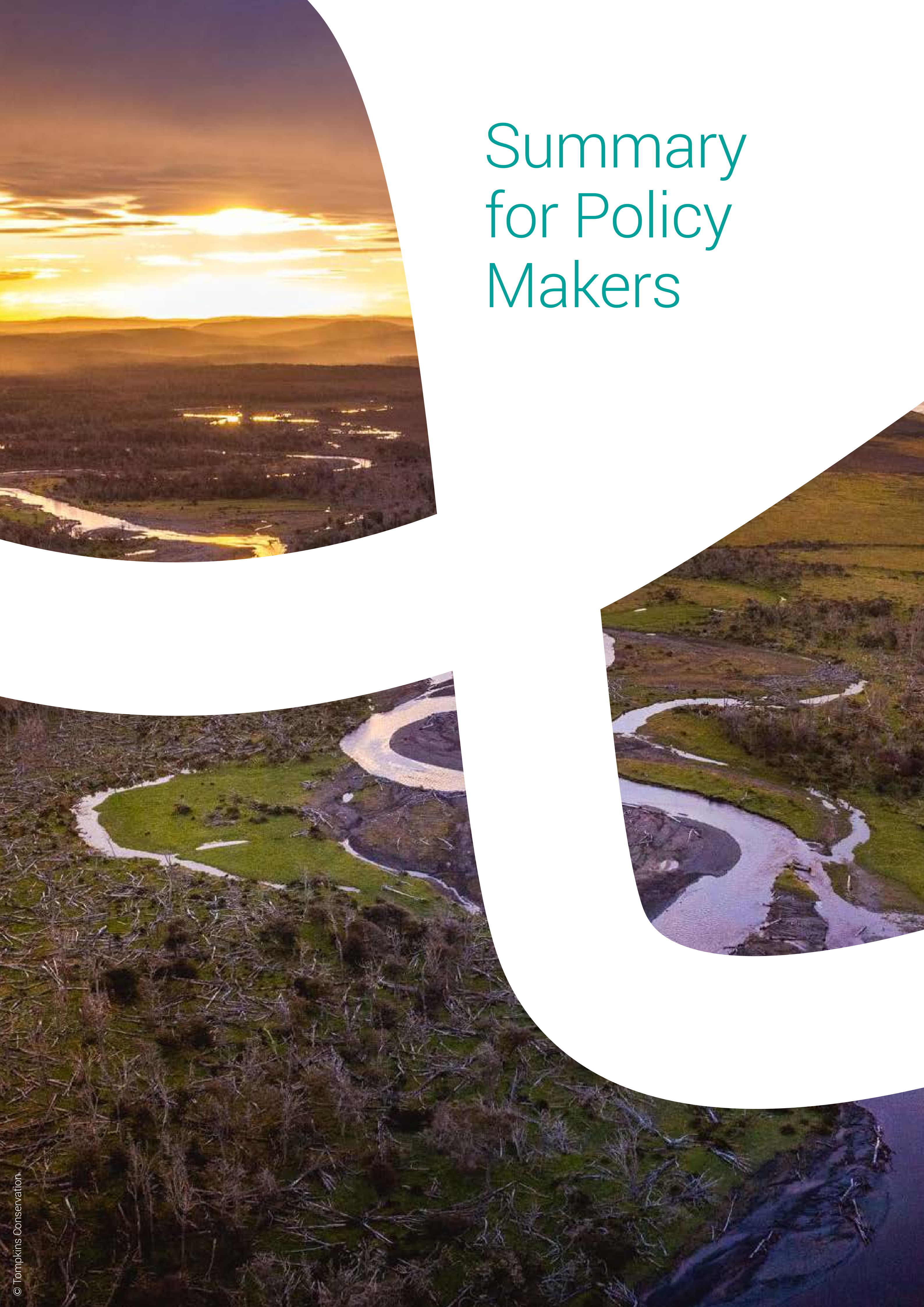

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Policy Summary

Peatlands are ecosystems with a unique type of peat soil formed from plant material that has only partially decomposed due to water saturated soil conditions (and in polar areas also due to the cold). While they are relatively rare, covering around 3-4% of the planet's land surface, they contain up to one-third of the world's soil carbon. This is twice the amount of carbon as found in the entirety of Earth's forest biomass. Keeping this carbon locked away is absolutely critical to achieving global climate goals.

The Global Peatlands Assessment is the most comprehensive assessment of peatlands to date. It has been created by a group of 226 contributors from all regions of the world to provide a better understanding of what peatlands are, where they are found, what condition they are in, and how actions can be taken to protect, restore and sustainably manage them. It also provides a valuable baseline for improvement against future assessments and paves the way for the development of a comprehensive global peatland inventory. It was created using expert-based reviews with new data on the extent and state of the world's peatlands and clearly reveals regions where information on peatlands is particularly scarce so follow-up work can be conducted to fill these data gaps.

A major focus of this assessment is on how better peatland management can be deployed as a nature-based solution to halt biodiversity loss, support climate change adaptation, support climate change resilience, mitigate further climate change and support the wellbeing of communities living in these landscapes. It has been written to help decision-makers advance sustainable peatland management and encourage urgent action for their conservation and restoration.

Although the carbon value itself of peatlands is immense, with total carbon stored in them globally estimated to be in the range of 450,000 to 650,000 megatons [Mt], this assessment considers the wider extent and condition of peatlands as it is their overall health that governs their effectiveness.

Beyond the vast quantities of carbon that they slowly sequester and store, peatlands provide a range of valuable additional benefits and services to humanity. They play a critical role in the water cycle by storing and filtering water, slowing peak flows and reducing the impact of floods. They are home to unique plants and animals that millions of people depend upon. These special wetlands also often contain important archaeological relics and include information on past environmental conditions within their peat layers that are valuable for predicting what climate will be like in the future.

Peatlands are more extensive than previously estimated. This assessment reveals that they cover about 500 million hectares globally and are found across all continents. Despite their importance in the landscape, they are often misunderstood and undervalued. Peatlands are being degraded in every part of the world. They are drained for agriculture and forestry, eroded by overgrazing of livestock, mined for fuel and horticulture, and polluted by human activity. Infrastructure development disturbs their hydrology and many are deliberately burned. These activities drive peatlands to release carbon and abruptly terminate the other benefits that they grant to people and wildlife. Degraded peatlands currently emit about 2,000 Mt of carbon dioxide equivalent [CO_2e] of greenhouse gases by microbial oxidation, which is 4 % of all anthropogenic emissions, fires excluded. Fires on drained peatlands are particularly serious as they can lead to very substantial emissions of greenhouse gases.

This situation is being made worse by climate change as higher temperatures and unpredictable rainfall patterns render peatlands drier and more vulnerable to fires that release more greenhouse gases, warm the climate further and create a dangerous feedback loop.

The situation is critical but not hopeless. It is imperative that the 88% of the world's peatlands that have not been drained and not been heavily degraded be urgently protected to prevent their immense carbon stocks from being mobilized. This combined with early action to halt further degradation through restoring drained peatlands can achieve rapid carbon emission avoidance and reductions. If implemented with urgency, the protection, restoration and sustainable management of peatlands offers a huge win for people, climate and nature. Conservation and restoration of tropical peatlands alone can reduce global greenhouse gas emissions by 800 Mt CO_2e per year (close to 2% of current annual global emissions) at an estimated investment of just $40 billion US Dollars. Such action would simultaneously support biodiversity, improve water quality, reduce flood risk, reduce air pollution from peatland fires and enhance the protection of important cultural heritage. The benefits are enormous.

Efforts to conserve and restore peatlands have met with limited success. For example, while 88% of all countries are signatories to the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Convention on Wetlands), many have not yet developed national peatland policies or plans. Typical challenges include incomplete information on the characteristics, location, extent and condition of peatlands coupled by a lack of awareness, policies and resources. This assessment aims to provide governments, other decision-makers and peatland managers with this vital information.

Protecting, restoring and sustainably managing peatlands goes far beyond meeting commitments made under the Convention on Wetlands. Taking these actions will also contribute towards targets adopted under a number of other multilateral environmental agreements. The critical role of peatlands in addressing climate change and biodiversity loss has been recognized in resolutions from the United Nations Environment Assembly, the International Union for the Conservation of Nature and the Convention on Biological Diversity. Nature-based solutions from the sustainable management of peatlands can be included in Nationally Determined Contributions and Long-Term Strategies under the Paris Agreement. They can address biodiversity targets under the UN Convention on Biological Diversity. They support connectivity for migratory species under the Convention on Migratory Species and contribute towards land degradation neutrality targets under the UN Convention to Combat Desertification. Protection and restoration of peatlands helps safeguard the human right to a clean, healthy and sustainable environment (A/RES/76/300) and can help move towards reconciliation with Indigenous Peoples and Local Communities who have lived in harmony with peatlands for thousands of years.

Key Recommendations

This assessment calls for the following actions to be taken by governments and other interested or affected parties as they develop and implement national peatlands policies, strategies and action plans:

- Develop and maintain data systems on peatland extent, condition and uses, to inform policy planning and regulations. National Wetland Inventories prepared by parties to the Convention on Wetlands are a good starting point for such systems.
- Expand protected area systems to include peatlands using evidence on the location and conservation status of peatlands provided in this assessment.
- Place buffer zones around peatlands so that encroaching threats can be averted in collaboration with local communities before they result in damage.
- Strengthen regulations to prevent or halt harmful operations like peatland drainage for agriculture and forestry, and inadvertent loss of peatlands for other uses (like minerals, oil and peat extraction).
- Initiate medium-term plans for phasing-out harmful operations that are already taking place and establish licenses that require more sustainable practices and peatland restoration obligations for the transition period.
- Form fair, transparent gender-responsive governance systems that cross sectors and empower stewardship by Indigenous Peoples and Local Communities through devolved decision-making such as indigenous co-management and community-led conservation.
- Create subsidies and fiscal mechanisms that incentivize practices that support the protection, restoration and sustainable management of peatlands.
- Eliminate perverse incentives and disincentivize activities that are driving peatland degradation and conversion.
- Use blended finance to combine public and private sector funding to scale-up the conservation, restoration and sustainable management of peatlands. Carbon and other ecosystem market mechanisms as well as a range of green finance instruments have the potential to provide returns to investors and benefits to local populations if proper safeguards are in place.
- Establish robust monitoring frameworks to ensure action for peatland conservation, restoration and sustainable management is tracked. It must then be reported on in line with national and international reporting obligations and used to inform future management.
- Support collaboration and engage in international networks and initiatives that work to advance inter-sectoral decision-making and interdisciplinary research on peatlands.

Summary on the State of Peatlands Globally

What we know

Global peatlands are estimated to cover close to 500 million hectares in this assessment. This is more than the land size proposed in previous assessments and may still be thought to be an underestimate. Like in earlier assessments, the global mapping does not reach full consistency. This is mainly because of the diversity amongst peatland definitions in use in different parts of the world and a lack of a uniform indicator of the presence of peat. Global mapping and statistics rely on the compilation of (sub)national data with different, often historically determined, definitions of peatland. The assessment has therefore mainly used the peatland definitions contained within the original studies.

In this respect it is good to be aware that conventional peatland definitions were mainly informed by agricultural considerations (e.g., plow depth), leading to common thresholds of 20-50 cm of peat depth. Inclusion of climate concerns would, because of the enormous carbon density of peat, lead to more shallow thresholds (e.g. 10 cm), which would significantly increase the area of peatland regionally and globally. For example, if using a ≥30 cm threshold, Russia's peatlands extend over 139 million hectares but, if using a ≥10 cm threshold, the country has over 368 million hectares i.e., 2.6 times more. Because of lack of global data, the Global Peatland Map 2.0 produced for the GPA (below) reflects mainly a 30-40 cm threshold, although a shallower threshold might be more appropriate in order to account for peatlands' contribution to climate. This issue could be further addressed in future updates of the assessment. More work is also needed to identify peatlands that still remain undetected.

Thanks to an unprecedented international data gathering effort, the Global Peatland Map 2.0 is the most comprehensive peatlands map ever created. It is a tool for decision-makers to help them identify priority areas for conservation, restoration and sustainable management. Created from data collected from peer-reviewed publications and national agencies complemented by remote sensing work, the new map largely overcomes key gaps in previous maps. It reveals that the majority of the world's peatlands can be found in Asia (33%), North America (32%), Latin America and the Caribbean (13%), Europe (12%), and Africa (8%). The remaining 2% are spread between Oceania and Sub-Antarctic Islands.

Whereas degraded peatlands cause enormous environmental, health and economic challenges, around 88% of global peatlands remain undegraded in a mostly natural state. The map shows that these are concentrated in remote and inaccessible areas, mainly in subarctic and boreal zones. Peatlands in both temperate and tropical regions that are readily accessible are more likely to be modified or degraded.

The assessment reveals a number of newly recognized peatlands in regions where they were under-represented in previous maps. This will inform more comprehensive mapping and assessment and raise awareness of the importance of peatlands in these locations. Unfortunately, there are still significant knowledge gaps around peatland extent and condition in many parts of the world, particularly in Africa, Amazonia and the far north.

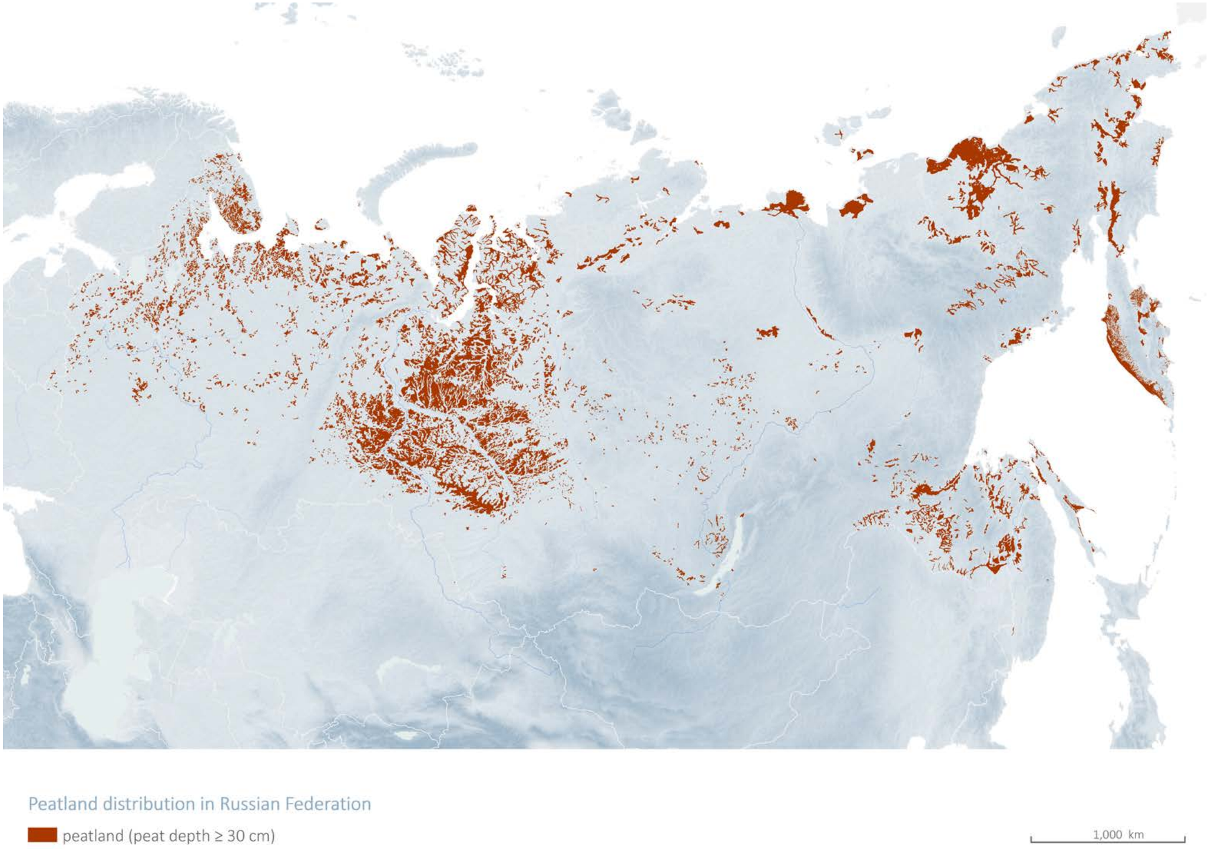


Figure 0.1: Comparison between peatland distribution in the Russian Federation when considering two different peat depth thresholds: Figure 0.1a: peat depth ≥30 cm and Figure 0.1b: peat depth ≥10 cm.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

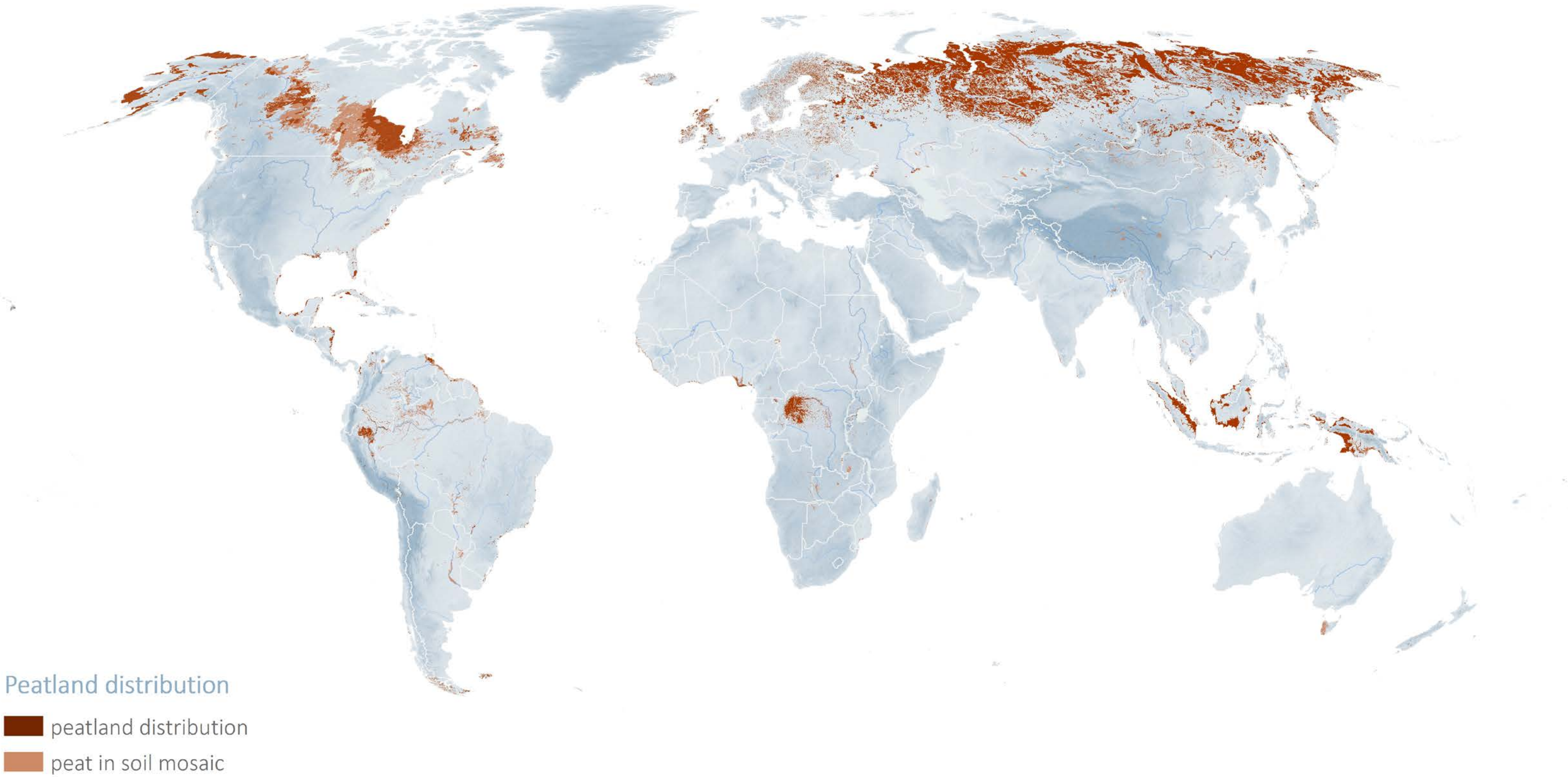


Figure 0.2: The Global Peatland Map 2.0.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Key Findings

Three important discoveries

The Global Peatlands Assessment reveals three key findings.

First, healthy peatlands are being lost and degraded at a rate that is ten times faster than their rate of expansion over the last 10,000 years. Worldwide, around 12% of current peatlands are degraded to the extent that peat is no longer formed and the accumulated peat carbon stock is being lost. 500,000 hectares of peatlands that are accumulating peat (and thus actively capturing and storing carbon) are being destroyed by human activities annually.

Second, peatland degradation, excluding fires, is releasing about 2,000 Mt CO_2e of greenhouse gas emissions per year. This represents around 4% of total global anthropogenic emissions. If greenhouse gas emissions from drained and degraded peatlands continue at this rate, this will consume 12% of the emissions budget that remains to keep global warming below +2 °C and 41% of the emissions budget that remains to keep global warming below +1.5 °C. The dry conditions that follow drainage also increase the risk of severe losses in the event of peatland fires and increased erosion. Emissions from degraded peatlands are revealed in the graph below which shows 85% of these emissions originating from 25 parties to the UN Framework Convention on Climate Change.

Third, the diversity amongst peatland definitions in use in different parts of the world has hampered efforts to consistently identify, map and manage peatlands on a global scale. This assessment uses the definition of peatlands as ecosystems with a peat soil of any thickness and is consistent with the Convention on Wetlands definition (Convention on Wetlands COP8 VIII.17) and for practical purposes, widely used a 30-40 cm peat threshold. It however recognizes that a 10 cm threshold might be more appropriate in order to account for peatlands' contribution to climate. Countries may consider this especially in future mapping and inventories or assessments to fully capture the extent of their peatland carbon stock and facilitate effective policies for protection, restoration and sustainable use.

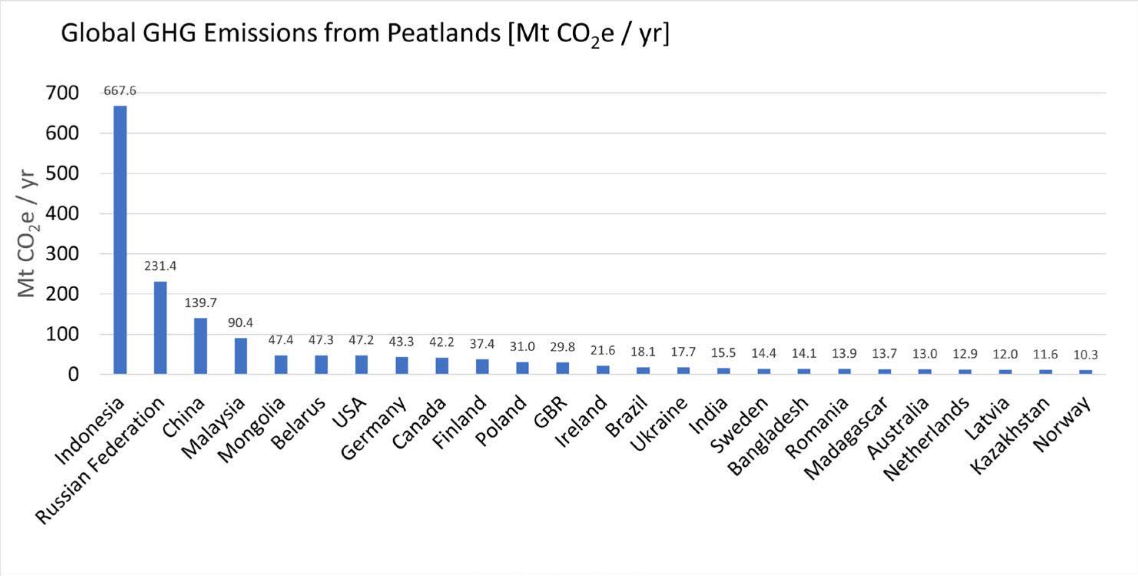


Figure 0.3: Estimated global greenhouse gas emissions from degraded peatlands from top 25 countries. Calculations are based on the peatland drained area for forestry, agriculture and peat extraction and IPCC (2014) emission factors including CO_2, CH_4, N_2O, DOC, and emissions from ditches. Includes only net, on-site GHG emissions. Wildfire emissions are not included.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Regional Summaries

Essential peatlands information on each part of the world

Asia Summary

33% of global peatlands

Asian peatlands are among the most diverse and geographically extensive in the world with over 160 million hectares spread from boreal North Asia to the temperate region of East Asia and tropical Southeast and South Asia. The Asian part of the Russian Federation contains 118,500,000 hectares of peatland. With 33% of global peatland extent, Asia is the continent with the largest peatland area in the world. Southeast Asia contains close to 24 million hectares or 5% of the global peatland resources. Besides the Russian Federation, large peatland areas are found in Indonesia, China, Kazakhstan, India, Malaysia and Mongolia. Southeast Asian tropical peat swamp forests contain some of the highest floral diversity in the world. This diverse flora supports a range of fauna including charismatic species like the Orangutan, Tiger, Clouded Leopard, Sun Bear and Gibbon.

These peatlands are under threat. It is estimated that, of Asia's 160 million hectares of peatlands, 13% are degraded while just 10% are situated within protected areas. Climate change is exacerbating degradation. So too is overgrazing by livestock, peat extraction and peatlands mining in highlands of Central Asia, conversion of peatlands for agriculture and industrial plantations in Northeast China and logging, drainage for plantations and wildfires in Southeast Asia. Southeast Asia alone lost more than half of its peat swamp forests between 1990 and 2010. Estimated greenhouse emissions from degraded peatlands in Asia are more than 1,000 Mt CO_2e per year. Indonesia reported average annual emissions of around 500 Mt of CO_2e from peat decomposition and fires. Malaysia reported around 29 Mt of carbon losses from drained organic soils. Few other countries in the region include peatlands as a key category of emissions in their reports to UNFCCC.

Subregional and transboundary agreements to tackle peatland fires causing widespread haze provide a good example for the type of coordination that will be needed to scale up solutions to degradation. The Association of Southeast Asian Nations (ASEAN) Agreement on Transboundary Haze Pollution signed in 2002 is a commitment of 10 Member States to work together to monitor and tackle the problem of haze pollution. The associated ASEAN Peatland Management Strategy (2006-2020) has facilitated National Action Plans and on-the-ground measures across the region to protect and restore peatlands and prevent peatland fires. Collaboration on implementing the agreement has enabled countries affected by the degradation of peatlands to work together to better protect and restore peatlands, reducing fires and greenhouse gas emissions.

North America Summary

32% of global peatlands

Peatlands cover an estimated 158 million hectares on the continent. The majority is found in the subarctic and boreal zones. Less than 2% of peatlands in the region are degraded. Estimated greenhouse emissions from degraded peatlands in Canada and the United States are 89 Mt CO_2e per year.

Historically, drainage for agriculture has been the main threat to North American peatlands, but they are now also threatened by oil and gas exploitation. The impact of thawing permafrost as a result of climate change needs more investigation. Mining concessions have been granted within many peatland areas, with the potential for substantial greenhouse gas emissions and loss of other ecosystem services.

Climate change may lead to increased plant productivity and uptake of carbon in some North American peatlands, but this effect is expected to be more than offset by substantial emissions from permafrost thaw, coastal erosion by sea-level rise, oxidation of dried out peats and fires which are expected to increase in frequency and severity.

Where peatlands are damaged, compensatory mitigation and offsetting policies can drive restoration, but policies and implementation vary across the continent. Most Canadian provinces have wetland policies that provide for compensatory peatland restoration to offset unavoidable loss and damage to peatlands. However, in most states, there is no moratorium on removal and destruction of peatlands to access oil and gas or ore mining or complete flooding for hydro-dams and no requirement that restoration is like-for-like (so loss of peatlands could be compensated via restoration of wetland habitats that are not peatland). An exception to this rule is Quebec's financial compensation procedure, which makes peatland destruction significantly (sometimes prohibitively) more expensive and includes a legal obligation for an action plan and follow-up measures to preserve biodiversity, restore habitats for species and maintain ecosystem services. USA federal law operates under a "no-net-loss" principle for wetlands that also requires compensatory restoration or offsetting. This has promoted carbon offsetting schemes, habitat banking systems and investment in non-regulatory conservation programmes. However, differences in implementation across states and exemptions for agriculture and drainage activities have sometimes undermined this protection.

Less than 20% of peatlands in North America are within protected areas. This includes national, provincial, territorial or state parks, land trusts and Indigenous Protected and Conserved Areas (IPCA). Some of the most biodiverse peatlands are found in the subtropical zone. For example, The Everglades of Florida are an expansive peatland landscape, covering 100,000 hectares, with Everglades National Park at its southern end designated as a Ramsar Wetland of International Importance and a United Nations World Heritage Site. Nevertheless, a number of species that depend on peatlands in North America are in decline including the Woodland Caribou, Blanding's Turtle, the Eastern Massasauga Rattlesnake and many migratory bird species.

Further policy development and implementation in collaboration with Indigenous Peoples is needed, ensuring that both women and men benefit from peatland services and contribute to their development. Regulators and government bodies need to better enforce existing peatland/wetland policies before co-developing new policies and strategies for the restoration and sustainable management of peatlands.

Given the large proportion of intact peatlands in North America, conservation is particularly important. A good example from Canada can be seen in the IPCAs, where Indigenous governments have the primary role of protecting and conserving ecosystems through Indigenous laws, governance and knowledge systems. Several IPCAs have been established since 2018, including the Edéhzhíe Dehcho Protected Area/National Wildlife Area that covers 1.4 million hectares of boreal forest and the Thaidene Nëné IPCA that includes 2.6 million hectares of forest and tundra.

Latin America and the Caribbean Summary

13% of global peatlands

Peatlands are estimated to cover 63 million hectares in Latin America and the Caribbean. Peatlands are found mainly in the (sub)tropical lowlands of South America, Central America and the Caribbean, the (sub)tropical mountains of Guyana, the Andes, the Central American and Central East Brazilian Highlands, and temperate Patagonia in southern South America. Research into peatland carbon stocks is limited in the region but recent studies estimate that peatlands in the Peruvian Amazon store ca. 5,400 Mt of carbon. Peatlands of Patagonia are the principal carbon sink and carbon stock in the extratropical Southern Hemisphere. Estimates of the amount of carbon stored differ due to uncertainties in peatland extent and depth but they are thought to be substantial.

Peatlands in Latin America and the Caribbean support a unique floral diversity that is adapted to peatland environments. Lowland Amazonian peatlands host particularly high levels of regional species diversity. High Andean peatlands have characteristic cushion plants, and Patagonian peatlands host unique plant species. These plant communities provide important habitats for fauna, with many species found in peatlands under threat. For example, in lowland palm swamps, *Mauritia flexuosa* provides an important food source for many species, such as the Lowland Tapir, and provides nesting sites for species like the Blue and Yellow Macaw. Mangroves, freshwater swamps and marshes also provide nesting sites for migratory bird species and habitat for crocodiles, turtles, jaguars, monkeys and raccoons.

Peatlands in the region help to regulate water flow into rivers and provide clean water for many communities. For example, peatlands in the Brazilian Cerrado are the only source of water for rural communities and wildlife. Quito, Ecuador, is home to nearly 2 million people of whom 90% depend upon montane peatlands for their domestic water supply. Peatlands also produce many food products and materials and are closely linked with the cultural identities of some Indigenous Peoples.

The intensity of human impacts on peatlands varies greatly across the region. Estimated greenhouse emissions from degraded peatlands in Latin America and the Caribbean are around 91 Mt CO_2e per year.

There are intact peatlands that require protection and highly degraded peatlands that require restoration. Overall, peatlands in the region are poorly protected and increasingly under threat from resource extraction, mining, changing climate, establishment of infrastructure, overgrazing by livestock, drainage, active burning, invasion by invasive species, conversion for agriculture and urbanization. Timely protection and management can reduce these threats.

Most countries in Latin America and the Caribbean lack peatland inventories and only a few have peatland policies or strategies in place. Furthermore, few have included them into international commitments like Nationally Determined Contributions. This undermines attempts to protect remaining peatlands in the region. There are also conflicts between different policies. For example, Brazilian palm swamps (Veredas) are protected by 50 metre buffers under the New Forest Code, but drainage and agricultural use of floodplains is promoted through the Provárzeas national program which leads to the degradation of protected peatlands.

There is an urgent need to improve awareness and understanding of Latin America and the Caribbean peatlands as they are not well recognized. Peatland policies and strategies need to be developed in collaboration with Indigenous Peoples and Local Communities, ensuring gender-responsive approaches. There are now examples of local knowledge being used to sustainably manage peatlands. For example, in the Pacaya Samiria national reserve (Peru), climbing techniques for fruit harvesting were developed by local people to replace the practice of cutting palms. In the Andes the traditional pre-Hispanic water management practices can contribute to manage and restore peatlands. And a participatory process has been carried out with local communities in Argentinian peatlands over 20 years leading to the Tierra del Fuego Peatland Use Plan that regulates peat mining and protects peatlands identified as important for conservation.

Europe Summary

12% of global peatlands

Peatlands cover an estimated 59 million hectares in Europe. They are distributed unevenly with a higher density in the northern lowlands, highlands and coastal areas, and more sparsely distributed in steppe and broadleaved forest zones. Europe has experienced the largest proportional degradation of peatlands of any continent in the world, and so their former extent has been significantly higher.

Large-scale, drainage-based economic use of peatlands began in Europe over a thousand years ago and still includes a wide range of uses from food, fodder, timber and energy production from peat extraction. Large peatland areas were historically transformed into construction areas, mining sites or fragmented by roads. Many of these uses have compromised the provision of wider ecosystem services. This has led to biodiversity loss, a reduction in water supply in quality and quantity and significant greenhouse gas emissions as well as losses in resilience of ecosystems and adaptation capacity. Non-degrading land use of wet peatlands such as the collection of berries, collection of medicinal plants, collection of reeds and hunting of animals have a longer history but were displaced in many regions by drainage-based peatland use.

Almost 50% of the European peatland area is degraded. This makes Europe the second largest current greenhouse gas emitter from drained peatlands at close to 600 Mt CO_2e per year and also the highest historical emitter in cumulative terms. The main reason for peatland drainage is agriculture. Close to 20% of the continent's peatlands are currently situated in protected areas. The European Red List of Habitats contains thirteen peatland habitats, three of which are listed as endangered and one as critically endangered. Conservation of undegraded peatlands on the continent is of highest priority.

The challenges associated with peatland management in Europe have not been fully addressed in land-use and climate policies. Peatland drainage and its maintenance for agriculture, forestry as well as energy are still subsidised in many countries. Furthermore, the EU and national agricultural policies and payments from associated agri-environment schemes rarely support sustainable peatland management practices but increase competitiveness of drainage-based land use artificially. The use of peat as local fuel, substrate and growing media in European households is still considered in many countries as a usual practice.

In several European countries, large scale restoration programmes are now underway, although to date these are addressing only a fraction of the damaged area. Where damaging practices cannot be reversed and peatlands restored, policies to raise water levels in peatlands still used for forestry and agriculture should be considered. In many cases, a return to a natural state for peatlands on the continent may not be possible due to the severity of the degradation. However, restoration of some peatland ecosystem functions, such as reduced carbon emissions, regulation of water flow and sedimentation retention, may still be viable. Raising the water level in peatland forests and agricultural peatlands decreases but does not halt peat loss in all cases but, by reducing drainage intensity in situations where full rewetting is not possible, some climate benefits can still be realized. Drained peatlands represent only 3% of the EU's agricultural land and rewetting them would avoid up to 25% of the EU's greenhouse gas emissions from agriculture.

Paludiculture, defined here as 'productive land use of wet and rewetted peatlands that preserve the peat', can reduce greenhouse gas emissions rapidly while also maintaining income for farmers, fisher-folk and others who make their livelihoods from peatlands. Paludiculture therefore has significant potential, particularly on degraded peatlands, to deliver social, economic and carbon reduction objectives over large land areas. Although the opportunity costs of switching to paludiculture can be high on sites that are currently used for profitable land use (e.g., horticulture, dairy farming), new markets are developing for wetland species crops and additional income (through for example ecosystem services payments) may make paludiculture increasingly attractive in the future.

National Peatland strategies have been developed in many key European peatland countries, but mainstreaming with overall climate, biodiversity and land use policies is still lacking ambition and enforcement. This will need to change in order to achieve overarching societal targets including those of a future EU Nature Restoration Law. A joint strategy or Pan-European initiative could foster peatland conservation and sustainable use across the continent, including sharing of best practices and addressing land use driven by international demand and supply.

Africa Summary

8% of global peatlands

Peatlands cover close to 40 million hectares across Africa. The Nile Basin peatlands store 4,200-10,000 Mt of carbon while the Congo Basin peatlands store around 30,000 Mt. The greenhouse gas emissions resulting from degradation of Africa's peatlands are around 130 Mt CO_2e per year, with eight countries contributing 50% of these emissions.

Africa's peatlands play an important role in regulating water flow and maintaining water purity. Millions of people depend upon them. Several major river systems arise in peatlands, such as the Okavango, Orange and Zambezi in Southern Africa and the Congo and Nile rivers in Western and Eastern Africa. Their loss will threaten water supplies as well as increase the likelihood of flash flooding downstream due to lost upstream water retention capacities in peatlands. Local communities benefit directly from the collection of food, fibre and medicines from wet peatlands. Many peatlands have significant cultural value too.

Africa contains some of the world's most important and most recently recognized peatlands. Their protection and sustainable management are crucial for climate, biodiversity and people. There are several important biodiverse African peatlands. The Palmiet peatlands of South Africa are dominated by the endemic *Prionium serratum* semi-aquatic shrub which creates a home for many rare and valuable species. Other important peatlands include the cushion plant-dominated Bale Mountains of Ethiopia and the Cuvette Centrale peat swamp forests that are home to populations of Lowland Gorilla, Forest Elephant, Bonobo and Dwarf Crocodile. While most African countries have wetland policies, the majority make no specific reference to peatlands.

African peatlands are being degraded at an alarming rate. This is creating an urgent need to protect, restore and sustainably manage them. Peatland degradation has been reported in all African countries known to host peatlands. Indeed, twelve countries report that more than 50% of their peatlands are already degraded. Drivers of degradation include drainage for plantation and smallholder agriculture, extraction of peat for burning in power plants and for use in agriculture. Other threats include urbanization drainage to satisfy increasing demands for water supply and infrastructure development.

Regional policy initiatives related to the conservation and sustainable management of African peatlands include the Brazzaville Declaration on Peatlands and the Nile Basin Initiative with its specific peatlands workstream. South Africa also has a supportive policy framework. Enforcement remains a major issue across much of the continent.

There are a number of important knowledge gaps and needs to be met to ensure protection and sustainable management of Africa's peatlands. These include collecting baseline data on the occurrence of peatlands and the status of poorly known sites, increasing awareness of the importance of peatlands, raising awareness among policy-makers on how these sites can be better managed and mobilizing international funds and private finance to protect these peatlands. As new policies and market-based approaches are developed, it is essential to engage local populations, promote gender-responsive approaches, and draw upon local knowledge to sustain livelihoods alongside the protection, restoration and sustainable management of Africa's peatlands.

Oceania and Antarctica Summary

2% of global peatlands

Oceania and Antarctica is a diverse region including Papua New Guinea, Australia and New Zealand, Pacific Island countries and territories, Antarctica and Sub-Antarctic islands. Papua New Guinea and the southern regions of Australia and New Zealand support extensive peatland ecosystems. Oceania has few peatlands due to biogeographical conditions for peatland formation being rare. Overall, peatlands are estimated to cover 7 million hectares in Oceania and around 70,000 hectares in the Sub-Antarctic Islands.

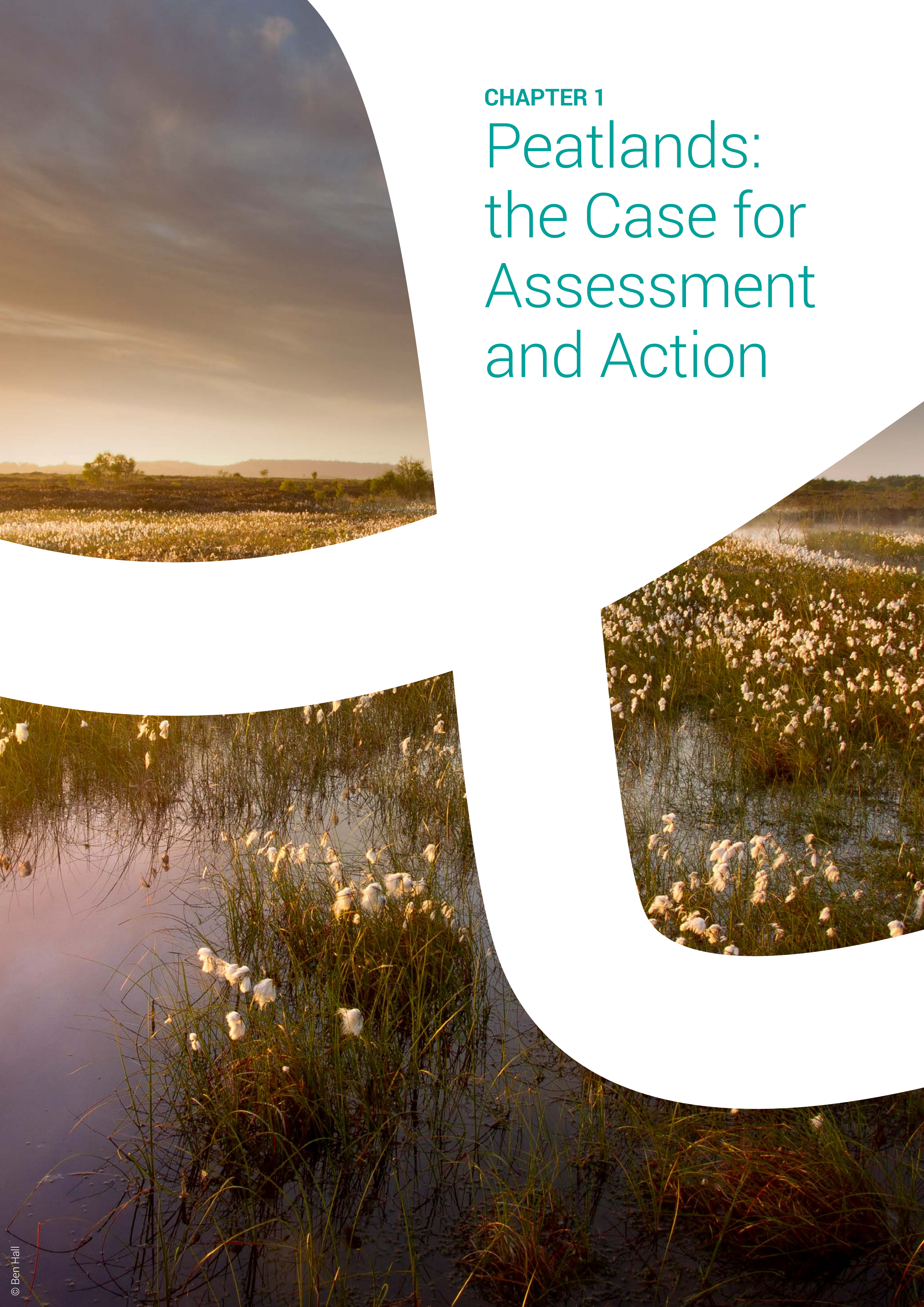
Oceanian peatlands are among the most threatened and least understood in the world. Substantial areas of coastal and lowland peatlands in Oceania have been lost since European settlement, particularly in Australia and New Zealand. Key drivers of change across the region are drainage and agricultural conversion, climate change and fire. Other notable drivers in specific areas are peat extraction, pollution, invasive species, logging and infrastructure development. New Zealand has lost large areas of peatlands due to drainage and development for agriculture. Rewetting and restoration of degraded peatlands is urgently needed to meet biodiversity and climate goals. However, until this assessment, little was known about the distribution and state of Oceanian peatlands. There is still precious little known about the carbon stocks of these areas.

Peatlands in the region are home to many unique habitats and species. Many are under threat. For example, the endemic Sunset Frog is only found in the wettest peatlands of southwestern Australia where it is vulnerable to climate change and land use impacts. Similarly, buttongrass moorlands of western Tasmania are the last stronghold for the Eastern Ground Parrot, one of only five ground-dwelling parrots in the world.

Indigenous knowledge and stewardship of peatlands is fundamental to their wise use and sustainable management in Oceania. Peatlands in the region often form part of Indigenous People’s interconnected lands, water and living things. In Australia, 39% of the peatlands are co-managed by Indigenous Peoples (mainly in Tasmania) and 8% are subject to special rights. Peatlands often form part of cultural origin traditions and are often believed to be the sacred dwelling places of important deities or ancestors. A common thread across most indigenous societies of Oceania, prior to colonization, was that peatlands commonly used to preserve, through burial, treasured items that would normally rot away, such as wooden canoes. Papua New Guinea retains vast areas of peatlands that are critical for traditional and modern economies and human wellbeing. These intact peatlands are increasingly threatened by economic development, including industrial activities.

While many regions of Oceania do not have a strategy for peatland protection, restoration and sustainable management, peatland conservation and restoration policies have been implemented in Australia and New Zealand. However, peatland degradation continues and the lack of information on the status and extent of degraded peatlands in the Oceanian region hampers regional plans and action. Estimated greenhouse emissions from degraded peatlands in Oceania are around 28 Mt CO_2e per year.

Better information on peatland carbon stocks in Oceania is urgently needed to improve management of intact and degraded peatlands for climate change mitigation and other benefits. Support and resources to develop a unified and robust Pacific Island soil information system, knowledge resource and monitoring program are crucial to assess these peatlands as a natural asset and carbon sink and to ensure that peatlands in Pacific Island countries are not lost before they are even documented.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CHAPTER 1

Peatlands: the Case for Assessment and Action

CHAPTER 1

Peatlands: the Case for Assessment and Action

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The goal of this Global Peatlands Assessment is to inform and inspire action in policy, research and practice that can help to protect, restore and sustainably manage peatlands now and long into the future.

1.1. Why Take Action to Protect, Restore and Sustainably Manage Peatlands

The planet is facing multiple severe environmental challenges. Climate change, biodiversity loss, pollution, land degradation and sea degradation are interconnected with food, energy, and water security. They are also tightly bound to rising levels of inequality, greater poverty, increasing health disruption and more displacement of people (United Nations Environment Programme [UNEP] 2021a). Immediate action is needed that reflects the commitments and ambitions agreed in the Rio Conventions (on Biodiversity, Climate Change and Desertification), the Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Convention on Wetlands, also referred to as the Ramsar Convention on Wetlands), the United Nations (UN) 2030 Agenda for Sustainable Development and the UN Decade 2021-2030 on Ecosystem Restoration.

Nature is a vital ally in the strategy to face the interconnected environmental and socioeconomic crises (UNEP 2021a). At the same time, “protecting our planet” appears as the second priority in the list of the twelve selected actions of the United Nations’ “Common Agenda” and is closely interlinked to people-related priorities such as ‘leave no one behind’ which takes first position (United Nations [UN] 2021). Protecting, restoring, and sustainably managing ecosystems are necessary to ensure that they can effectively provide the services upon which human lives depend (Rockström *et al*. 2009).

The conservation, restoration and sustainable management of peatlands is a nature-based solution (NbS) that helps tackle climate change, supports biodiversity and livelihoods and secures a range of ecosystem services. Peatlands are a special type of wetland ecosystem that occurs in almost every country on the globe. Despite only covering around 3% of land surface area peatlands are responsible for storing up to one-third of the world’s soil carbon (Joosten 2009; Scharlemann *et al*. 2014). This is twice as much carbon as in all the world’s forest biomass combined. Peatlands also play a critical role in the water cycle – filtering and storing water. They provide clean water, improve water quality and prevent floods (UNEP and International Union for Conservation of Nature [IUCN] 2021). They are home to rare and unique biodiversity. They hold great cultural meaning and are connected to the well-being of millions of people (Crump 2017). Despite their important roles for nature, climate and people, peatlands are misunderstood, undervalued, and underinvested (UNEP 2021b). This Global Peatlands Assessment is an effort to improve knowledge on where peatlands are and how they are changing in order to inform and inspire action in policy, research and practice.

Box 1.1. Peatland – a Key Definition in the Context of this Assessment

'*Peatland*' is a general term for land with a naturally accumulated layer of peat near the surface. Peatlands include both ecosystems that are actively accumulating peat, and degraded peatlands that no longer accumulate but in contrast lose peat.

The definition of peatland used in this assessment is consistent with the definition established by the Convention on Wetlands (COP 8 Resolution VIII.17) (Ramsar Convention on Wetlands 2018). The threshold for the depth of peat that constitutes a peat soil, and thereby the definition of peatland, varies by country (Intergovernmental Panel on Climate Change [IPCC] 2014).

Peatland ecosystems are under threat by deforestation, they are drained for agriculture, mined for fuel, degraded by pollution, damaged by overgrazing, harmed by fire, destroyed for infrastructure development and exposed to a range of other threats. Because peatlands are such incredible carbon storage and capture ecosystems, their degradation poses a great risk. When peatlands are disturbed, drained and degraded, they contribute disproportionately to greenhouse gas (GHG) emissions. This assessment shows that just 0.4% of Earth's land surface area is covered by degraded peatlands yet these degraded areas contribute close to 4% of the global anthropogenic GHG emissions annually (UNEP 2021c). When there are significant peatland wildfires the contribution of these degraded peatlands to emissions can double. By conserving, protecting and restoring peatlands globally, humanity can dramatically reduce and avoid emissions and revive a key ecosystem that alongside tropical forests and mangroves holds the highest carbon stocks per hectare of all natural ecosystems in the world (Epple *et al*. 2016; UNEP and IUCN 2021).

Peatlands represent incredible and unique ecosystem diversity ranging from northern bogs and fens to tropical forests and swamps. These peatland habitats, in turn, are home for a rich biodiversity, including endemic and endangered species, such as the orangutans found in the tropical peatlands of Southeast Asia, bonobos and Western Lowland Gorillas found in both the Democratic Republic of the Congo (DRC) and Republic of the Congo (Congo) and the Aquatic Warbler of central and northern Europe (Crump 2017). Peatlands also support animal species from other habitats that use them intermittently (Minayeva and Sirin 2012) and, in the specific case of bird species, peatland habitats can work as stopover sites during migration routes, offering food and refuge during global flyways (Bonn *et al*. 2016). By conserving, sustainably managing and protecting intact peatlands, humanity can maintain an essential ecosystem that provides many services for people and the planet.

Taking actions to conserve and sustainably manage intact peatlands, and to restore degraded ones, is a valuable NbS that offers socio-economic opportunities while simultaneously helping to tackle climate change, biodiversity loss, water scarcity, and other environmental threats. Solutions in peatlands have been estimated to contribute 10% of the total of emission reductions and removals that can be delivered by solutions implemented across all ecosystems by 2030 (of between 5,000 and 12,000 Mt CO_2e, according to one study) (UNEP and IUCN 2021). For peatlands restoration alone, the annual investment between 2022 and 2050 to keep climate change below 2°C, stabilize biodiversity levels and achieve land degradation neutrality should be 320 billion US Dollars (UNEP 2022b).

1.2. International Commitments to Peatland Protection and Restoration

Countries are increasingly becoming aware that conserving, restoring and sustainably managing peatlands is important for climate action, biodiversity conservation and resilience building. This has been reflected in a growing number of international peatland resolutions:

- Ramsar Convention on Wetlands - Resolution VIII.17: Guidelines for global action on peatlands; Resolution XIII.12: Guidance on identifying peatlands as Wetlands of International Importance (Ramsar Sites) for global climate change regulation as an additional argument to existing Ramsar criteria; and Resolution XIII.13: Restoration of degraded peatlands to mitigate and adapt to climate change and enhance biodiversity and disaster risk reduction, as well as mainstreaming a gender perspective in the implementation of the Convention and by extension, to peatland-related activities (Ramsar Convention on Wetlands 2002; Ramsar Convention on Wetlands 2015; Ramsar Convention on Wetlands 2018).
- International Union for the Conservation of Nature (IUCN) Resolution 43: Securing a future for global peatlands (IUCN 2016).
- Resolution on the conservation and sustainable management of peatlands, adopted at the fourth United Nations Environment Assembly (UNEA-4) (UNEP 2019).

These advances are also reflected in a number of related resolutions, including:

- Resolution on NbS for supporting sustainable development, adopted at the fifth United Nations Environment Assembly (UNEA-5) (UNEP 2022a) which defines NbS. This Resolution's implementation will benefit the design, implementation and evaluation of solutions based in peatlands.
- Decision 14/5 of the Convention on Biological Diversity (CBD) (Convention on Biological Diversity [CBD] 2018a), which encourages parties to collaborate on the conservation, restoration and wise/sustainable use of wetlands recognizing their importance in the context of climate change and disaster risk reduction. This includes supporting the process towards developing a joint declaration of multilateral environmental agreements (MEAs) with respect to peatland conservation, restoration and wise use, thereby safeguarding the multiple benefits of peatlands, including restored peatlands, and contributing to the Sustainable Development Goals (SDGs).
- Decision 14/8 of the CBD on protected areas and Other Effective area-based Conservation Measures (OECMs) (CBD 2018b), which encourages parties to apply the voluntary guidance on the integration of protected areas and OECMs into wider land- and seascapes and mainstreaming across sectors to contribute, inter alia, to the SDGs. One of the suggested steps for enhancing and supporting that mainstreaming is to identify, map and prioritize ecosystem areas important for essential ecosystem functions and services. Peatlands are specifically mentioned as one of the ecosystems that are important for climate change mitigation.
- Decision 7/4 of the CBD (CBD 2004) which recognizes peatlands as an important water ecosystem, emphasizing that the programme of work on inland water biological diversity should *"consider, support and collaborate with ongoing and/or new initiatives in these areas and in particular those related to the conservation and sustainable use of peatlands"*.

A recent report aiming to monitor the implementation of the UNEA 4/16 Peatlands Resolution, Convention on Wetlands' Resolution XIII.13 and IUCN's Resolution 43 has assessed peatland policies and strategies in 54 countries with the most extensive peatlands. This report led by IUCN has identified 23 countries with policies or strategies dedicated to these systems at the time of reporting (Reed *et al*. 2019). Since then, a further five countries (Germany, Chile, Russia, Belarus, Austria) have introduced or been found to have specific peatland policies or strategies, and these are outlined in the regional chapters of this assessment. A number of other countries support peatland conservation, restoration and sustainable management via other policies, for example as part of general environmental, conservation, agricultural, planning, mining, forestry or wetland policies. Another analysis found that only 9% of countries had developed national wetland specific policies, despite 88% being signatories to the Convention on Wetlands (Peimer *et al*. 2017). In addition to a lack of resources, one of the key barriers to developing national peatland policy is a lack of a national definition of peatlands, their extent, location, and condition.

Peatlands are critical in the context of biodiversity conservation however they appear to greater and lesser extents across a number of biodiversity focussed policies (CBD 2021; Posa *et al*. 2011). Peatlands can help address biodiversity targets as set out by the Convention on Wetlands and the CBD (Posa *et al*. 2011). The Strategic Plan 2016-2024 of the Convention on Wetlands encompasses a target to achieve a significant increase in area, numbers and ecological connectivity in the network of Wetlands of International Importance, in particular of under-represented types of wetlands including peatlands (Target 6), as well as a target on restoration of degraded wetlands, with priority to wetlands that are relevant for biodiversity conservation, disaster risk reduction, livelihoods and/or climate change mitigation and adaptation (Target 12). National reporting under the Convention on Wetlands also covers the adoption of wetland agriculture.

The Post-2020 Global Biodiversity Framework (GBF)[1] will set goals and targets for governments to meet by the end of the decade, and peatland conservation and restoration could play an important role in 'bending the curve' of species loss, both directly (e.g., through conservation and restoration), and indirectly (e.g., through contributing to climate change mitigation and adaptation). A strong post-2020 framework can help deliver the SDGs through inclusive interested/affected groups participation, and in particular, through the inclusion of women and Indigenous Peoples in peatland conservation and restoration activities.

The importance of soil carbon stocks for climate change mitigation was first recognised in the United Nations' Framework Convention on Climate Change (UNFCCC) Kyoto Protocol (1997). Under the Paris Agreement (2015) parties should take measures to conserve and enhance carbon stores and sinks. To meet their commitments under this agreement, countries set targets in Nationally Determined Contributions (NDCs), which can include peatland management. Convention on Wetlands Conference of Parties (COP) Resolution XIII.13 encourages parties to pursue peatland conservation and restoration in NDCs (Ramsar Convention on Wetlands 2018). However, a review of NDCs showed that only 22 countries of the 147 parties (i.e., including the European Union, one party which consists of 27 countries) mention specifically peatlands in one or several of the NDC submissions, and some of them specified concrete targets and/or measures. These parties are known to have peatlands in their territory (the studied NDCs have been submitted between 2015 and 23 September 2022) (Schiettecatte *et al*. 2022). On the other hand, emission reduction paths in NDCs often include solutions like bioenergy use that may increase land-use intensity or increase drainage and extraction in peatlands.

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[1] The Phase two of the Fifteenth meeting of the Conference of the Parties (COP15) to the Convention on Biological Diversity will be held in Montreal, Canada, from 7 to 19 December 2022. More info available at: https://www.cbd.int/meetings/COP-15

Even if mitigation targets are clear, reporting of the GHG emissions from organic soils is often incomplete, as many peatlands are considered “unmanaged land” of which GHG emissions do not need to be reported. This leads to the omission of permafrost thaw and wildfire emissions (e.g., see Harris *et al*. 2022 for Canada and Bellassen *et al*. 2022 for the European Union). Furthermore, although the protection, restoration and sustainable management of ecosystems including peatlands can help facilitate climate change adaptation, most NDCs and national adaptation plans have only general goals relating to NbS. Indeed, an analysis of UNFCCC adaptation projects showed that only 16% of these goals dealt with rivers, floodplains and peatlands.

A number of countries are restoring previously drained peatlands as part of their voluntary commitment to achieving land degradation neutrality targets under the UN Convention to Combat Desertification (UNCCD) (United Nations Convention to Combat Desertification [UNCCD] 2016).

Several policy-relevant Resolutions/Decisions on peatlands are already in place under different international agreements. Efforts are already underway to ensure that these different agreements support joined up action and that their implementation aims are aligned for the conservation, restoration and sustainable management of peatlands. The Global Peatlands Initiative is building on these synergies and working to ensure that the knowledge generated on peatlands is available to help countries advance on implementation through many tools, including through dedicated national peatland policies. These Resolutions/Decisions have also highlighted gaps in knowledge, including on peatlands’ extent, location, and condition, showing the need to strengthen the evidence base for the development of national policies and plans.

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1.3. The Global Peatlands Initiative Working Together for Impact, Speed, and Scale

The Global Peatlands Initiative (GPI) is an international partnership launched at UNFCCC COP 22 in Marrakech, Morocco, in late 2016. Led by the United Nations Environment Programme (UNEP), its goal is to protect and conserve peatlands as the world's largest terrestrial organic carbon stock and to prevent this carbon stock from being lost and emitted into the atmosphere. It now represents a multi-stakeholder partnership of 51 members who are working together to improve the conservation, restoration and sustainable management of peatlands. Drawing attention to peatland issues and helping countries and partners to understand and make evidence-based decisions about their management enables the Initiative to contribute to several Sustainable Development Goals.

The GPI makes an impact by highlighting cases, gathering lessons and sharing best practice examples from different types of peatland ecosystems found all around the world. It also facilitates and stimulates south-south and triangular exchanges between countries and between decision makers and interested or affected parties. The goal of the partnership is to enable and inspire action based upon evidence that shows the importance of peatlands and the contribution they make to the climate, people and the planet.

Through this Global Peatlands Assessment (GPA), GPI is bringing together the latest science to inform policies, decisions, research and actions and is building the evidence base to establish the state of the world's peatlands. The GPI intends to hold this GPA as a solid foundation and as a basis for work towards future assessments and the development of a future Global Peatlands Inventory, as called for by all countries of the world in the UNEA-4 Resolution on the Conservation and Sustainable Management of Peatlands in 2019.

1.4. About this Assessment

This assessment, delivered through the Global Peatlands Initiative partnership, is another key step on the road toward the Initiative making an impact and advancing climate and nature action. It is the most comprehensive assessment of peatlands to date, providing important new insights on the definition, location, extent, condition and governance of the world's peatlands, their contribution to climate change and how they can be harnessed as NbS for climate, biodiversity and people. The goal of this assessment is to inform and inspire action in policy, research and practice that can help to protect, restore and sustainably manage peatlands now and long into the future.

This assessment was undertaken between 2020 and 2022 and provides a global overview of the current state, extent, governance and contributions to people of peatlands and of the drivers of peatland ecosystem change. Drawing on the best available science, the assessment is designed to help decision makers plan for sustainable peatland management and to mobilize and inspire peatlands conservation and restoration action at scale and at speed.

In each of the UN regional chapters we have included the latest information on peatlands extent and status while highlighting some cases to show the different ongoing challenges, actions and efforts to conserve, restore and sustainably manage peatlands in: Africa, Asia, Europe, Latin America and the Caribbean, North America, and Oceania. The effect of land-use change on peatland carbon still remains a major knowledge gap and deserves further research and best practice development.

This assessment shows how peatland conservation, restoration, and sustainable management can offer a triple win for the climate, people, and the planet. At the same time, it also addresses the urgency of establishing more general definitions for "peat" and "peatland" and takes an interdisciplinary approach to make use of the best science and available data to develop improved peatland distribution maps. Further work in the area of the amount of carbon stored in peatlands is warranted as peatlands store a significant proportion that can be released as emissions through disturbances.

The assessment process was inspired by procedures developed under the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). It included a preparatory stage where the scope and partnerships were defined and approved, an assessment stage including nomination of authors, the development of the assessment through three author meetings and several peer-review cycles including an open peer-review process, an approval stage with the acceptance of the final assessment report and summary for policy makers (SPM) and is accompanied by an outreach stage for disseminating the main assessment findings.

The concept and process of the GPA were approved by the GPI Steering Committee in February 2021 and presented to the public at the Global Peatlands Pavilion during the UNFCCC COP26 (November 2021). The Global Peatland Map version 2.0 was also launched during the same session and an invitation to all interested parties was delivered to request their help to improve the base knowledge on the extent of peatlands (UNEP 2021d). A detailed description of the procedural aspects of this assessment can be found in Annex I.

This assessment has been made possible through the generous and voluntary contributions of 226 contributors (44% women; 56% men) coming from 51 different countries who were involved as coordinating lead authors, contributing authors, reviewers, editors and information providers. The financial contributions of both the Governments of Germany and Sweden through the International Climate Initiative (IKI) and the Swedish International Development Cooperation Agency (SIDA), respectively, were also essential for the whole GPA process. The GPA was led by UNEP and the process was coordinated by UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), with guidance and technical support from the Greifswald Mire Centre (GMC), the Food and Agriculture Organization of the United Nations (FAO), the Secretariat of the Convention on Wetlands and others mentioned who made up the GPA Development Team. The team paid close attention to geographic representation, gender balance, and welcomed viewpoints from many disciplines drawing on different areas of expertise in peatlands. Besides being an effective global assessment that fills the knowledge and research gaps identified by the Initiative, it also captures the essence of the GPI partnership representing a huge collaborative, participatory and voluntary effort.

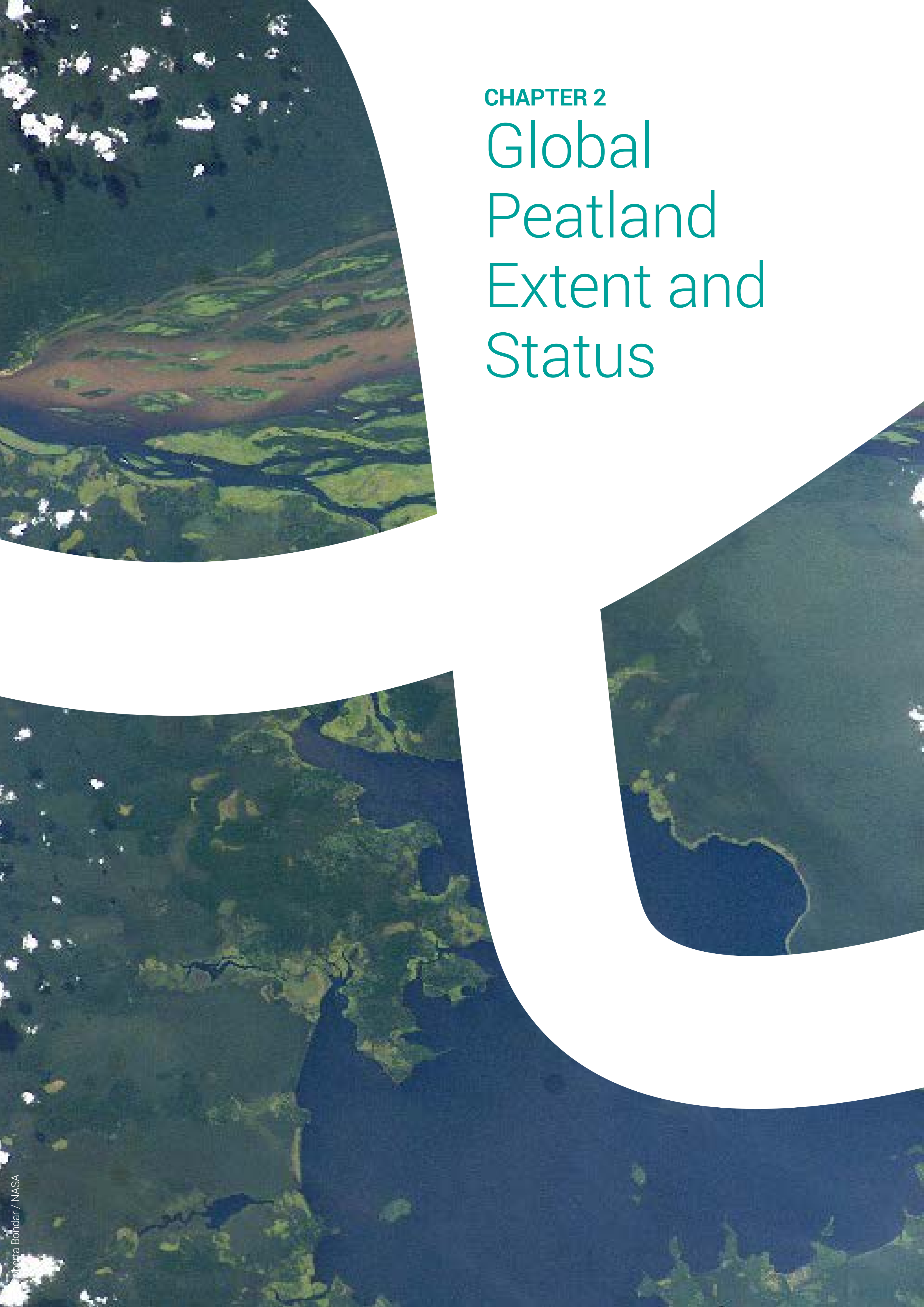
This report is the first global peatlands assessment in almost 15 years (since the release of the Assessment on Peatlands, Biodiversity and Climate change in 2008) (Parish *et al*. 2008) and builds upon the rapid assessment developed under the GPI (Crump 2017). It is built upon the best available science to date including spatial data and information on peatlands from multiple contributors from around the world and from academia to governments, businesses and the third sector. Representatives from Indigenous Peoples and Local Communities (IPLC), early career researchers and practitioners were sought out to achieve a balance in the wider team of contributors, to consider diverse world views, values and knowledge systems. So, it combines an expert-based, narrative (rather than systematic) review with new data on the extent and state of the world's peatlands collated through a collaborative effort the GPA has made possible. As a result of this and a lack of evidence in some geographic areas, the assessment has information gaps. Its purpose is to install the foundations for a structured process in the near future to produce more comprehensive assessment reports by the science-policy interfaces of the major conventions and multilateral environmental agreements. The assessment is an open invitation by UNEP and the GPI to all groups with knowledge, experience and data on peatlands to actively engage and join us in our effort to advance the science, policies and practice that are needed to deliver on our global goals.

The assessment starts in Chapter 2 by providing the most comprehensive assessment of global peatland extent and status to date, drawing on new data that were compiled and represented in several GPA maps. The GPA maps show the location and diversity of peatlands worldwide as well as their occurrence within different ecological zones, the greenhouse gas emissions of degraded peatlands, the global human impact on peatlands including hotspots of land-use change, peatlands within protected areas, biodiversity hotspots and species richness, peat fires, permafrost peatlands, mountain peatlands, and hotspots of forest integrity on peatlands.

This sets the scene for the regional chapters (3-8) that provide a more detailed assessment of regionally specific peatland challenges, opportunities and progress in Africa, Asia, Europe, Latin America and the Caribbean (LAC), North America and Oceania. Finally, Chapter 9 reviews regulatory, market-based and other policy and governance options to promote the protection, restoration and sustainable management of peatlands.

CHAPTER 2

Global Peatland Extent and Status



Roberta Bondar / NASA

CHAPTER 2

Global Peatland Extent and Status

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Global Highlights

Key Facts

KEY GLOBAL DATA PRODUCED FOR THE GLOBAL PEATLANDS ASSESSMENT 2022[1]	
Total peatland area (hectares)	487,754,199 ha
Peatland cover over total global surface area (%)	3.8%
Degraded peatlands (%)	11.7%
Annual GHG emissions from peatlands (Megatons of carbon dioxide equivalent emissions per year)	1,941.2 Mt CO_2e / yr
Undegraded peatlands (%)	88.3%
Peatlands within protected areas (%)	18.6%
Top 10 Countries with largest peatland area (hectares)	1. Russian Federation (139,300,000 ha) 2. Canada (119,377,000 ha) 3. United States (38,813,000 ha) 4. Brazil (26,019,489 ha) 5. Indonesia (20,949,000 ha) 6. Democratic Republic of the Congo (18,157,111 ha) 7. China (12,885,443 ha) 8. Republic of the Congo (9,540,799 ha) 9. Finland (8,313,381 ha) 10. Peru (7,651,400 ha)
ADDITIONAL DATA	
Total peatland carbon stock[2] (Megatons of carbon)	600,000 Mt C
Threatened peatland species[3] (VU = vulnerable; EN = endangered; CR = critically endangered)	Flora: 112 VU, 133 EN, 58 CR Fauna: 324 VU, 302 EN, 141 CR
Ramsar Wetlands of International Importance with peat[4]	657 sites (26.8% of total Ramsar sites)

[1] Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

[2] Yu *et al*. (2010). Global peatland dynamics since the Last Glacial Maximum. Geophysical Research Letters 37, L13402

[3] Data extracted from the IUCN Red List of Threatened Species.

[4] Data extracted from the Ramsar Sites Information Service.

2.1. Introduction

Over the last decades, we have come a long way in understanding peatland ecosystems and their biogeochemical processes, mapping their extent and distribution and appreciating their ecosystem services. Peatlands are found across the globe, from the low latitude tropical peat swamp forests and the high latitude palsa peatlands to the low altitude peaty mangroves and high altitude paramo peatlands (Hofstede *et al*. 2013; Rydin *et al*. 2013; Joosten 2016; Crezee *et al*. 2022; Hastie *et al*. 2022).

Peatlands are incredibly important, despite being often overlooked. Aside from supporting important endemic and endangered species in their diverse habitats, peatlands provide vital contributions to people through their capacity to store vast amounts of carbon, providing fresh water and limiting the impacts of rainfall events and so avoiding floods. However, degraded peatlands emit huge amounts of greenhouse gases that are disproportionate to the area they occupy (Joosten *et al*. 2016a). As such, they have a big part to play in the global carbon cycle.

Peatlands are difficult to map when they are remote and difficult to access. This is made more difficult because the belowground peat is often “hidden” by different land cover types and cannot be directly observed by satellites. For this reason, the use of Earth Observation for mapping peatlands has to be conducted in conjunction with field campaigns or ‘ground truthing’ (Vernimmen *et al*. 2020). The mapping of peatlands at the global scale is not complete nor straightforward. Global maps that have been produced, including those developed as part of this assessment, have some level of uncertainty associated with them (Yu 2012; Xu *et al*. 2018; Minasny *et al*. 2019; Melton *et al*. 2022). Various regions and countries still require surveying and mapping of their peatlands, particularly in developing countries, as reflected in this assessment and this needs to happen urgently.

This chapter contains information from a global perspective on the extent of peatlands and a definition of what peatlands are. It also explains how they are mapped, how they are monitored and which methods were applied for developing the Global Peatland Map 2.0 (GPM2.0). It then reviews the state of peatlands with respect to degradation, emissions and protection. Finally, the chapter reviews peatlands in the context of their biodiversity and carbon storage capabilities in relation to nature’s contributions to people. Thus, it sets the stage for the successive regional chapters.

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2.2. Definition of Peat and Peatland

Peatlands are known by many names around the world including the English terms muskeg, bogs, mires, fens, tropical peat swamp forests and more. This variety in terminology reflects the diversity of peatland habitats and ecosystems (Rydin *et al*. 2013).

'**Peatland**' is a general term for land with a naturally accumulated layer of peat near the surface. Peatlands include both ecosystems that are actively accumulating peat and degraded peatlands that no longer accumulate but in contrast lose peat. This definition is consistent with the definition established by the Convention on Wetlands (COP 8 Resolution VIII.17) (Ramsar Convention on Wetlands 2018).

Peat consists of partly decomposed (but partly still macroscopically recognizable) plant remains that have accumulated where they have been produced (*in situ*). Peat is formed when microbial decomposition of dead organic matter is incomplete as a result of anoxic (oxygen-free) conditions caused by near permanent water logging, and/or low temperatures. Also, the recalcitrance against decomposition plays an important role in peat formation, resulting in only selected plant species and parts producing peat. The definition of peat used in this assessment has been informed by the Convention on Wetlands (Ramsar Convention on Wetlands 2018).

Peatlands store carbon that plants have taken up as carbon dioxide (CO_2) from the atmosphere and have transformed by photosynthesis into plant material. When these plants die but do not completely decompose, they become peat. About 50-60% of this peat consists of carbon.

A key feature of peat-accumulating peatlands is their high water table, which creates the anoxic conditions necessary for peat accumulation and preservation. Peat-accumulating peatlands are therefore almost always wetlands. In (ant)arctic regions, peat may also accumulate because organic material is protected by permafrost. Degraded peatlands no longer accumulate peat/carbon and, when they are deeply drained, they are no longer wetlands. They may, however, still have significant (but diminishing) carbon stocks in their residual peat layers.

In addition to organic matter, peat also contains mineral materials that, during peat accumulation, have washed or blown in. The maximum content of mineral material that 'peat' may hold has not been standardized at the international level and varies widely from 35% to 95% dry weight depending on country, scientific discipline and depositional setting (Joosten and Clarke 2002). The boundary between mineral and organic material in soil science is defined at 80% of mineral material (=20% of organic matter) by weight (Food and Agriculture Organisation [FAO] 2014).

By definition, land with any thickness of in-situ peat is a peatland. However, for mapping and statistical purposes, a minimal peat depth has to be defined. In national surveys across the world, peat depths ranging from 5 to 50 cm (and more) have been (and are being used) to define and map peatlands/organic soils. Because of this variety, the IPCC has never specified and the UNFCCC has never adopted, a globally valid standard minimum thickness. Rather, the UNFCCC allows every country to use its own country-specific definition as long as that definition is clear and applied consistently across the entire national land area and over time (Hiraishi *et al*. 2014). This flexibility complicates the consistent mapping and statistics of peatlands on a global scale based upon the aggregation of national and regional data. How the new Global Peatland Map 2.0 (GPM2.0) has addressed this challenge is explained in § 2.4.

Peatlands are found in a wide variety of climatic zones and under many different landcover types (Rydin *et al*. 2013; Joosten 2016). This makes mapping the global extent of peatlands a challenging task (Yu *et al*. 2010; Melton *et al*. 2022).

2.3. Mapping Methods and Approaches Seeking the Global Extent

In order to progress global peatland extent mapping, multiple methodologies have been employed to date, including top-down approaches e.g., machine learning (Melton *et al*. 2022) and remote sensing (Gumbricht *et al*. 2017) and bottom-up approaches e.g., amalgamation of country data (Yu *et al*. 2010; Xu *et al*. 2018). Bottom-up country data or national scale maps are created from a range of methods including field survey and mapping, data amalgamation and earth observation (EO) including aerial and satellite data analysis (Minasny *et al*. 2019).

Mapping peatlands using these top-down and bottom-up approaches (Tarnocai *et al*. 2002; Connolly *et al*. 2007; Connolly and Holden 2009; Thompson *et al*. 2016; DeLancey *et al*. 2019) has often been achieved by modelling topographic, geomorphic, climatic, pedologic and hydrologic data (with or without the inclusion of remote sensing data) that may indicate the presence of peatland ("proxy data"). Peatland probability maps have also been produced by process-based modelling (e.g., Müller and Joos 2020) using the process hierarchy governing the accumulation of peat (Minasny *et al*. 2019). The outcome of such approach depends on the assumptions made. Probability maps may be regarded as first order approximations that are also useful to target areas for field sampling, of which the results can then be used for supervised classification mapping from remote sensing data to extrapolate the field-sampled data.

Top-down approaches apply a specific classification algorithm (e.g., maximum likelihood, machine learning - random forests, support vector machines, convolutional neural networks) to specific data sources for the whole Earth and often incorporate ancillary data on climate and/or soils (Abatzoglou *et al*. 2018). The advantage of a top-down approach is coherent mapping across the globe with a consistent definition of 'peatland' (i.e., the peatland proxy used). The disadvantage may be coarser resolution due to the large volume of data and the need to reduce processing time, or a bias towards certain peatland types based on their formation processes. It is critical to understand bias in the training data and model assumptions in both top-down and bottom-up models. Some maps are also not spatially explicit but rather depict the fractional cover of peatland (e.g., Tarnocai *et al*. 2002; Müller and Joos 2020; Melton *et al*. 2022) which limits their utility.

Top-down approaches work well where peatlands are intact and water tables are permanently at, above, or slightly below the surface or vary considerably with seasonal inundation (e.g., palm swamp peatlands) (Bourgeau-Chavez *et al*. 2021). Such patterns of seasonal change in hydrology often allow discerning peatland types via remote sensing, especially those that are otherwise floristically similar to non-peat wetlands and/or uplands (Bourgeau-Chavez *et al*. 2021). However, coarse resolution remote sensing data (e.g., MODIS at 250–1000 m resolution) will omit many individual peatlands or group them into an undifferentiated wetland typology. Therefore, peatland mapping needs fine resolution EO data (higher than 30-m resolution), combined with sufficient ground truthing data to validate the presence of peat and peatland (Bourgeau-Chavez *et al*. 2021). High and very high-resolution EO data (10-m or higher) are now becoming more widely and freely available (e.g., Sentinel-1, 2, NISAR in 2024) and their storage in cloud platforms (e.g., GEE, Gorelick *et al*. 2017) facilitates rapid mapping and monitoring of areas of interest (e.g., Mahdianpari *et al*. 2021).

The combination of different types of sensors and/or frequencies, i.e., optical-infrared (IR), microwave, or laser imaging, detection, and ranging - LiDAR (for Digital Elevation Models - DEM, etc.), and data from multiple dates to capture phenological and hydrological seasonal differences, have been found to enhance wetland mapping in general (Lawson *et al*. 2014; Barthelmes *et al*. 2015; Bourgeau-Chavez *et al*. 2015). These high temporal and high spatial resolution datasets and cloud platforms will be beneficial for future global peatland mapping. However, some of these, such as LiDAR derived DEMs, are expensive. This limits acquisition and application, especially at a global level. Also, large field training datasets and region- or peatland type-specific classification algorithms and data layers will be necessary to obtain high-accuracy maps (Congalton and Green 2019). Even with these enormous data requirements, not all peatlands across the globe can be accurately mapped using a single classification top-down approach (FAO 2020).

Peatland ecosystems are typically classified using hydrological, botanical and physiognomic information. These features disappear or are altered if peatlands are drained or intensively used. Peatlands that have undergone land use change may be difficult to discriminate from the surrounding landscape with remote sensing data, particularly where their areal extent is small or where they are part of wider forest biomes. This is due to the fact that their characteristic feature, peat, is below the surface and cannot be readily identified from above.


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The bottom-up approach amalgamates existing maps that have mainly been produced at the country level or smaller scale, have higher resolution and accuracy, and contain regionally appropriate classes that can be aggregated to the most accurate and detailed product possible (Arrouays *et al*. 2017). However, such maps contain data created with different classifiers, input data sources, and possibly different peatland definitions (see § 2.1), which can affect consistency in a map with regionally varying accuracy (Arrouays *et al*. 2017). The diversity of peatlands and their condition around the world may exceed the limits of a single classifier, ultimately resulting in lower accuracy and unaccounted peatland types (e.g., tropical mountain peatlands). For a peatland mapping campaign, the diversity and landscape-ecological niches of the peatlands in the study area should be identified by a comprehensive literature study in the preparation phase and thoroughly investigated by fieldwork.

When mapping covers different peatland types and/or crosses boundaries between global ecological zones that differ in climate, seasonality and dominant land cover, the best mapping results are presently obtained with regionalized approaches. The high temporal and spatial resolution datasets and cloud platforms mentioned above will be beneficial for future global peatland mapping as well as for increasing monitoring capability. However, in-situ data on peat type, depth and specific ecological features are needed to create geospatially accurate maps for decision-making and to estimate carbon stocks more accurately (Crezee *et al*. 2022). In case of drained peatlands without natural vegetation, historical imagery, accurate historical maps and country level mapped data, which capture the undisturbed peatlands in the past, can be consulted for mapping (Vernimmen *et al*. 2020). Large field training datasets and region- or peatland type-specific classification algorithms and data layers will likely be necessary to obtain high-accuracy maps.

A full coverage map, including pristine and degraded peatlands, is essential for a global peatland assessment, to inform conservation, to assist in restoration and to support sustainable management policies and planning. Whatever mapping approach is chosen, it cannot be emphasized enough, that *in situ* ground truthing in the field is essential to validate the maps and to collect data on peat depths, bulk density and carbon content by region and peatland type. Such ground truthing will require time, skills and investment.

The costs associated with field data collection for validating peatland classifications are dependent on environmental conditions and the variety of peatland characteristics (Congalton and Green 2019).

To inform nature and climate decision-making now, we have combined many different data, information and modelling approaches to produce the most comprehensive global peatlands map to date: The Global Peatland Map 2.0 (GPM2.0).

2.4. The Global Peatland Map 2.0 (GPM2.0)

The Global Peatland Map 2.0 (GPM2.0) (Fig. 2.1) was produced specifically for the GPA to provide the most up to date data on peatland location and extent globally. It covers all regions of the world and allows decision-makers to identify priority areas for conservation, restoration and sustainable management. It also presents 'probable' peatland areas, i.e., areas where on the basis of their physical constitution and remote sensing signal, peatlands can be expected but whose presence has not yet been confirmed by 'ground truthing'.

We included these areas to raise awareness and encourage more comprehensive mapping and assessment in hitherto under-represented regions. The countries with a varying representation of 'probable' peatlands are indicated in Table III.3 of Annex III. Production of the Global Peatland Map 2.0.

The GPM2.0 has been compiled by amalgamating country level peatland maps and high-resolution peatland 'proxy' data contained in the Global Peatland Database (GPD) following the 'bottom-up approach' (see § 2.2 and Annex III). The map is spatially explicit and presented in a 0.9 x 0.9 km raster, with varying levels of uncertainty depending on the region (see Table III.3 of Annex III).

The vast majority of data was derived from scientific publications on soil and peatland research and obtained from other 'external' sources such as national agencies and online sources (see Table III.2 of Annex III). Following mainly Xu *et al*. (2018), we gave preference to datasets that:

1. directly identified peatlands and distinguished them clearly from other land cover types, e.g., non-peatland wetlands,
2. possessed a large to mid spatial scale (1:25,000 to 1:250,000),
3. offered a comprehensive coverage of peatlands in the landscape unit.

The original sources with full references can be found in the GPM2.0 metadata file (see § III.1 of Annex III). Many of the consulted original publications provide detailed information on the methods used and uncertainties involved. All data integrated for this assessment have adopted the definitions of the original studies. Peatland and organic soils data were included if they surpass the threshold of soil organic carbon - SOC >12%. Peat depth thresholds were not established for the assessment to allow for the use of data with regionally varying definitions. It remains to be noted that thresholds for SOC and peat depth were not specified for some integrated peatland data, and in particular not for proxy data indicating potential peatlands.

We used the original definitions of 'peatland' and 'organic soil' of the regional maps, which normally encompass a 30-50 cm peat depth threshold. If studies with multiple thresholds were available for a region or area, we selected the study with a threshold closest to 30 cm. The effect of choosing different peat depth thresholds is illustrated in Fig. 2.2 for the Russian Federation (for which such data are available). If using the ≥ 30 cm threshold, Russian peatlands extent cover 139 million hectares, if using the ≥ 10 cm threshold (c.f. Vompersky *et al*. 2005; 2011), the peatland area is 2.6 times larger (368 million hectares).

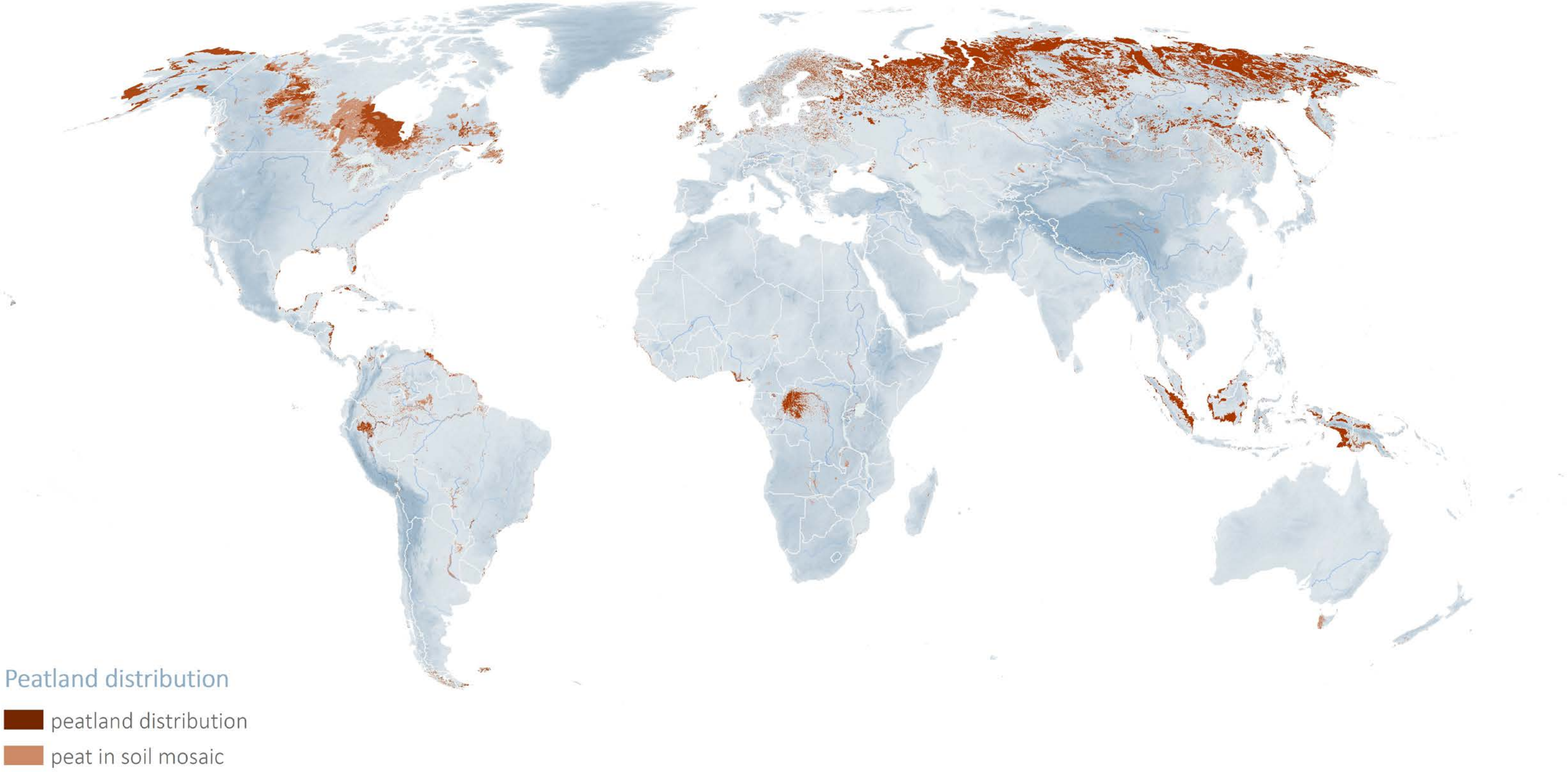

Figure 2.1. The Global Peatland Map 2.0 (GPM 2.0) developed as a base-map for the GPA.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III. Production of the Global Peatland Map 2.0.

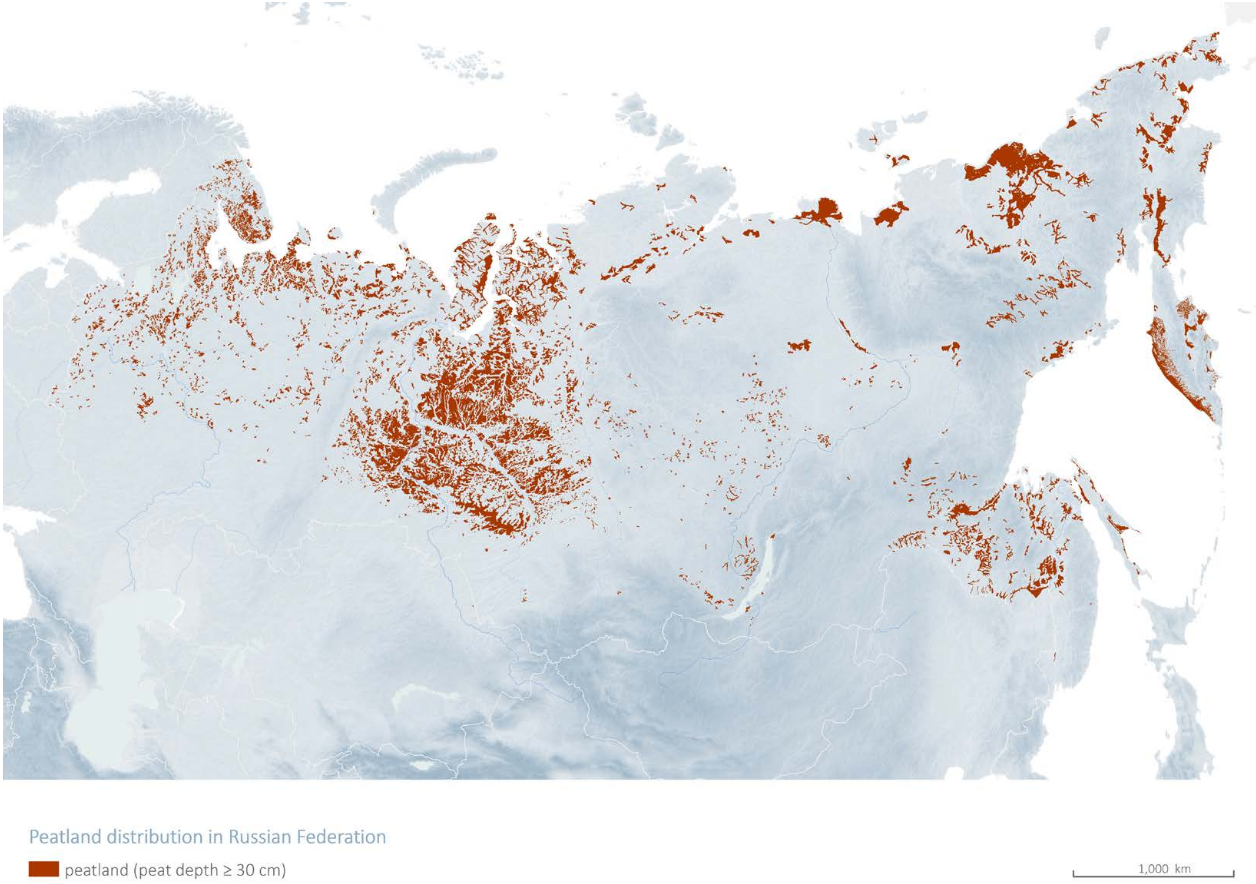

Figure 2.2. Comparison between peatland distribution in the Russian Federation when considering two different peat depth thresholds: Figure 2.2a: peat depth ≥30 cm and Figure 2.2b: peat depth ≥10 cm.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III. Production of the Global Peatland Map 2.0.

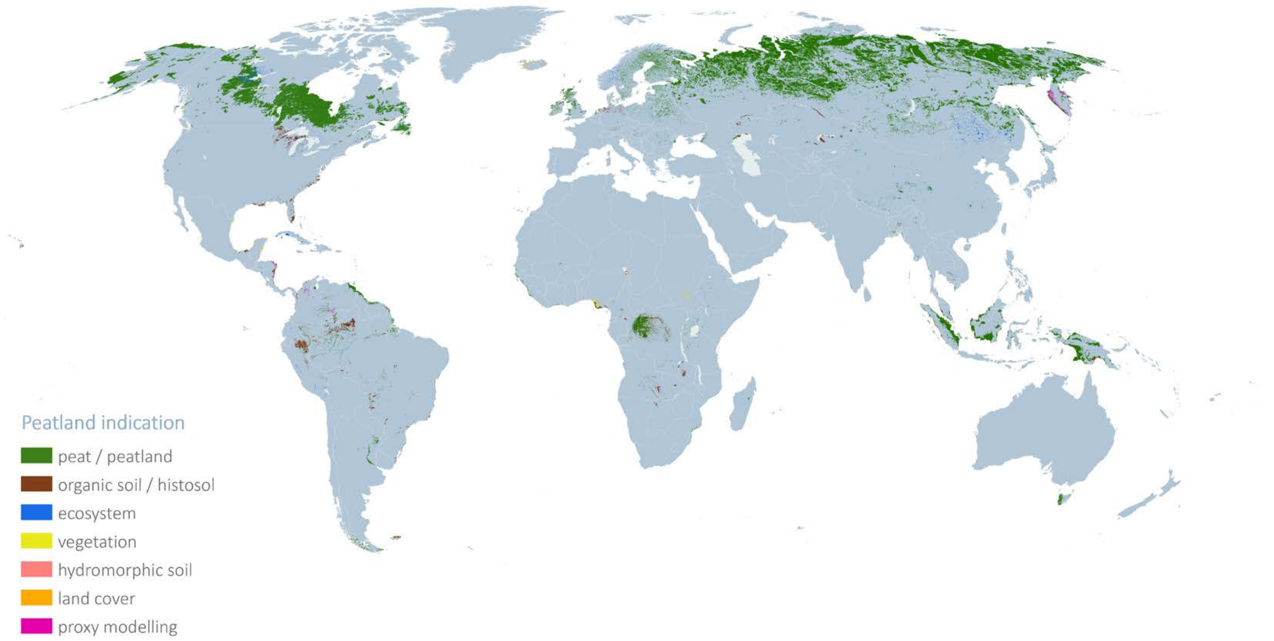

Figure 2.3. Types of 'direct' peatland ('peat/peatland', 'organic soil', histosol') and 'indirect' proxy mapping data ('hydromorphic soil', and selected 'ecosystem', 'land cover' and 'vegetation' types) used in the Global Peatland Map 2.0.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III. Production of the Global Peatland Map 2.0.

The accuracy of each dataset was checked through comparison with independently collated peat point observations and with proxy data (such as Digital Elevation Models - DEM, Topographic Soil Wetness - TSW), satellite imagery and ancillary data using landscape and peatland expert judgement ('plausibility check'). The GPM2.0 workflow and explanation of data treatment and development of data are fully explained in Annex III. Production of the Global Peatland Map 2.0.

This publication has tried to present a map and a dataset (see metafile in Annex III) that are as consistent and transparent as possible. Similar to the 'Global map of peatland regions' (Yu *et al*. 2010), the 'PEATMAP' (Xu *et al*. 2018), and the 'Global peatland distribution map' (Leifeld and Menichetti 2018), the Global Peatland Map 2.0 follows a bottom-up approach. The most obvious improvement compared to these maps is the inclusion of multiple datasets of mid- to high resolution (see § III.1 of Annex III). Moreover, the input data for the GPM2.0 have undergone a plausibility check and were cleaned or amended as necessary (see § III.1 of Annex III). How this GPM2.0 relates to other global maps on peat, histosol or soil organic carbon is explained in detail in the Annex III.

It is important to underline that the GPM2.0 map still suffers from biases and coverage gaps. Until now, peatland inventories have been unsatisfactory. Most countries have insufficient information about their peatland location, extent and status. This is related to the fact that the decisive feature 'presence of peat' cannot be observed directly by remote sensing. The available data often differ extremely in scale and quality, and only some data are available in GIS format. This hampers the harmonization of data and in most cases precludes automatic treatment. The vast diversity of peatlands, peatland use and the collated spatial data in the GPM2.0 also prohibits an objective estimation of uncertainty levels.

Especially, many countries in the southern hemisphere and in Central and East Asia are not mapped comprehensively or with sufficient accuracy. Even so, it is still relatively straightforward to spot where overestimates and underestimates likely are and to know where knowledge gaps are likely to be present. Annex III (Production of the Global Peatland Map 2.0) provides a table of countries with considerable coverage gaps and uncertainty of GIS data based on evidence from scientific and ancillary data (Table III.3).

Peatland inventory in terms of drainage, conventional use and associated emissions is also still unsatisfactory and many countries have insufficient information about the status of their peatland resources. Estimates on the extent and emissions of main land use types, forestry, agriculture (if possible divided in cropland and grassland) and peat extraction in each country have been derived by considering (again) multiple input data, specific integrated emission factors and using an iterative process of data integration (see Annex III for details).

While being aware of concrete regional biases in the GIS data, the country-wise statistics from the GPM2.0 have been checked against other global maps, a broad range of scientific and ancillary data and in collaboration with the GPA Coordinating Lead Authors. The data ranges presented by these varied sources are often not real reliability ranges but compilations of different estimates. The assessment does not present all these (sometimes extremely dissimilar) estimates but instead presents the most probable figure. Details of considered input data and best estimates are given in Annex III.

The inevitable inconsistency in the definition of ‘peatland’ between various countries is inherent to all ‘bottom-up’ global peatland maps and is supported by IPCC and UNFCCC policies (see § 2.1). It is important to remember that national definitions have never been informed by climate concerns and go back to historical agricultural/land use considerations. From a climate policy point of view, it can be argued that it would be better to have a peatland/organic soil definition with a peat depth threshold of e.g., 10 cm, as peatland of this depth already approaches or surpasses the minimum carbon threshold of a High Carbon Stock (HCS) tropical forest (Raison *et al*. 2015, see § 2.9). This would require peatland remapping in major parts of the world but would better appreciate the enormous carbon density of peat and its importance for the climate.

2.5. Global Distribution of Peatlands

According to the Global Peatlands Assessment best estimates, peatlands (including probable peatlands) cover about 500 million hectares globally of which 33% are in Asia and 32% in North America, and less than 13% in Latin America and the Caribbean, Europe, Africa, and Oceania each (Table 2.1, Fig. 2.4).

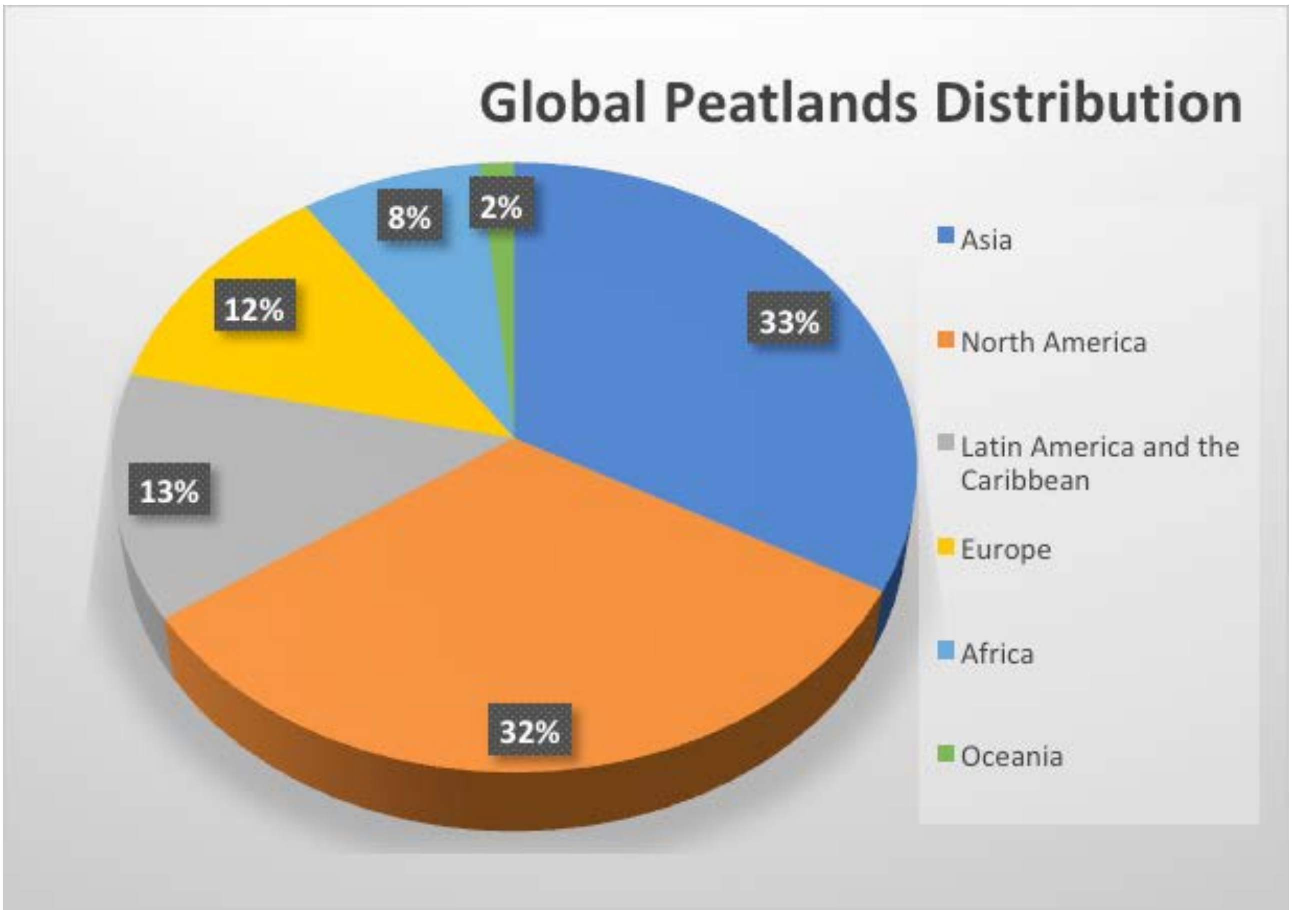

Figure 2.4. Proportional distribution of peatlands (including probable peatlands) over the various continents/regions.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Table 2.1. Peatland distribution (including probable peatlands) per continent/region based on the Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Continent/region	Area of peatland (ha)	Percentage (%)
Asia	161,030,209	33.01
North America	158,200,825	32.43
Latin America and the Caribbean (LAC)	63,373,122	12.99
Europe	58,755,644	12.05
Africa	39,037,313	8.00
Oceania	7,285,883	1.49
Sub-Antarctic Islands	71,204	0.01
WORLD	**487,754,199**	

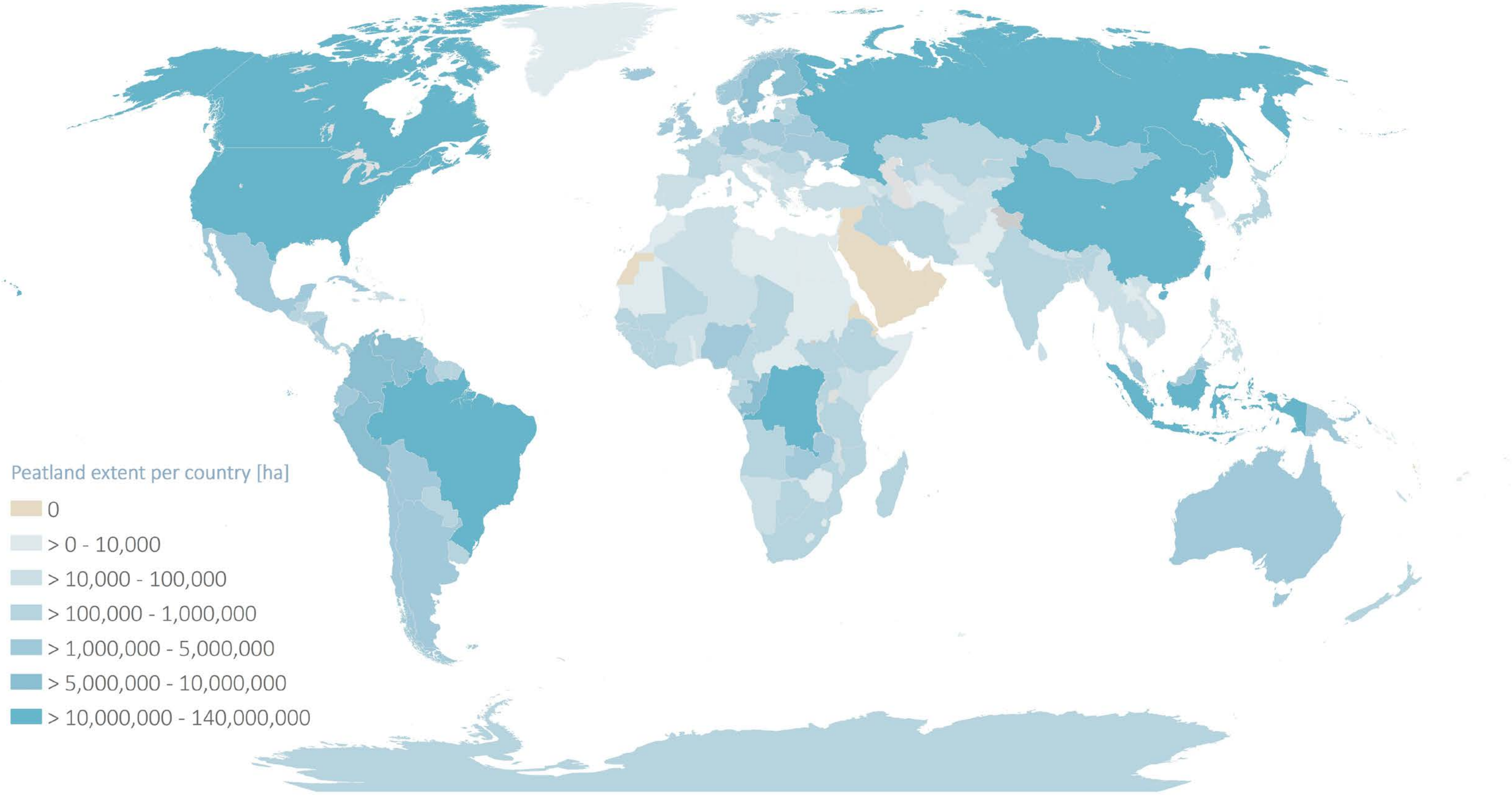

Figure 2.5. Global peatland extent per country (including probable peatland).

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III. Production of the Global Peatland Map 2.0.

The general distribution of peatlands reflects global atmospheric circulation with its three zones of rising air masses and abundant precipitation. These are near the equator and along the polar fronts around 60° latitudes in both hemispheres (Fig. 2.1). The southern zone is inconspicuous because of a lack of land at the relevant latitudes. The northern zone is very rich in peatlands, due to its low temperature, limited evapotranspiration, and flat topography. Towards the poles, permafrost obstructs subsurface drainage and facilitates peatland development. This is true even under extremely low precipitation. A flat topography with poor drainage has supported the formation of the largest peatland concentrations globally, e.g., West Siberia (Asia), the Hudson Bay Lowland and Mackenzie River Basin (North America), Southeast Asia, the Congo Basin (Africa) and Western Amazonia (South America) (Kirpotin *et al*. 2021).

Outside these three zones, peatlands may still occur anywhere where local climate, substrate, relief and hydrology allow permanent wet soil conditions. This results in peatlands being found in at least 177 out of 193 UN member states (Fig. 2.5). However, peatlands are less common and extensive in subtropical regions around 30° N and 30° S, where global atmospheric circulation causes the descending air to be very dry. Peat development here is driven by moist air masses resulting from ocean currents and the Earth's rotation. Peatlands also abound on the windward side of mountainous regions where condensing vapour in ascending air leads to increased rainfall (e.g., on the west side of the Cordillera Mountains in South America) and in floodplains receiving large water volumes from rain fed mountain rivers (e.g., Brahmaputra, Mississippi, and Rio Paraná), as seen on the global map of mountain peatlands distribution by elevation (Fig. 2.6).

The distribution of peatlands over the various global ecological zones is depicted in Fig. 2.7.

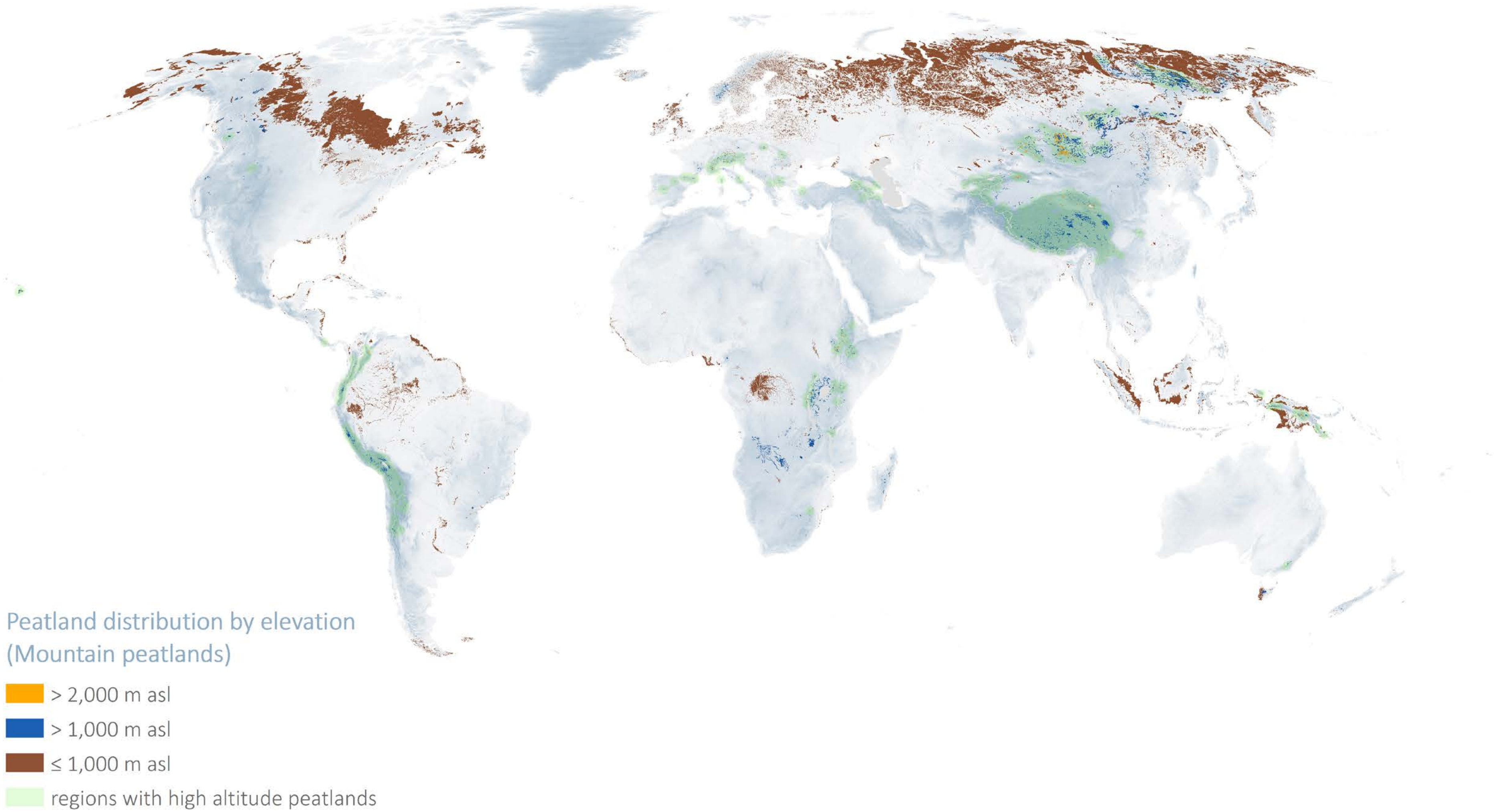

Figure 2.6. Global Mountain peatlands (including probable peatland) distribution by elevation (in meters above sea level).

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III.3 Production of Thematic Maps.

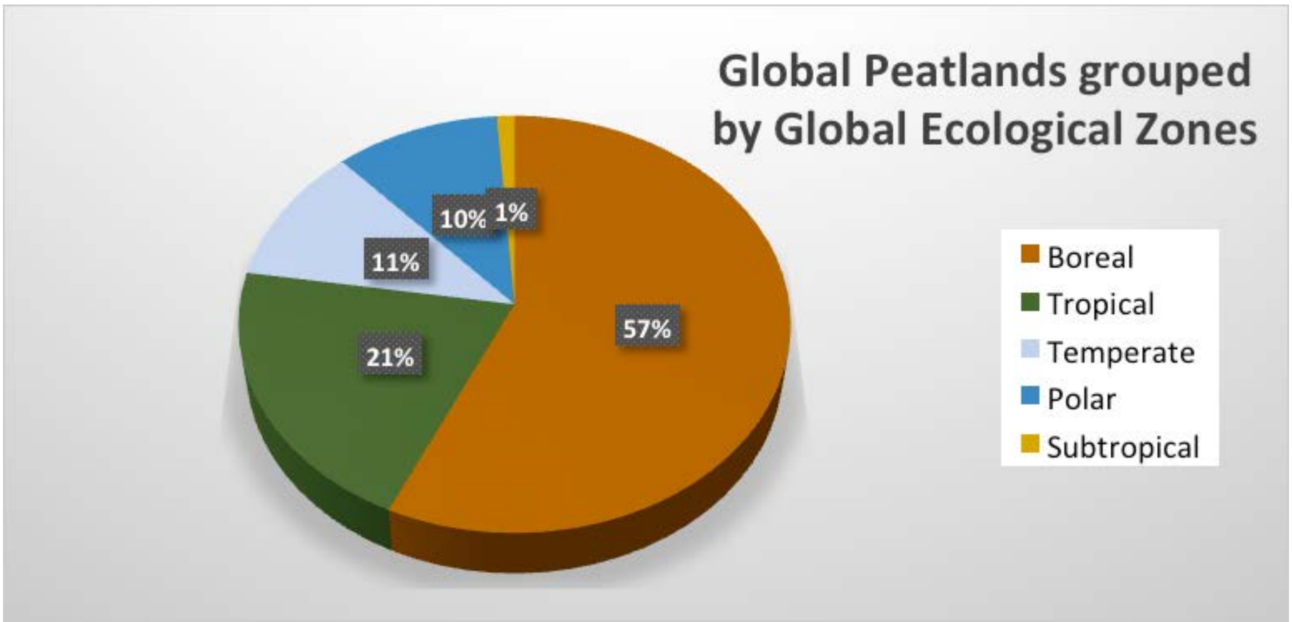

Figure 2.7. Distribution of peatlands (including probable peatlands) over the various FAO Global Ecological Zones.
Source: based on the Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

2.6. Monitoring Peatlands Change

Knowing where peatlands are is essential for monitoring their size and understanding how they are changing. Many approaches to monitoring landscape change exist. While this assessment aims to enhance knowledge on peatlands and their status, it does not cover peatland monitoring development in detail. For further reference, consult e.g., FAO 2020, Bhomia and Murdiyarso 2021, keeping in mind that approaches and technology are advancing rapidly, with new datasets becoming available.

Hydrological condition is a key driver of peatland ecosystem processes and may be monitored directly in the field or from remote sensing EO data[1]. Both passive (e.g., Soil Moisture and Ocean Salinity – SMOS and Soil Moisture Active Passive – SMAP) and active microwave data (e.g., C-band and L-band imagery) as well as passive optical-infrared EO data are suitable for monitoring various aspects of peatland hydrology depending on the typology. This is an area of active research and there is not a one size fits all method for monitoring changes in hydrology. However, when accurate, high-resolution maps of peatland typology are in hand, the types of imagery and products needed to monitor change are easier to define and apply.

Remote-sensing techniques to characterize peatland hydrology over large spatial extents include drainage patterns, vegetation inundation extent, surface moisture content and water table position. These sensing techniques can be conducted with either passive optical-IR (Meingast *et al*. 2014; Banskota *et al*. 2017; DeVries *et al*. 2017; McPartland *et al*. 2019) or active microwave sensors (Bourgeau-Chavez *et al*. 2005; Bartsch *et al*. 2007; Evans *et al*. 2010; Bourgeau-Chavez *et al*. 2013; Dettmering *et al*. 2016; Huang *et al*. 2017; Bechtold *et al*. 2018; Millard *et al*. 2018; Izumi *et al*. 2019; Chapman *et al*. 2020).

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[1] see more on the combination of the field and remote-sensed data in FAO, 2020

Broad peatland complexes may be monitored with either coarse resolution, high repeat (2–3 day) data such as SMAP or SMOS, or high resolution EO data. Note that radar data are particularly important for monitoring in the tropics and other areas with frequent cloud cover because they penetrate clouds. Peatland vegetation structural characteristics and footprints should be matched to specific EO data types. For example, low biomass, open canopied peatlands are best monitored by the shorter wavelength radar systems (e.g., ~5.7 cm C-band) and optical-IR data. In contrast, higher biomass forest canopies from boreal bogs to tropical palm swamp peatlands need longer wavelength radar systems (e.g., ~24 cm L-band), which have greater capability to penetrate through the forest canopy and interact with the soil layers, allowing retrieval of hydrologic information from forested peatlands. Current L-band satellite systems have limited on board storage capacity and downlink stations. This limits their utility for monitoring. In 2024, two new L-band satellites (JAXA's ALOS-4[2] and NASA-ISRO's Synthetic Aperture Radar – NISAR[3]) are planned for launch and will be freely available. In addition, the NISAR system will collect global data every 12 days.

In addition to technological advances, national capacities, motivation and system-wide development are required to support holistic peatland monitoring. Integration of peatlands into national monitoring systems, such as those for forests or fire risk reduction, are expected to be increasingly needed in the future (see for more: FAO 2020).

2.7. The Global State of Peatlands

In relative terms, the world's peatlands do not appear to be doing badly. According to the Global Peatlands Assessment data retrieved from the Global Peatland Database, about 88% of the current global peatland area is still intact, while a third of all former forest areas on Earth have disappeared (Crowther *et al*. 2015). Globally, the area of intact peatlands is decreasing by 0.1% per year, while primary tropical forests are declining by 0.3%. Global peat volume is also being reduced by 0.1% while oil reserves are being reduced by 2% annually (Joosten and Clarke 2002).

Our analysis shows that worldwide 487,754,199 hectares of peatlands (including probable peatlands) exist, of which 12% are degraded to the extent that peat is no longer actively formed and the accumulated peat is disappearing. Fig. 2.8 shows the percentage of drained peatland area versus undrained peatland area over the different regions. Yet 500,000 hectares (~ 0.1%) of intact peatlands are destroyed annually by human activities. This is 10 times faster than the average rate of peatland expansion during the Holocene (Joosten 2016).

Peatlands are more extensive than previously estimated. The GPA estimations are over 5% greater than the previous calculations made by Leifeld and Menichetti (2018), where they estimated the global peatland extent on 463.2 million hectares. They report a total area of "degrading" peatlands of 50 million hectares (11% of total peatlands, of which 5% are in tropical regions, 3% in temperate, 2% in boreal and <1% in polar regions). These figures fit well with the data from the GPD.

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[2] JAXA's ALOS-4 is the Advanced Land Observation Satellite 4 from the Japan Aerospace Exploration Agency (Japan Aerospace Exploration Agency [JAXA] n.d.)

[3] NISAR is a joint partnership between the National Aeronautics and Space Administration (NASA) and the Indian Space Research Organisation (ISRO) (NASA 2019)

According to FAO (2020), between 20 and 25% of the world's peatlands have been moderately or significantly degraded, including ~11-15% that have been drained and a further 5-10% that have been degraded due to land use or land cover change. This difference with our analysis will result from the use of different sources and different concepts of 'degradation'. Furthermore, the GPA statistics do not generally cover former peatlands that have lost so much peat that they no longer qualify as peatlands. It is, however, possible that by the use of historical maps (legacy soil maps), especially in Africa, such areas are still included, e.g., in Madagascar.

Intact peatlands are concentrated in inaccessible areas far from international markets in the (sub)arctic, boreal and tropical zones. There are huge areas of intact peatlands in North America, the Russian Federation, Central Africa and Western Amazonia. Modified or impacted peatlands predominate in the temperate and (sub)tropical zones.

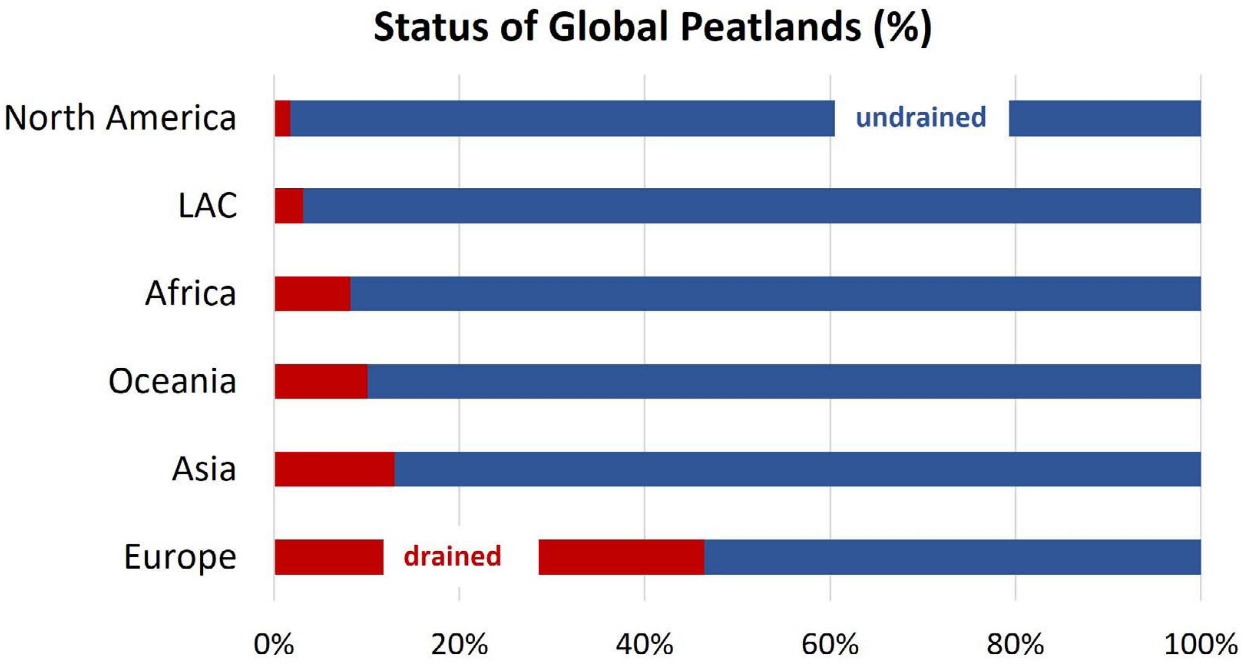


Figure 2.8 Proportion of drained (red) and undrained (blue) peatlands in the world across the different regions (partly including organic soils). Calculations are based on the drained area for forestry, agriculture and peat extraction.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

2.7.1. Peatlands and Nature's Contributions to People

From a climate perspective, peatlands have contributed to cooling the climate by about 0.6°C during the Holocene by sequestering CO_2 and storing carbon for millennia (Frolking *et al*. 2006; Frolking and Roulet 2007; Yu *et al*. 2011).

Drainage, deforestation and other land use changes have had a detrimental effect on many peatland nature's contributions to people (NCPs) by destroying peatland-specific biota and biodiversity (Yule 2010; Posa *et al*. 2011), by negatively impacting water supply and regulation (Xu *et al*. 2018), and by reducing carbon sequestration and storage and causing net GHG-emissions (Premrov *et al*. 2021). This can often eventually deteriorate livelihoods but may also improve livelihoods to the detriment of the habitat (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES] 2018).

Recent mechanization and industrialization have intensified peatland use. This was initially in temperate regions and has more recently taken place in the tropics where peatlands have been widely drained and undergone land use change to provide food, fibre, timber, fodder and fuel (Miettinen *et al*. 2008; Koh *et al*. 2011; Erkens *et al*. 2016; Miettinen *et al*. 2016; Joosten and Tanneberger 2017; Connolly 2019; Basuki *et al*. 2021; Tanneberger *et al*. 2021).

Peatlands provide material goods like water and food. They also make non-material contributions to people who live near them (particularly Indigenous Peoples and Local Communities - IPLCs) often holding sacred meaning and cultural value (Gearey and Fyfe 2016; Crump 2017; López Gonzales *et al*. 2020). Peat commodities produced by local women have also translated into improved livelihoods for the wider community and others in the supply chain, directly contributing to gender equality and poverty reduction. It is important to note that societies (particularly indigenous ones) have interacted with peatlands for thousands of years and depend upon them for vital goods (Gearey and Fyfe 2016; Crump 2017).

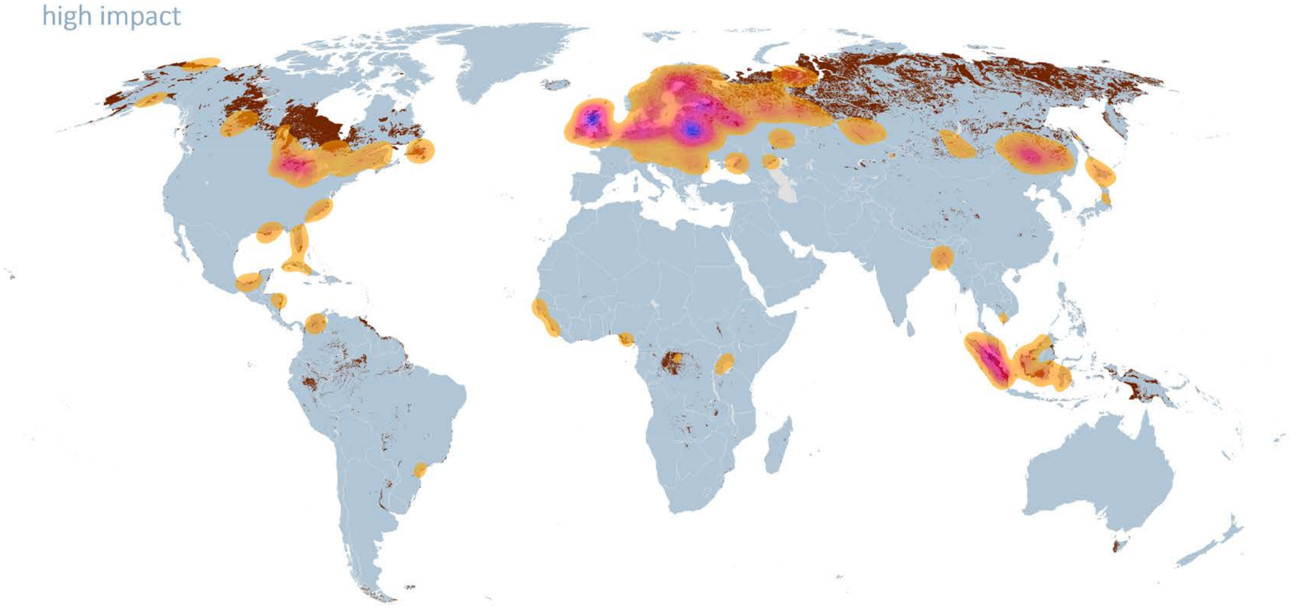
2.7.2. Drivers of Peatland Degradation

The central role of water in the functioning of peatlands makes them particularly vulnerable to disturbances, like drainage and land use change, that may significantly alter the water table (Bourgeau-Chavez *et al*. 2017).

The main direct anthropogenic driver of change in peatlands is drainage for agriculture and afforestation. Other threats facing peatlands include road construction, reservoir creation, oil sands mining, overgrazing and pollution. Europe is a global degradation hotspot, because of widespread land use change to agriculture, forestry and peat extraction. Fig. 2.9a shows the global hotspots of mainly agriculture driven peatland degradation. Next to Europe major hotspots are NE China, SE Asia and the American Midwest. Fig. 2.9b, in contrast, shows the peatland areas where "low impact" prevails, especially the extensive northern peatlands. Little disturbed peatlands are conspicuously missing from the hotspots of Figure 2.9a.

Climate change is an indirect anthropogenic driver of peatland degradation particularly in areas with extensive permafrost thawing and where wildfires are becoming more common (Frolking *et al.* 2011). The high northern latitudes, where peatlands are most abundant, are predicted to continue to be among the areas most strongly affected by climate induced changes in temperature and precipitation (Chapin *et al.* 2000; IPCC 2021). However, permafrost thaw also leads to renewed and expanding peatland areas. Similarly, changes in precipitation rates and frequency will affect peatlands differently in different parts of the world. For example, increased drought can regionally be expected to reduce the carbon storage capacity of peatlands while increased rainfall will speed up development of peatlands in other locations.

high impact



low impact

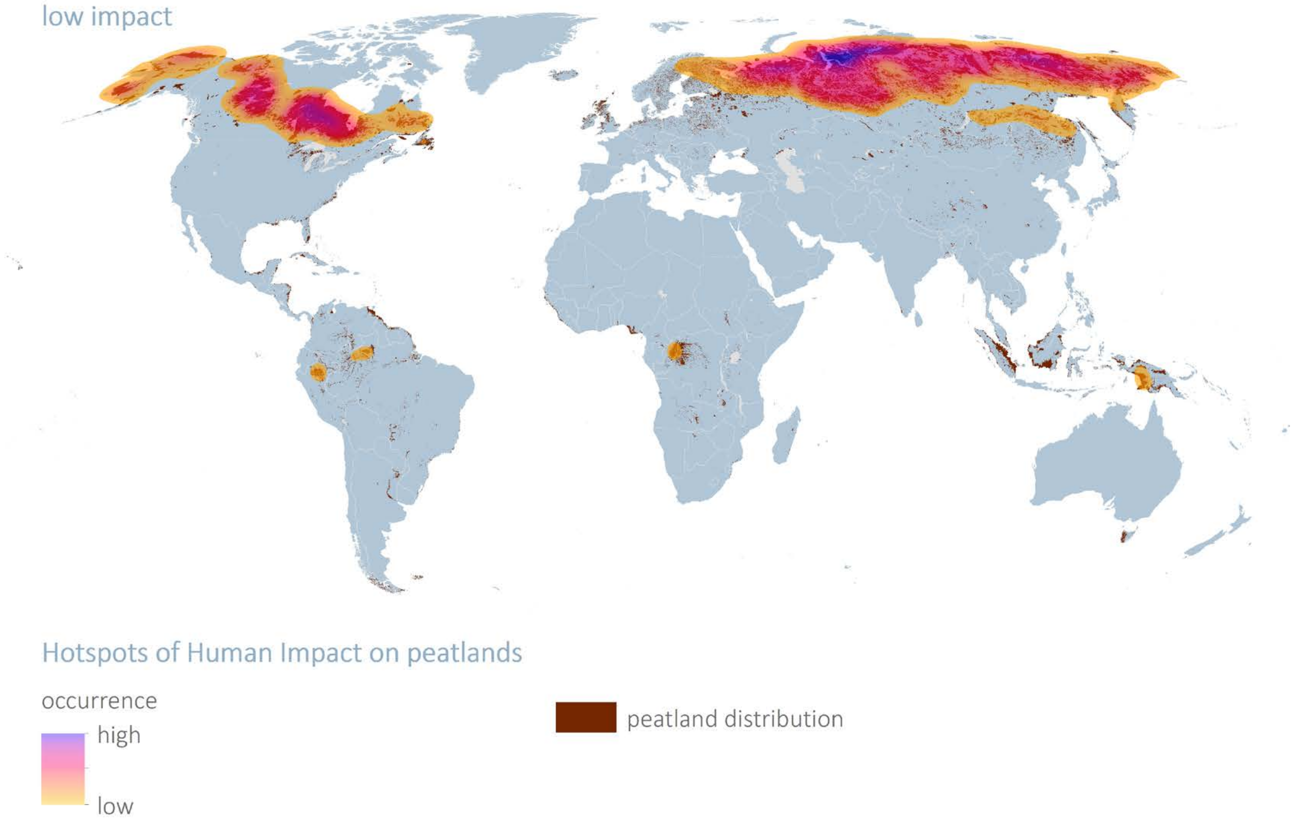


Figure 2.9. Hotspots of Global Human Impact on peatlands. Figure 2.9a: high impact or areas heavily influenced by humans and Figure 2.9b: low impact or areas lightly influenced by humans.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III.3 Production of Thematic Maps.

2.7.3. Peatland Emissions

Because of the enormous density of carbon stored in peatlands, peatland drainage and degradation cause globally significant GHG emissions. As oxygen enters the upper peat layers, microbial degradation leads to a rapid loss of the peat and emissions of mainly CO_2 and nitrous oxide (N_2O) to the atmosphere. When burning and smouldering, dry peatlands release a host of other gases. In addition, degraded peatlands lose carbon through dissolved and particulate carbon to water ways. This then partly oxidizes and contributes CO_2 and methane (CH_4) to the atmosphere with a smaller fraction reaching the oceans.

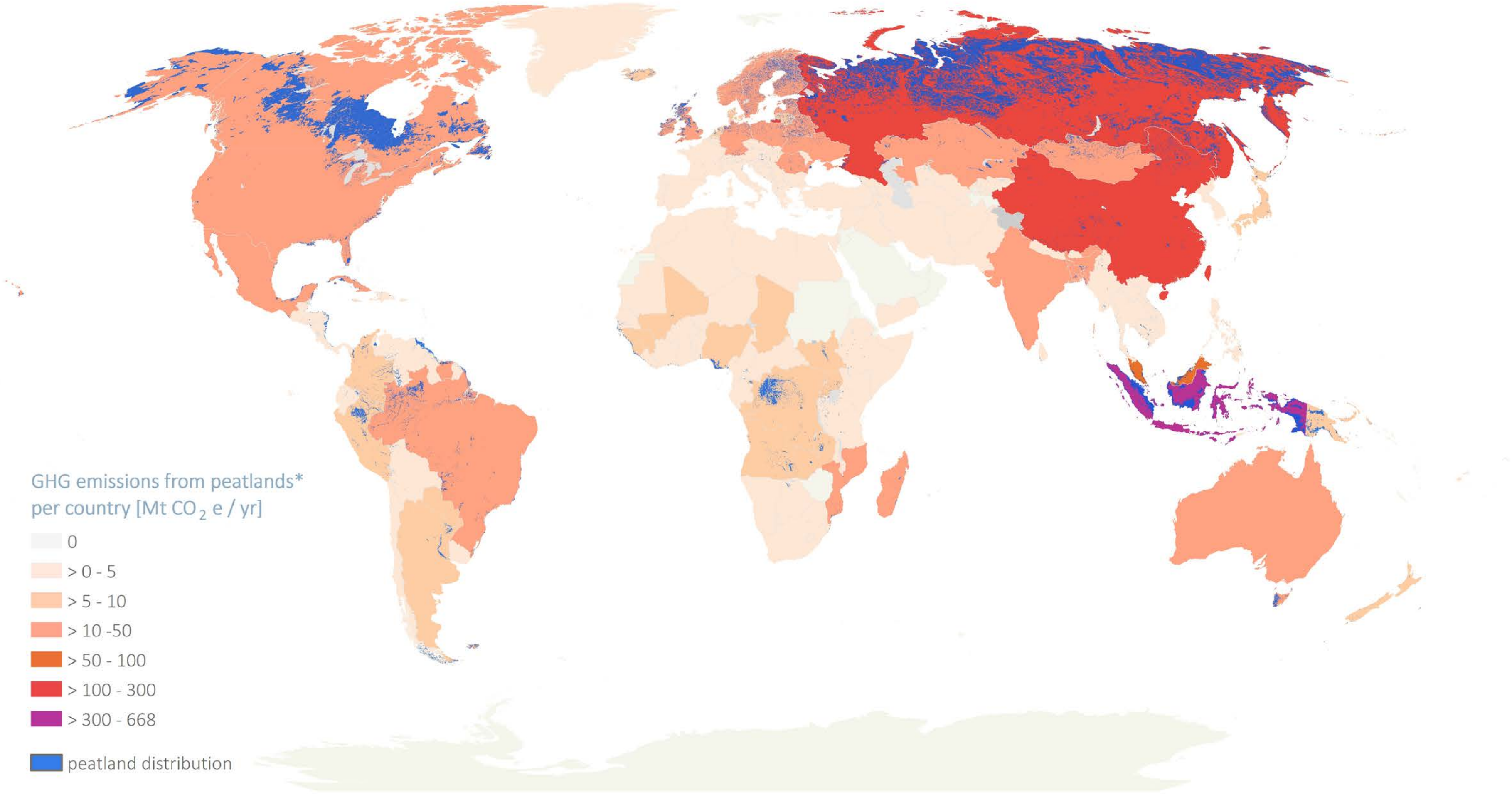
Our global estimate arrives at a total volume of emissions from degraded peatlands of more than 1,940 Mt CO_2e per year, without peat fires, i.e., ~ 4% of total global anthropogenic GHG emissions (Evans *et al.* 2021; UNEP 2021; IUCN 2022) (for methods see Annex III). Fig. 2.10 shows the global distribution of peatland emissions per country.

Leifeld and Menichetti (2018) estimated the global area of degraded peatlands to emit ~ 1,910 Mt CO_2e per year (also without emissions from peat fires). In addition, there is a highly variable (and difficult to quantify) amount of greenhouse gas emissions from peat fires and smouldering fires in the order of magnitude of an annual average of 500 to 1,000 Mt CO_2e per year (Joosten 2009; Rossi *et al.* 2016; van der Werf *et al.* 2017). There is evidence from the tropics that severe droughts will not only increase CO_2 emissions but also lead to higher CH_4 emissions from fires, particularly in degraded peatlands (Field *et al.* 2016).

Countries with large GHG emissions from peatlands are found all over the world. 85% of the emissions are caused by 25 parties to the UNFCCC (Fig. 2.11). The emission distribution per continent/region is presented in Fig. 2.12.

For various countries, peatland emissions constitute a considerable proportion of their total national emissions (Fig. 2.13) illustrating the relevance and urgency to include peatland and their emissions in their Nationally Determined Contributions (NDCs).

It is predicted that if emissions from drained peatlands continue to be released at this rate until 2100, they will consume 41% of the GHG emission budget that still remains to keep global warming below +1.5 °C, and 12% of the GHG emission budget that still remains to keep global warming below +2 °C (Humpenöder *et al.* 2020). Furthermore, the drier conditions that develop after peatlands are drained will worsen this emissions situation, as they will increase the risk and frequency of carbon emitting wildfires. Along with producing massive emissions, smouldering peat fires are causing widespread haze with deleterious effects on human health (Marlier *et al*. 2019; Graham *et al*. 2020).



* Emissions from degraded peatlands from forestry, agriculture and peat extraction

Figure 2.10. Emissions from peatlands degraded by forestry, agriculture and peat extraction per country (microbial respiration only, without fire; including CO_2*,* CH_4*,* N_2O*, DOC, and emissions from ditches. Data have been derived from multiple sources. Numbers may change with future assessments, but the order of magnitude will probably stay the same for many countries (especially for developed countries and main emitters).*

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III.3 Production of Thematic Maps.

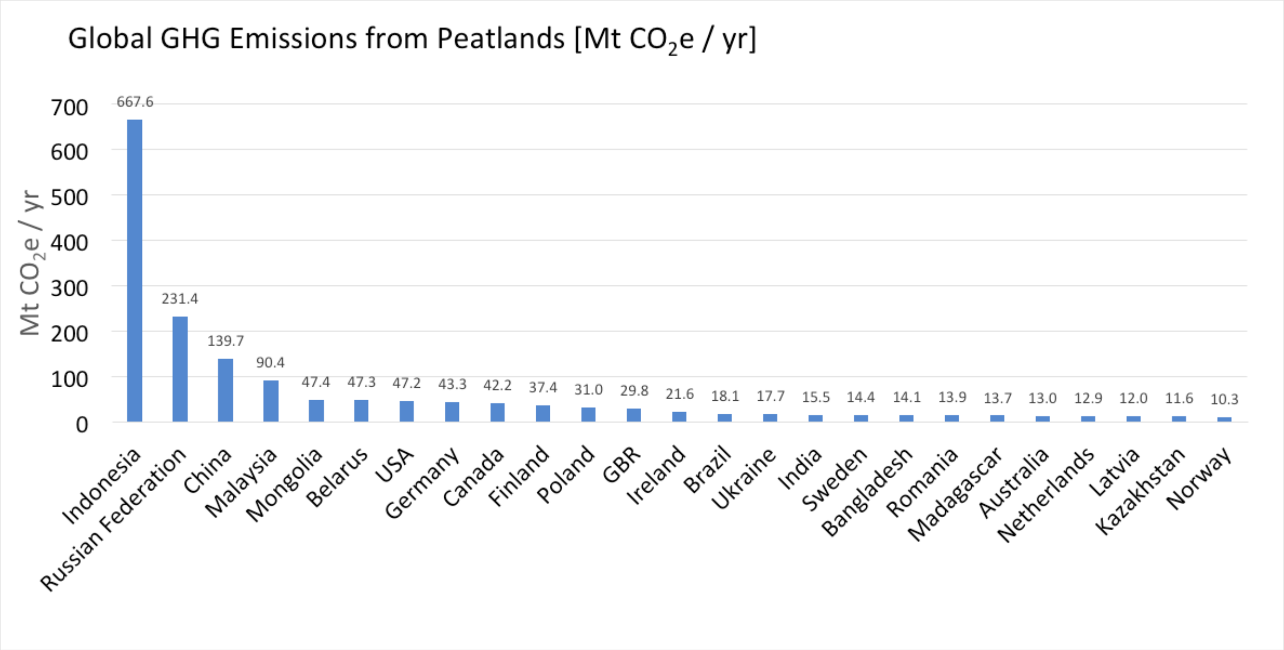


Figure 2.11. Estimated global greenhouse gas emissions from degraded peatlands from top 25 countries. Calculations are based on the peatland drained area for forestry, agriculture and peat extraction and IPCC (2014) emission factors including CO_2, CH_4, N_2O, DOC, and emissions from ditches. Includes only net, on-site GHG emissions. Wildfire emissions are not included.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

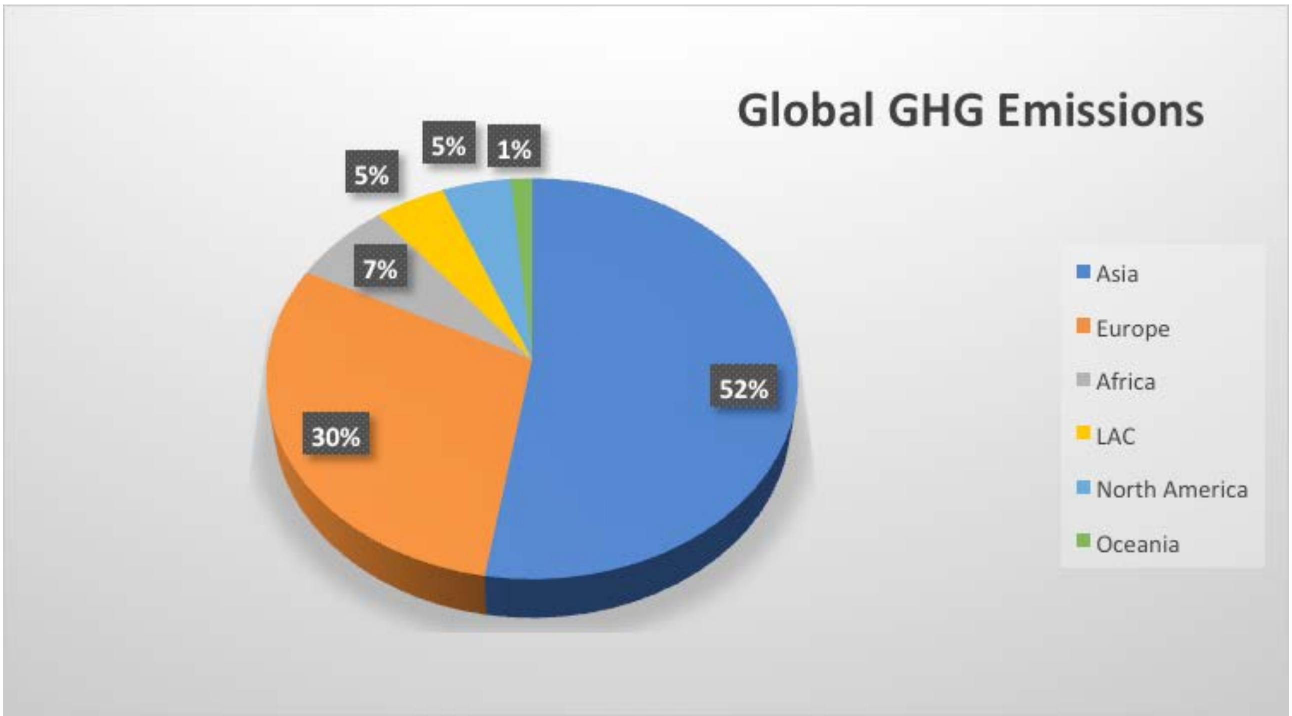
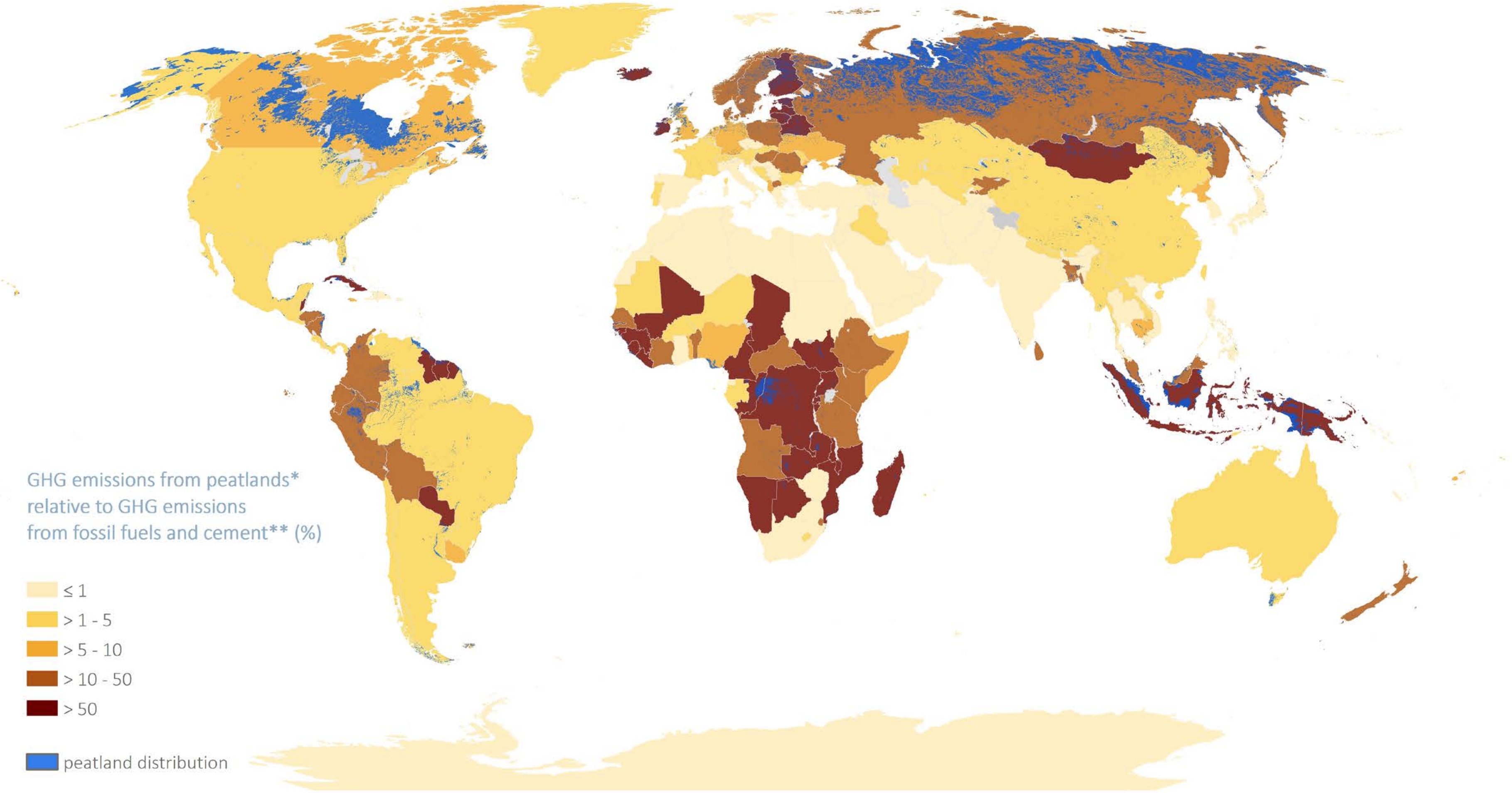


Figure 2.12. Proportional distribution of peatland GHG emissions (without fires), based on the area figures for degraded peatlands and relevant emission factors.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.



* Emissions from degraded peatlands from forestry, agriculture and peat extraction
** Global Carbon Project 2020

Figure 2.13. National emissions from forestry, agriculture and peat extraction on drained peatland (elaborated for this study; incl. CO_2, CH_4, N_2O, DOC, emissions from ditches; see Annex III) as a percentage of their national emissions from fossil fuels and cement (the latter as being reported for 2020 by the Global Carbon Project). Data have been derived from multiple sources. Numbers may change with future assessments in detail, but the order of magnitude will probably stay the same for many countries (especially for developed countries and main emitters).

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III.3 Production of Thematic Maps.

2.7.4. Effects of Peatland Drainage/Degradation Beyond Climate Damage

There are many problems associated with peatland drainage beyond climate damage. The lowering of water levels leads to an immediate reduction in evapotranspiration cooling in the landscape and the loss of peatland specific biodiversity. Nitrogen mineralization by peat oxidation leads to nitrate emissions and eutrophication of downstream rivers, lakes, and ultimately seas and oceans (Joosten 2022).

Because peat consists largely of water, drainage also causes compaction of the peat body. Compaction and oxidation change the hydraulic properties of the peat, reducing the water storage capacity of the peatland and its capacity to regulate runoff. Drained peatlands lose, through peat oxidation, between a few millimetres to several centimetres of peat thickness per year. This results in damage to roads, sewer systems and buildings (Erkens *et al*. 2016; Van den Born *et al*. 2016; Zeitz 2016; Joosten 2022). In coastal areas, peatland subsidence increases the risks of flooding and saltwater intrusion. This, in combination with rising sea levels resulting from global warming, creates a particular threat to the dense populations that are often found near the shore.

Significant parts of Malaysia and Indonesia will be flooded by the sea in the next decades due to rapid peatland subsidence and sea level rise (Hooijer *et al*. 2015). Diking, poldering and pumping, i.e., the interim solution tried in the Netherlands, Germany, England, California or Florida, will not work in coastal Southeast Asia because of the extensive peatland areas and the enormous amounts of rainfall. Such tactics will only somewhat delay the inevitable abandonment of drainage-based land use (Dommain *et al*. 2016).

In more continental and warmer climates, the frequent water level fluctuations in drained peatlands lead to the formation of cracks in the drained peat. This prevents capillary water supply and leads to even more frequent and deeper drying of the soil. A loose, fine-grained, water-repellent topsoil then develops that can only support a limited range of extreme dryland species (Joosten *et al*. 2016b; Zeitz 2016). Within a few decades, millions of hectares of peatland in Eastern Europe have been turned into dry deserts in this way. Drainage-based peatland use may thus also eventually frustrate peatland agricultural livelihoods (Joosten *et al*. 2012).

There may be new pressures in the future that may intensify peatland utilization and degradation. For example, in the Democratic Republic of the Congo (World Data 2022), the government has launched in late July (28th-29th July 2022) the tendering process for 27 oil blocks to drill in the Congo Basin, of which three cover the central Congo peatlands (Lewis *et al.* 2022). Similarly, there is competition for land, e.g., in Europe, for onshore renewable energy generation.

2.7.5. Protection State

This GPA has also produced a map of peatlands located within and outside of protection areas (Fig. 2.14) using the World Database on Protected Areas (WDPA)[4]. The WDPA is the most comprehensive global database on terrestrial and marine protected areas. A wide range of data providers, including governmental and non-governmental organizations help to compile the WDPA, which accepts data on protected areas as defined by IUCN and the CBD (United Nations Environment Programme World Conservation Monitoring Centre [UNEP-WCMC] 2019).

The map shows that in Asia and North America only a small proportion of peatlands are protected. In contrast, peatlands in Antarctica are almost all protected. Ratios on other continents are somewhere in between. However, even if peatlands are located in protected areas, this does not mean that they are in a good condition. Nor does it mean that they are actively managed or restored.

[4] The WDPA is a joint project between UNEP and IUCN, managed by UNEP-WCMC. https://www.unep-wcmc.org/resources-and-data/wdpa

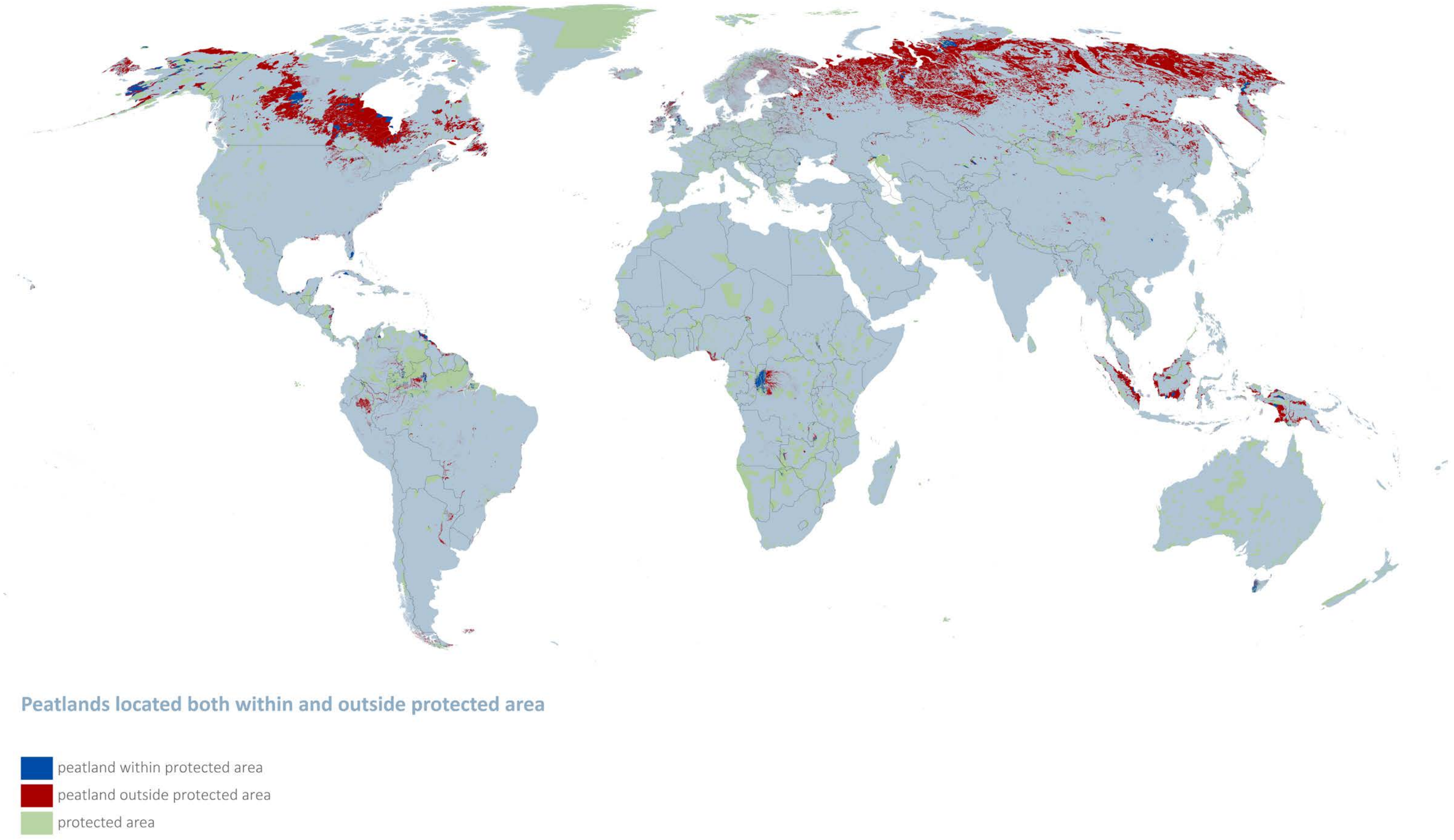


Figure 2.14. Peatlands located both within and outside protected areas.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III.3 Production of Thematic Maps.

2.8. Global Diversity of Peatlands

Peatlands host a diversity of habitats ranging from northern bogs and fens to tropical swamp forests. These habitats, in turn, are rich in biodiversity and include many endangered species, such as orangutans in the tropical peatlands of Southeast Asia, Western Lowland Gorilla in the Congo Basin and Aquatic Warbler of Central Europe (Crump 2017). Peatlands also support animal species from other habitats that use them intermittently (Minayeva and Sirin 2012). In the case of bird species, peatland habitats often work as stopover sites during migration routes, offering food and refuge (Bonn *et al*. 2016).

Fig. 2.15 shows the levels of species richness supported by peatlands worldwide and the hotspots of species richness on peatlands for mammal, bird, amphibian and reptile groups.

Peatland development is a function of climate, substrate, topography, vegetation and time (Yu *et al*. 2009) and, consequently, peatlands are very diverse in terms of appearance, species composition and associated ecosystem processes. Peatlands are also diverse in their relief forms and surface patterns (see Fig. 2.16) and, as a result, they essentially share only one characteristic worldwide: the presence of a peat layer.

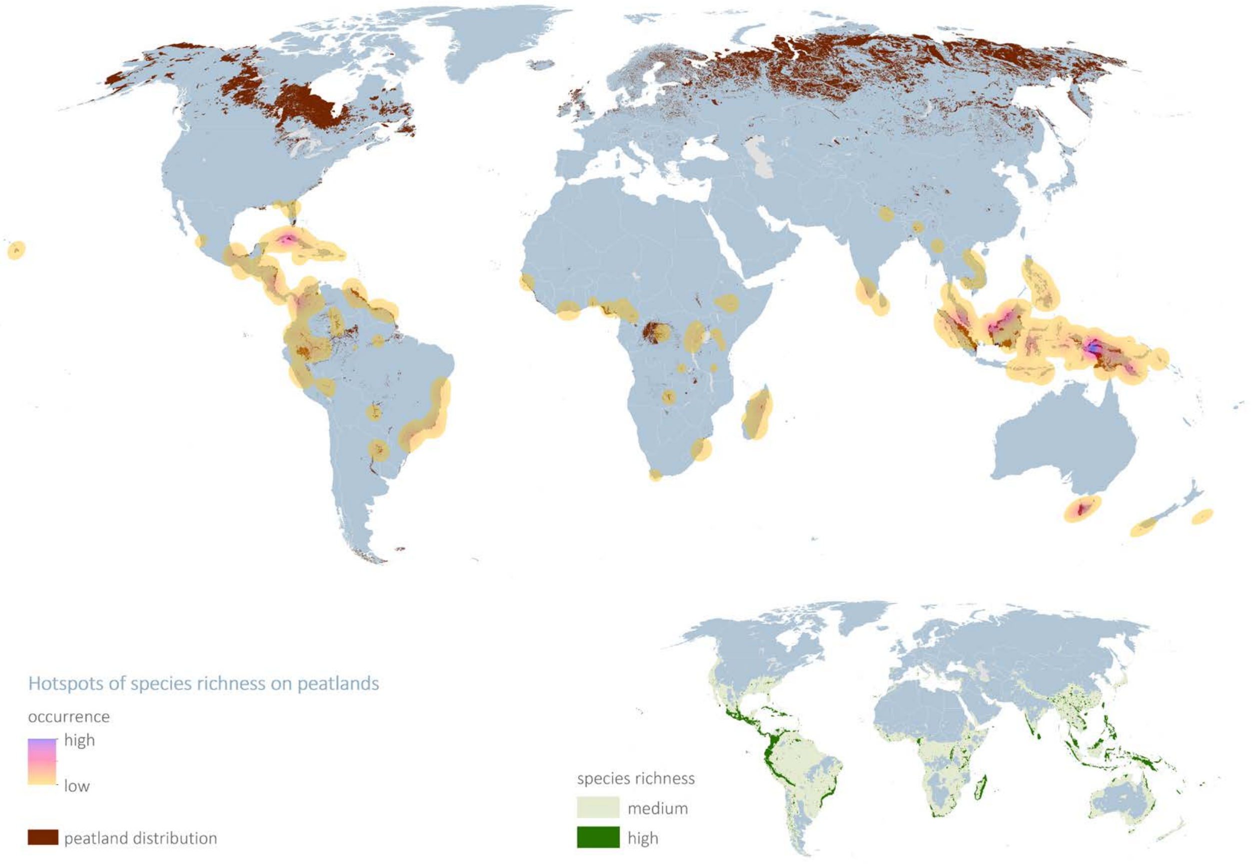


Figure 2.15. Hotspots of species richness on peatlands.

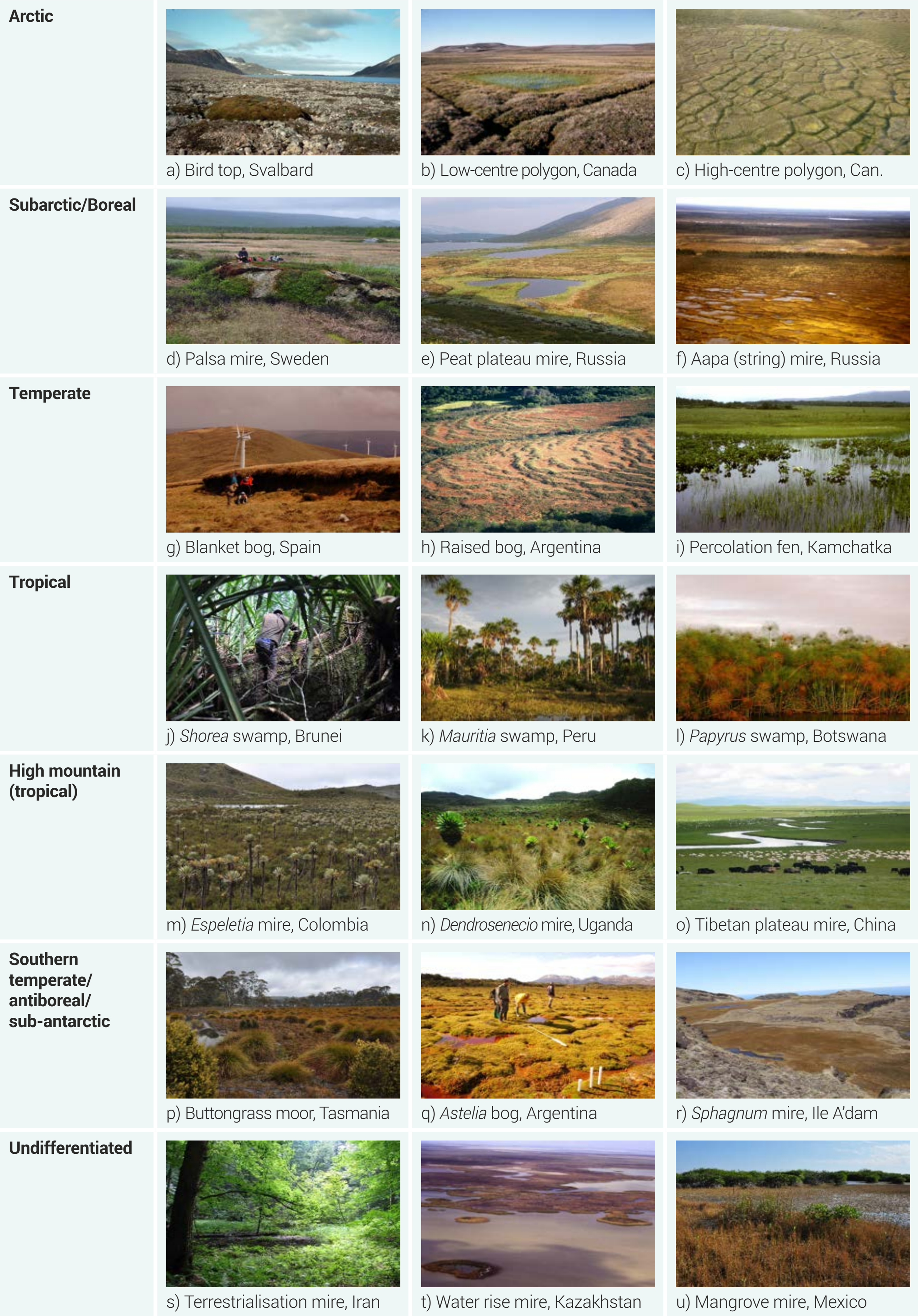
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III.3 Production of Thematic Maps.

The botanical composition of the peat, however, shows a clear general geographical pattern. In Northern cold (subarctic and boreal) and wet and cool (oceanic) regions, mosses control peat formation. Mosses lack water-conducting vascular tissues and roots, so they only produce substantial biomass when the water level remains close to their growing points and evapotranspiration is restricted during their growing season. Furthermore, the cold and wet conditions in these climate zones restrict mineralization and nutrient cycling, which suppresses the competitive growth of taller and deeper rooting vascular plants. In temperate-continental and subtropical parts of the world, above-ground plant remains decompose too quickly at the warm and well-aerated mire surface and the warmer and drier climate forces peat formation to 'go underground'. In these areas, peat accumulates in the first few decimetres below the surface by rhizomes and rootlets of grasses, sedges and other plants being inserted into the older matrix. In tropical lowlands, peat is formed even deeper under the surface by the deep-rooting lignin-rich roots of tall forest trees. In the most southern land occurrences of the world, such as in Tierra del Fuego (South America), the Sub-Antarctic Islands, Tasmania and New Zealand, the harsh, extremely oceanic and windy climate also gives rise to the accumulation of "underground" root peats, often produced by "cushion plants", from various botanical families (Table 2.2). Despite their wide geographic distribution and ecological diversity, all peatlands provide important ecosystem services at global and local scales.

Differences in climate, water sources, nutrient status, chemistry and vegetation determine the rich variety of peatland types worldwide. A common distinction is between 'bogs' and 'fens', the former only being fed by precipitation (ombrotrophic) and consequently acidic, mineral- and nutrient-poor. The latter also receive surface or ground water that has been into contact with the mineral subsoil (minerotrophic) and is generally less acidic and less nutrient poor. A 'transitional mire' (or 'poor fen', a very abundant peatland type in the northern hemisphere) receives acidic nutrient-poor minerotrophic water and functions hydrologically like a fen but has vegetation and hydrochemistry similar to that of a bog.

Table 2.2 Characteristic peat forming plants in different parts of the World
Source: modified after Prager et al. 2006.

Climate	Dominant peat formers (physiognomy)	Dominant peat formers (taxonomy)	Dominant peat forming plant parts
Northern Arctic / Boreal/ Oceanic-temperate	Mosses	Sphagnaceae, Hypnales	Stems, branches, leaves
Continental- temperate / Subtropical	Reeds, sedges	Poaceae, Cyperaceae, Equisetaceae, Restionaceae	Rhizomes, rootlets
Tropical	Trees	Dipterocarpaceae, Palmae, Euphorbiaceae, Meliaceae, Clusiaceae, Annonaceae, Bignoniaceae, etc.	Roots (and above-ground parts in case of tip up pools, Dommain *et al.* 2015)
Southern Antiboreal, Sub-Antarctic/extremely oceanic	Cushion plants	Asteliaceae, Stylidiaceae, Restionaceae, Cyperaceae, Juncaceae, Plantaginaceae, Montiaceae, etc.	Roots



Arctic

a) Bird top, Svalbard

b) Low-centre polygon, Canada

c) High-centre polygon, Can.

Subarctic/Boreal

d) Palsa mire, Sweden

e) Peat plateau mire, Russia

f) Aapa (string) mire, Russia

Temperate

g) Blanket bog, Spain

h) Raised bog, Argentina

i) Percolation fen, Kamchatka

Tropical

j) *Shorea* swamp, Brunei

k) *Mauritia* swamp, Peru

l) *Papyrus* swamp, Botswana

High mountain (tropical)

m) *Espeletia* mire, Colombia

n) *Dendrosenecio* mire, Uganda

o) Tibetan plateau mire, China

Southern temperate/ antiboreal/ sub-antarctic

p) Buttongrass moor, Tasmania

q) *Astelia* bog, Argentina

r) *Sphagnum* mire, Ile A'dam

Undifferentiated

s) Terrestrialisation mire, Iran

t) Water rise mire, Kazakhstan

u) Mangrove mire, Mexico

Figure 2.16 Images of some representative peatland types to illustrate diversity across the world and their characteristic occurrence. Photos: Hans Joosten: a, d, e, j, l, m, p, q, s, u; Steve Zoltai: b, c; Katja Hahne: h; Michael Succow: i, w; Outi Lähteenoja: k; Rene Dommain: n; Martin Schumann: o; Jennie Whinam: r.

2.9. Peatland Carbon Stock

As a result of the carbon density of the peat and the depth of the peat layer, peatlands hold more carbon per hectare on average than all other ecosystems, making them the largest carbon stock of the entire terrestrial biosphere (Temmink *et al.* 2022).

Recent estimates of the total amount of carbon (the carbon stock) in global peatlands converge in the range of 450,000 to 650,000 Mt of carbon (FAO 2020). This includes northern peatlands estimated at 400,000 to 550,000 Mt of carbon (Gorham 1991; Yu *et al*. 2010; Hugelius *et al*. 2020), tropical peatlands estimated at 100,000 Mt of carbon (Page *et al*. 2011; Dargie *et al*. 2017) and southern peatlands estimated at 15,000 Mt of carbon (Yu *et al*. 2010). The three approaches to estimate peatland carbon stocks (reviewed in Yu 2012) all require information on peatland area and, as such, reliable mapping of peatland extent is critical. The time history approach integrates carbon accumulation rates as derived from peat cores with peatland areas and time to arrive at the peatland carbon stock (e.g., Yu *et al*. 2010). The peat volume approach combines estimates of average peat depth with peatland area to calculate the total peat volume, and then uses bulk density and carbon concentration data to convert volume to carbon (e.g., Gorham 1991). The carbon density approach uses bulk density and carbon concentration from peat profiles to a certain depth (e.g., the top 1 m or 3 m) to estimate total carbon amount per unit area and then multiplies this amount by the peatland area to calculate the soil carbon stock (e.g., Armentano and Menges 1986).

However, carbon stocks in tropical areas are less well-known and new peatland discoveries have been made in remote tropical regions in recent years, including in the Amazonian Basin and the Congo Basin (Draper *et al*. 2014; Dargie *et al*. 2017; Elshehawi *et al*. 2019; Peters and Tegetmeyer 2019). The importance of the enormous carbon stocks of peatlands have meanwhile been recognized (Crezee *et al*. 2022; Hastie *et al*. 2022).

Reliable estimates of peatland carbon stocks are not yet available for all countries of the world. The latest full global overview (Joosten 2009) has, where more specific national data were absent, provided indicative values of national peatland carbon stocks that are based on the estimated peatland area, the physical characteristics of the country and global averages of peat depth and carbon content.

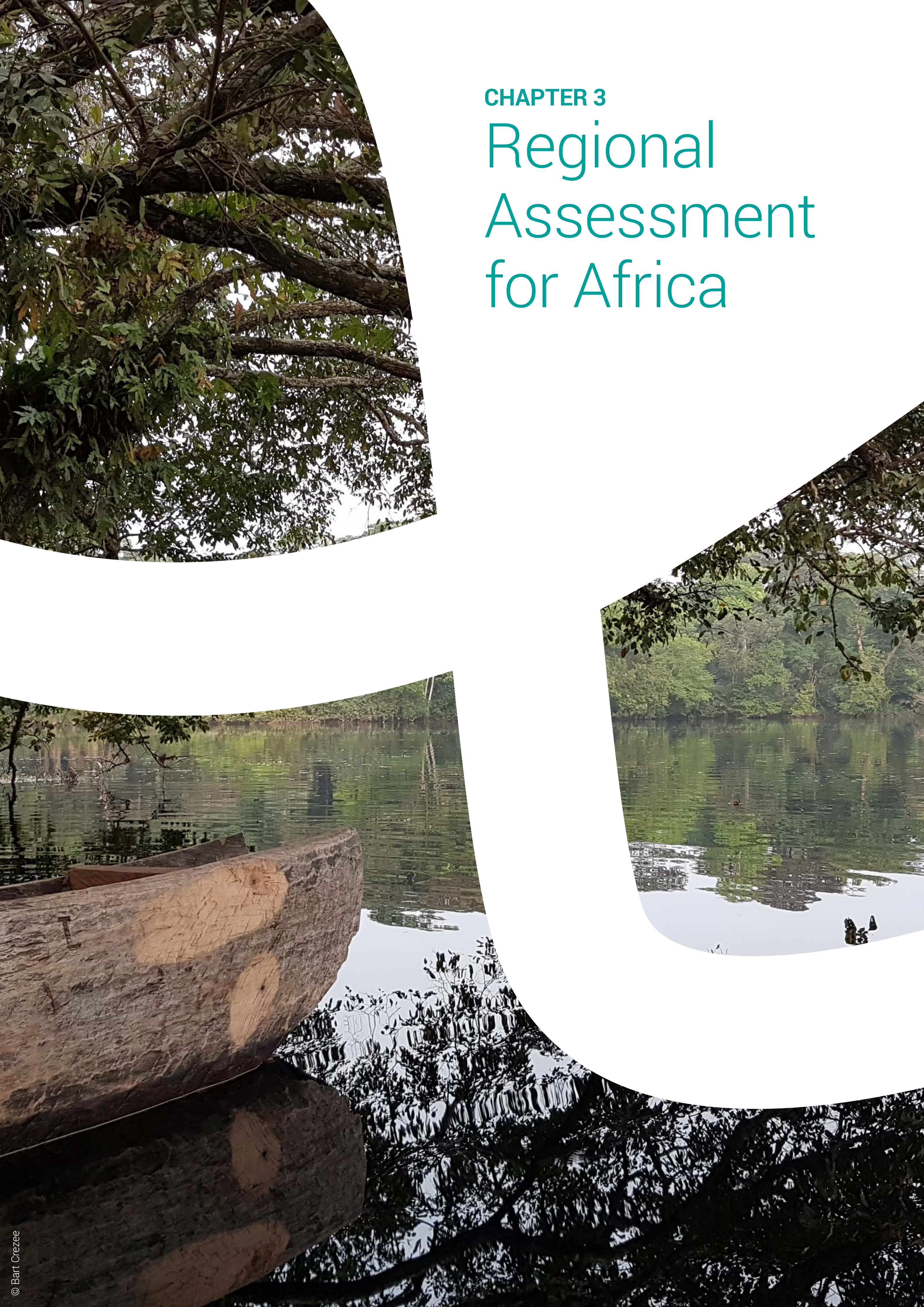
Knowing the total volume of peat and peat carbon in a country is, however, not of the highest priority for climate change decision-making, as the deeper peat layers will not immediately be mobilized (or may never be because some are deep below sea level). Microbial peat oxidation as well as peat losses associated with peat fires and wind and frost erosion concentrate on the uppermost peat layers. Only where gully erosion is relevant, e.g., in mountainous areas such as in the United Kingdom, Ireland, Lesotho and the Tibetan Plateau, deeper peat layers are mobilized.

Most relevant for shorter-term decision making with respect to GHG emissions from peatlands is the total area of peatland in a country and the status (pristine, drained, eroding) in which these peatlands occur. It is only when the spatial extent of peatlands is clarified, and their specific types and status are known, that the effects of land use change and other stressors on greenhouse gas emissions and carbon (C) stocks can be accurately quantified as a basis for inclusive, gender-responsive land use planning and management.

In this respect it is worth noting that conventional peatland definitions use to be informed by agricultural considerations (e.g., plow depth), not by climate concerns. Most countries use a threshold between 20 and 50 cm of peat depth. In contrast, a hectare of land with 10-15 cm of peat thickness (which has a peat carbon stock of 60-90 tons or more of carbon per hectare, Dommain *et al.* 2011; Warren *et al*. 2012; Roßkopf *et al.* 2015) already has a stock that equals or surpasses the threshold of 30-75 tons of above-ground biomass carbon per hectare used to define a High Carbon Stock (HCS) tropical forest (Raison *et al.* 2015). Thus, similar to HCS forests, shallow peatlands also deserve protection for climate change mitigation (cf. § 2.4, Fig. 2.2).

CHAPTER 3

Regional Assessment for Africa



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CHAPTER 3

Regional Assessment for Africa

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Regional Highlights

Key Facts

KEY REGIONAL DATA PRODUCED FOR THE GLOBAL PEATLANDS ASSESSMENT 2022[1]	
Total peatland area (hectares)	39,037,313 ha
Peatland cover over total region surface area (%)	1.3%
Degraded peatlands (%)	8.3%
Annual GHG emissions from peatlands (Megatons of carbon dioxide equivalent emissions per year)	130.1 Mt CO_2e / yr
Undegraded peatlands (%)	91.7%
Peatlands within protected areas (%)	34.8%
Top 5 Countries with largest peatland area (hectares)	1. Democratic Republic of the Congo (18,157,111 ha) 2. Republic of the Congo (9,540,799 ha) 3. Nigeria (2,155,663 ha) 4. Zambia (1,565,696 ha) 5. Angola (891,630 ha)
ADDITIONAL DATA	
Total peatland carbon stock[2,3] (Megatons of carbon)	36,896 Mt C
Threatened peatland species[4] (VU = vulnerable; EN = endangered; CR = critically endangered)	Flora: 66 VU, 80 EN, 30 CR Fauna: 81 VU, 66 EN, 31 CR
Ramsar Wetlands of International Importance with peat[5]	31 sites (7.3% of total Ramsar sites in Africa)

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[1] Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

[2] Joosten, H. (2009). The Global Peatland CO_2 Picture. Peatland status and drainage associated emissions in all countries of the World. Wetlands International, Ede, 10 p. + tables.

[3] Crezee, B., *et al.* (2022). Mapping peat thickness and carbon stocks of the central Congo Basin using field data. Nat. Geosci. 15, 639–644

[4] Data extracted from the IUCN Red List of Threatened Species.

[5] Data extracted from the Ramsar Sites Information Service.

There are significant knowledge gaps on peatlands mapping and assessment in the Africa region. The following maps, charts and tables summarize the current best estimates (see Annex III for the methods used to collect the data and information for this assessment).

Peatlands are widely distributed across the region of Africa, with particularly significant peatlands in the Congo Basin. Most of these peatlands host tropical rainforests, which helps explain why most have not been well studied. Although considerable uncertainties remain, it is estimated that peatlands cover 39,037,313 hectares. This represents 8% of global peatlands. Republic of the Congo (Congo) and Democratic Republic of the Congo (DRC) together account for the majority of peatland extent in the continent. Despite the recent mapping of peatlands in the Congo Basin which are currently healthy and intact (Dargie *et al*. 2017; Crezee *et al*. 2022), many peatlands across Africa are being destroyed and degraded at an alarming rate, creating a pressing need for action to restore, conserve and sustainably manage these crucial habitats. Peatland degradation has been reported in all of the African countries, with twelve countries reporting that more than 50% of their peatlands are degraded. The resulting annual GHG emissions are 130.1 Mt CO_2e per year, with eight countries alone being responsible for 50% of those emissions. This compares to annual emissions of 582 Mt CO_2e for Europe and 89.4 Mt CO_2e for North America.

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3.1. Biomes and Ecological Zones

Africa is the second largest landmass on earth. It is a continent with diverse landscapes ranging from the world's largest desert, the Sahara, to snow-capped mountains on the equator such as Mount Kilimanjaro and Mount Kenya. An abundance of different peatland types occurs across the continent. These are mostly associated with other types of wetlands including large systems like the Sahelian floodplains (e.g., the Niger) in Western Africa and the Sudd in South Sudan. The world's largest inland delta, characterised by a pristine wetland system, the Okavango Delta, occurs at the heart of the Kalahari Desert in Botswana (Wehberg 2013). A significant amount of tropical forests that occur in the Central Congo Basin are reported to be peatlands with the largest coverage of peat deposits in the tropics to date (Dargie *et al*. 2017; Sonwa *et al*. 2022), which helps explain why most have not been well studied (Fig. 3.1). The equatorial lakes of the Great Rift Valley in East Africa also contribute to this rich diversity of Africa's peatlands (Nile Basin Initiative [NBI] 2020). So too do the alpine mires of Ethiopia, Lesotho, South Africa, Tanzania and Rwanda (Grundling and Grobler 2005; Grundling and Grootjans 2016).

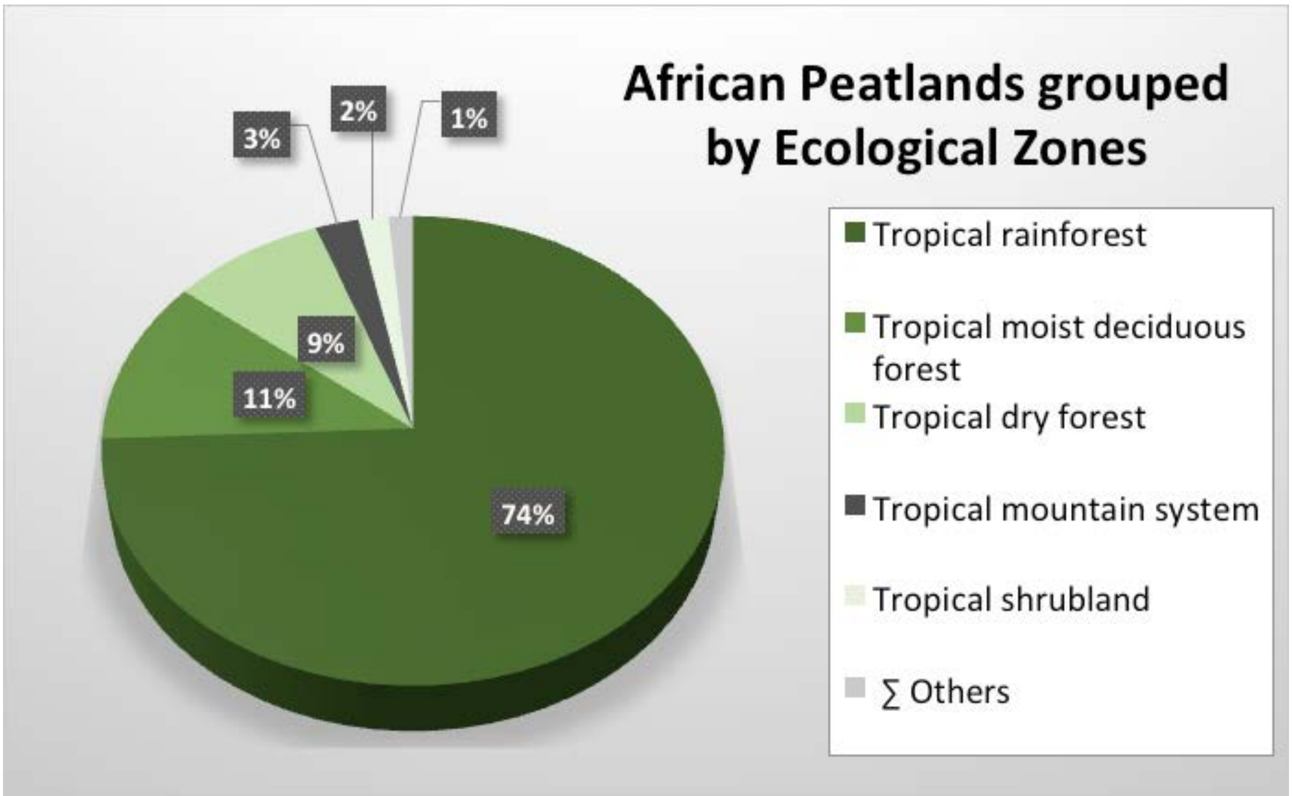

Figure 3.1. The distribution of African peatlands according to aggregated FAO Global Ecological Zones.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

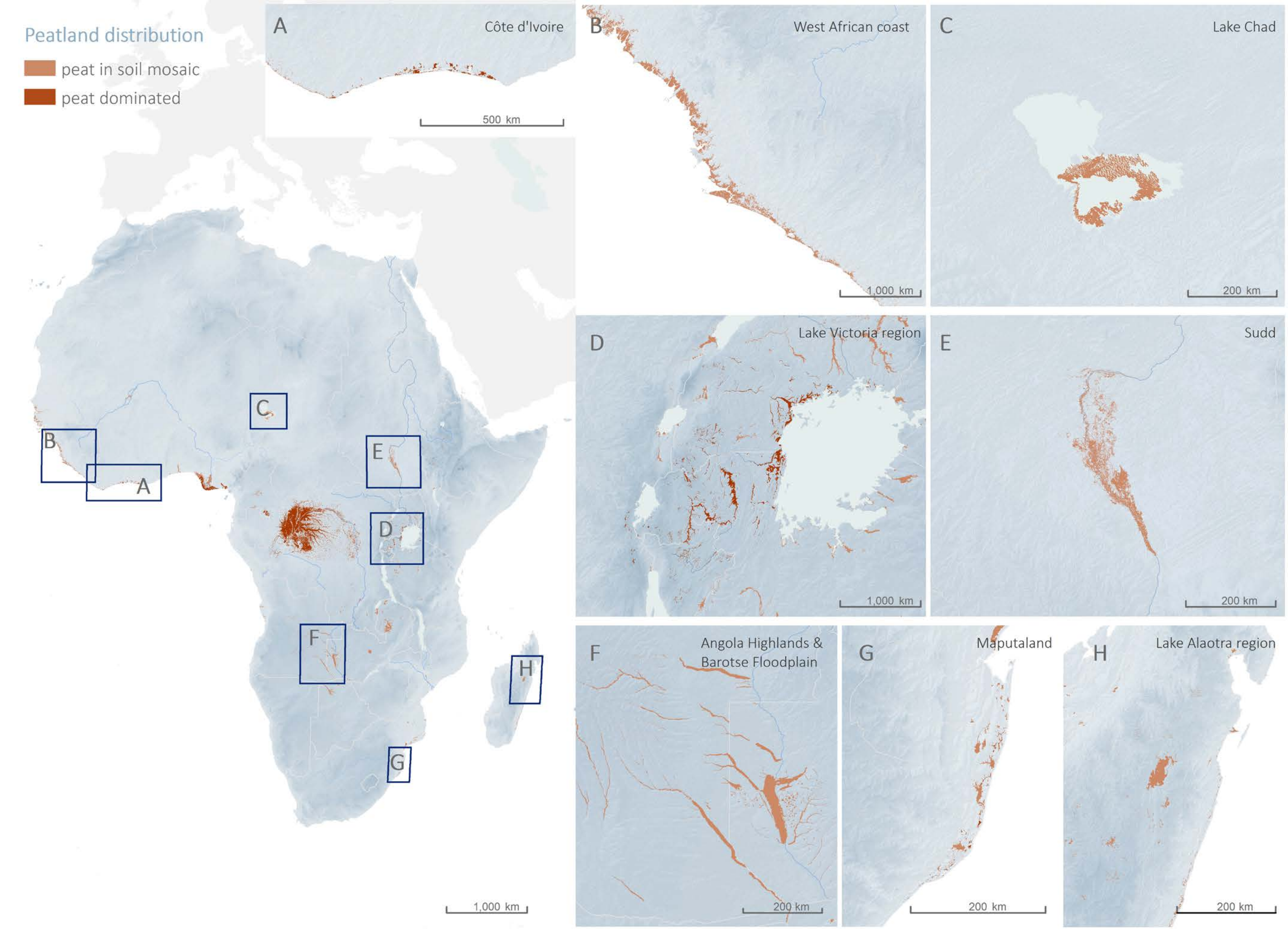

Figure 3.2. Major peatlands in Africa and their currently known distribution (partly including organic soils).

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III. Production of the Global Peatland Map 2.0.

3.2. Peatland Distribution and Extent

According to the global dataset produced for the GPA (see Chapter 2), peatlands in Africa are estimated to cover a total area of 39,037,313 hectares. Peatlands are widely distributed across the region, with particularly significant peatlands in the Congo Basin and in the locations shown in the inset maps in Fig. 3.2. Notably, four countries have more than one million hectares of peatlands each, namely: Democratic Republic of the Congo, Republic of the Congo, Nigeria and Zambia.

Fig. 3.3 shows African countries with over 100,000 hectares of peatlands. Congo and Democratic Republic of the Congo together account for a significant extension of the peatlands in the continent.

In the following sections, insights from subregions of the continent are given as examples. These examples are not aimed at covering the whole of the subregion.

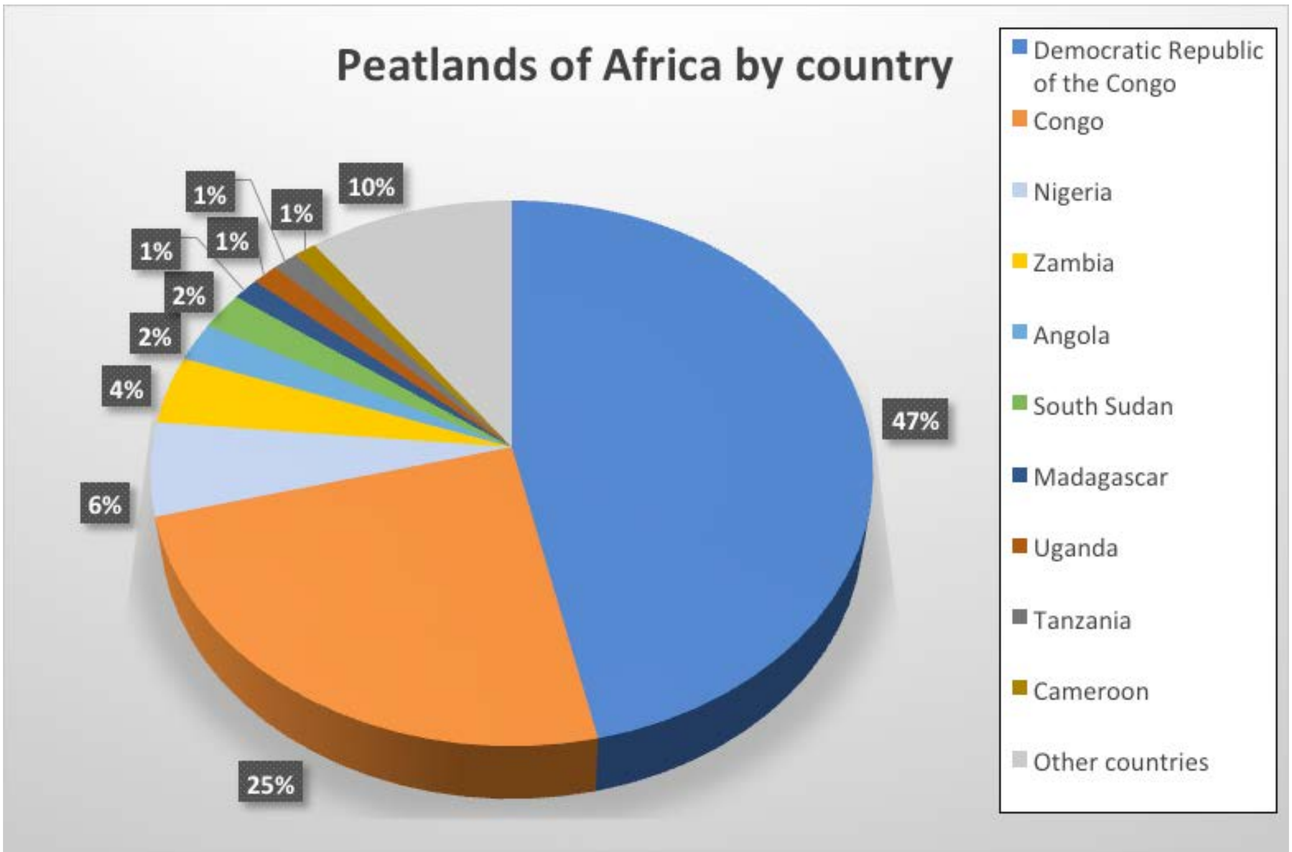

Figure 3.3. Top-10 countries holding the largest area of peatlands in Africa. Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

3.2.1 North Africa

There are further details on peatland areas in three countries of the Maghreb region: Morocco, Algeria and Tunisia. These areas include alder swamps, *Sphagnum* fens (particularly prominent in the Northern Morocco region) and peaty heathlands of *Erica scoparia* in Northern Tunisia and Northeastern Algeria (Dahlgren and Lassen 1972; Meddour and Laribi 1999; Ferchichi-Ben Jamaa *et al.* 2010; Ghit *et al.* 2018; Muller *et al.* 2022). In the Oriental part of Tunisia, peatland formation has also been documented in the Saouef Formation. These peatlands are covered with wet swamp forest vegetation. The peatlands of the Saouef Formation have developed in flood basins situated between alluvial ridges (Radhwani *et al*. 2022).

3.2.2. Western Africa

There are important data gaps in this subregion and further field work is needed to fill these gaps. Large potential peatland areas have been identified in Western Africa, primarily in Côte d'Ivoire and Nigeria, which encompass riverine floodplains, *Raphia*-dominated peat swamp forests, and mangroves. (Barthelmes *et al*. 2015). According to Barthelmes *et al*. (2015) hydromorphic soils in Côte d'Ivoire include alluvial organic soils on floodplains along riverbanks, partly with organic accumulations. Also, peat deposits have been identified in mangroves on the coast of Côte d'Ivoire, particularly along the San-Pedro Stream. Lastly, in the areas close to the cities of Grand Béréy and Tabou in Côte d'Ivoire, peaty soils with *Symphonia* and *Raphia* forests and mangroves were identified (Barthelmes *et al*. 2015).

3.2.3. Central Africa

Peatlands in Central Africa typically occupy riverine areas or lay within large interfluvial basins (Crezee *et al*. 2022). Peat is frequently found under much rarer palm-dominated swamp forests that occupy some old river channels (Dargie *et al*. 2017). The DRC and the Republic of the Congo host the largest tropical peatland complex in the world covering 16.76 million hectares. This represents 36% of the world’s tropical peatlands (Crezee *et al*. 2022). The Central Congo Basin (Cuvette Centrale) peatland complex is estimated to store about 29,000 Mt C within its peat soil. The median peat thickness is 1.7 ± 0.9 m across the complex, with a maximum depth of 5.9 m. Two common vegetation types exist in the central Congo Basin peatland complex namely hardwood swamp forests and palm dominated swamp forests. The area is covered by two very large Wetlands of International Importance, Lake Télé in Congo, covering 438,960 hectares, and Ngiri-Tumba-Maindombe in the DRC, covering 6,569,624 hectares, being the second largest transboundary Wetland of International Importance in the world (Crezee *et.al.* 2022). These two Wetlands of International Importance contain the largest continental freshwater body in Africa, making it one of the most important wetlands in Africa. In line with the Brazzaville Declaration, the Lake Tele/Lake Tumba Memorandum of Understanding, and the Binational Plan of Action on the Sustainable Management of the two lakes, the Republic of the Congo and DRC are working together for the development and promotion of a land use model that favours the sustainable management of peatlands and economic development of local communities in the Lake Télé and Lake Tumba landscape.

These peatlands largely depend on the rainfall regime of the entire Congo Basin. There is limited evidence that the boreal summer dry season in the Congo basin is lengthening (Jiang *et al*. 2019). This may be due to trends in atmospheric and oceanic oscillation systems, such as the Atlantic Multidecadal Oscillation, the North Atlantic Oscillation, and the Southern Oscillation Index (Ibiassi Mahoungou *et al*. 2017; Ibiassi Mahoungou 2018).

For Central Africa, IPCC (2021) states that ecological drought may have increased, albeit with a low confidence. The observed downward trend for precipitation cannot be attributed to climate change, but rather to direct human influence, e.g., deforestation (IPCC 2022; IPCC n.d.).

3.2.4. Eastern Africa

The region is estimated to host 5 million hectares of peatlands, representing close to 13% of the total peatland area in Africa. Several countries in Eastern Africa host peatlands, including Uganda, South Sudan, Rwanda, Ethiopia, Burundi, Tanzania, and Kenya (NBI 2020; NBI 2022). In Eastern Africa, peatlands can be found fringing lakes, across swampy riverine plains and in deep valley bottoms as well as in the highlands.

Natural peatland vegetation is often dominated by papyrus (*Cyperus papyrus*), but also includes *Sphagnum* moss, grasses, reeds, palms and forest, with plants either anchored into the soil or floating on the water surface (Elshehawi *et al*. 2019a). Papyrus is often present in the form of a floating mat that can be up to one meter thick (Kayendeke *et al*. 2018, Elshehawi *et al*. 2019a). The floating mat thickness is usually at its minimum at the fringes and reaches its maximum towards the middle while the average mat thickness changes through wet and dry seasonal cycles (Kayendeke *et al*. 2018). Below the water column, a peat layer can be present at the bottom, varying in thickness from a few centimetres to several meters (Langan *et al.* 2018; Elshehawi *et al.* 2019a).

The extent and depth of Eastern Africa's peat soils is still to be fully documented but known depths appear to vary spatially, with the greatest depths reported from the valley bottom wetlands of the Kigezi highlands in Uganda where peat can reach over 20 meters in depth (Hamilton and Taylor 1986). The peatlands of the Nile Basin store approximately 4,200–10,000 Mt of carbon, equivalent to 5–10 % of the known tropical peat carbon stock (Elshehawi *et al*. 2019a).

Conversion of Eastern Africa's peatlands typically involves drainage for use in small-scale commercial rice and potato cultivation, subsistence farming or cattle grazing (Iyango *et al*. 2005). Peatland conversion in Uganda is expected to lead to annual emissions of about 8 Mt CO_2e for the period of 2015-2035 (Elshehawi *et al*. 2019a).

Figure 3.4 Potato fields on peat soils in Uganda.
Photo: Jenny Farmer

Figure 3.5. Areas reclaimed by farmers through burn and slash for cattle grazing in Bor, South Sudan (left). Burned peat within the floating mat (right).

Photos: Samer Elshehawi

It is estimated that peatlands within the Sudd wetlands in South Sudan cover approximately 863,000 hectares, i.e., about 30% of the total peatland area of the entire Nile Basin, and 20% of its total peatland carbon stock (Elshehawi *et al.* 2019).

3.2.5. Southern Africa

A variety of peatland types occur across the Southern African landscape, with the South African peatlands being most studied and used here as an example. Both forested and non-forested peatlands can be found. The region is estimated to host 527,000 hectares of peatlands, representing 1.3% of the total peatland area in Africa.

A total of 120,000–121,128 hectares of peatlands have been mapped for South Africa, including 10% of forested peatlands (Grundling *et al*. 2021; Van Deventer *et al*. 2021). The majority of the peatlands are within the subtropical-temperate coastal forested wetlands of South Africa, along the east coast of the country (Van Deventer *et al*. 2021). Their occurrence stretches from the uMtamvuna Estuary in the south at the border between the Eastern Cape and KwaZulu-Natal Provinces and the uThukela Estuary northwards, in narrow bands along the wetlands. Further north of the uThukela Estuary towards the border with Mozambique, forested peatlands (floodplain, swamp and riverine forest subtypes) become more extensive in cover on the Maputaland Coastal Plain, which host 97% of all forested peatlands of South Africa (Van Deventer *et al*. 2021). In the most recent national assessment of South African freshwater ecosystems, these swamp forests were proposed for red listing as their range is restricted and they show evidence of ongoing decline (Van Deventer *et al*. 2021).

Wetlands on the Maputaland Coastal Plain are predominantly aquifer dependent and, during drier periods, become accessible to people from local communities who clear land for subsistence crop production in the peat soils (Silva 2004; Grundling and Grobler 2005). In addition, an increase in the areal extent of timber plantations on the Maputaland Coastal Plain in the past decade near the peatlands has caused a lowering of the regional water table. This, combined with extreme drought events, has resulted in increased desiccation of all peatlands in the region (Pretorius 2019; Grundling *et al*. 2021; Van Deventer *et al*. 2021).

In Botswana, the Okavango Delta peatlands are formed in three different settings in the Okavango valley. These include the backswamp settings where the open water coming from the highlands in Angola is converted into homogeneous emergent peatlands, the lake and channel margins where peat is deposited, and the inlets to lakes that connect to the main channel of the Okavango-Nqoga-Maunachira River system (Ellery and Ellery 2022).

Box 3.1. Upland and High-altitude Peatlands

The highlands of Africa host a variety of peatlands ranging from the alpine mires of the Bale Mountains in northern Ethiopia and the Maluti Mountains in southern Africa to the tropical peatland of Rugezi in the Buberuka highlands of Rwanda, the afroalpine mires of Rwenzori Mountains on the borders of the Democratic Republic of the Congo and Uganda and Kilimanjaro, Tanzania in East Africa. These peatlands are typically associated with the headwaters of major rivers in Africa and occur at altitudes between 2,000 and 4,100 meters above sea level (m.a.s.l.). The higher altitude peatlands (above 2,750 m.a.s.l.) in the lower latitudes are typically small in extent (2–10 hectares) with maximum peat thickness ranging from 3 m (Bale) to 6 m (Maluti). Though small, they can cover extensive hillslopes and valleys in these mountainous landscapes and are often groundwater fed. In contrast, the tropical peatlands close to the equator, such as the Rugezi Mire, occur in mountainous valleys at lower altitude (above 2050 m.a.s.l.) and are mostly rainwater fed. The Rugezi peatland covers an area of 6,735 hectares and the peat in the northern part of the mire is comprised of sedge peat while the peats in the central and southern parts are dominated by *Miscanthus violaceus* to a depth of 7 m, with some *Sphagnum* peat in the top 0.5 m in the south-western section. Maximum peat thickness is estimated to be between 12 and 20 m with an inferred peat volume of 5.25×10^8 m^3 (Chatanga and Seleteng-Kose 2021; Kahlolo *et al.* 2021).

These highlands peatlands are not always easily accessible and, for this reason, are less prone to intensive agricultural practices. What they are exposed to is livestock ranching, which can lead to overgrazing and erosion. They are also often targeted for hydroelectric power generation and water storage as they are located in areas of high rainfall and form natural water towers in drier areas. The difficult accessibility of these sites also means that they are not always well studied. There is little information about the extent of these peatlands across the highlands and mountains of Africa and their contribution to biodiversity, ecosystem services and the threats related to their use (Chatanga and Seleteng-Kose 2021; Kahlolo *et al*. 2021).

3.3. Biodiversity, Nature's Contributions to People and Hotspots of Value

This chapter contains some examples from the most studied regions, focusing first on biodiversity, then on nature's contributions to people and finally, on identifying some potential hotspots of value, even though in Africa their definition still require further work.

3.3.1. Biodiversity

Peatland vegetation is adapted to anoxic wet conditions. These plants engineer their ecosystems through feedback mechanisms and offer unique specialized biodiversity. A few examples of African species are described here.

One of the special peatland plants in Africa is *Prionium serratum* (Palmiet) (Fig. 3.6). This plant thrives in undrained valley-bottom peatlands. Palmiet is a unique species, endemic to South Africa, one of only four in its family (Thurniaceae). It is an ecosystem engineer, a species that exerts disproportionate influence on an ecosystem (Rebelo *et al*. 2017). Palmiet peatlands are mainly found in the narrow valleys of the Cape Fold Mountains, with measured peat ranging from 0.5–10 m deep. The deepest deposits are between 5,050 and 5,620 years old (Rebelo *et al*. 2017).

Another example of a specialized species is present in the Bale Mountain mires in Ethiopia. These mires are dominated by tussocky *Carex* species and locally also by the cushion plant *Eriocaulon schimperi* (Dullo *et al*. 2015). The cushion plant also occurs in other parts of eastern Africa in mountain areas at altitudes between 2,000 and 4,100 m.a.s.l.

Figure 3.6 A palmiet peatland in the Vyeboom area, above the Theewaterskloof Dam, Western Cape, South Africa. Photo: Cape Winelands Biosphere Reserve.

For the central Congo Basin, there is a lack of scientific knowledge on the peatland biodiversity including its plant communities, although recent research has shown that the tree species are typically generalists that can tolerate waterlogging (Dargie 2015; Crezee 2022). This is due to the inaccessibility of the Cuvette Centrale peatland complex and a lack of systematic surveys since the 1960s (Biddulph *et al*. 2021). However, the Cuvette Centrale peatlands in the Congo Basin have long been known as important habitat for megafauna populations, including substantial numbers of Lowland Gorilla (*Gorilla gorilla gorilla*), Forest Elephant (*Loxodonta cyclotis*), Chimpanzee (*Pan troglodytes*) and Bonobo (*Pan paniscus*). Allen's Swamp Monkey (*Allenopithecus nigroviridis*) is endemic to the Congo basin favouring swampy and riparian habitat (Maisels *et al.* 2006). The Dwarf Crocodile (*Osteolaemus tetraspis*) also finds refuge in these peatland swamp forests (Fay and Agnagna 1991; Rainey *et al*. 2010; Inogwabini *et al*. 2013). Research into less emblematic species within the peatlands is limited (Biddulph *et al*. 2021), but Indigenous Peoples and Local Communities likely have further knowledge of this biodiversity.

In Eastern Africa, papyrus provides critical biotopes for the reproduction of fish and birds, including some endemic bird species like the endangered Shoebill (*Balaeniceps rex*) (Pacini *et al*. 2018). In South Sudan, the Sudd marshes harbour most of the world's Shoebill population. It is estimated that a world population of 5,000–8,000 birds remain, of which 5,000 Shoebills are thought to live in South Sudan (Dodman 2013).

On the west coast of Africa, swamp forests act as important refuges for threatened primates and felids (Nowak 2013).

Southern African peatlands provide crucial habitat for diverse fauna. The peatlands of the central and western Highveld of South Africa are underlain, and geologically controlled, by the dolomites of the Malmani Lithological Group. The surface geomorphological features of the dolomites can often be related to the subsurface water-bearing characteristics (e.g., the valleys of surface drainage, in which the peatlands occur and coincide with karstified dolomite (Bredenkamp 1995)). These karst mire systems provide crucial habitat for many endemic and endangered species, including unique fish species, particularly *Barbus (Enteromius) cf. brevipinnis*. Further, these wetlands produced several new fish distribution records for South Africa and 21 species new to science. The results of the ostracod (including crustaceans) survey from these systems shows that of all the species found, 30% are new to southern Africa and one species is new to science (Skelton *et al*. 1994).

Certain antelopes, such as Lechwe (*Kobus lechwe*), Puku (*Kobus vardoni*) and Sitatunga (*Tragelaphus spekii*), are associated with African swamps and marshes and have narrow distribution ranges. Further research on the role of peatlands and swamp forests in the ecology and persistence of threatened mammals is needed.

On the Kenyan coast the following species occur in a biotope with mangrove peat: *Nassarius coronatus, Polinices mamilla, Thalamita gatavakensis, Nerita polita* and *Strombus mutabilis* (Ruwa 1990). The Rufiji River Delta mangrove ecosystem in Tanzania is estimated to have 40.5 tons per hectare of aboveground carbon, 21.08 tons per hectare of belowground carbon (roots) and 98.57 tons per hectare of soil organic carbon with the mangrove species *Rhizophora mucronata* contributing the highest (39.87%) biomass C, followed by *Avicennia marina* (28.06%) (Lupembe 2014).

In addition to providing species diversity outlined above, African peatlands support important ecosystem diversity through their specialised engineering species, e.g., the cushion plants in the Bale Mountain in Ethiopia and the endemic palmiet (*Prionium serratum*) mires of the Cape Fold Mountains in South Africa.

3.3.2. Nature's Contributions to People

African peatlands provide various contributions to people, like water regulation and climate change mitigation, which are mostly not empirically quantified or verified. Some of these contributions have a global impact through services like climate change mitigation and the conservation of existing carbon stocks. These vital contributions can be seen in the Cuvette Centrale in the Congo Basin and in the Sudd in South Sudan where conservation of undrained and restoration of drained peatlands may substantially reduce greenhouse gas emissions.

The multiple contributions that the Central Congo Basin provides to people living in the region still need to be determined in full. Indigenous Peoples and Local Communities clearly depend on peatland forest resources for their livelihoods, but exactly how is not yet fully understood (Dargie *et al*. 2018). Biddulph and collaborators observed local communities sourcing bushmeat, caterpillars, fish, fruits and honey and fuel for fires from the peatlands (Biddulph *et al*. 2022). Additionally, certain tree and liana species have medicinal uses and provide construction materials and fibres. *Raphia laurentii* fronds are used for roofing material. A demand for the species *Daniellia pynaertii*, which is used for construction in urban areas and can be floated out from the peatlands to the market, has led to high levels of selective logging for this species in the peatland forests of the DRC. There are very few studies on the socio-economic activities of the communities living within or adjacent to the Central Congo Basin peatlands (Biddulph *et al*. 2022).

Traditional papyrus commodities are widely available in areas like Bunyonyi and Nakivubo in Uganda and the shores of Lake Victoria in Uganda, Kenya and Tanzania. Widespread use of papyrus biomass for crafts making (e.g., mats, baskets, trays), roof and fence construction, rope elaboration, etc., has been observed by multiple studies. Findings in Kenya indicate that older women dominate the trade (harvesting, production and marketing) further contributing to women's economic empowerment whilst supplementing reduced household income levels (Morrison *et al*. 2012). This underlines the pivotal role that papyrus commodities have in local microeconomics and livelihoods (e.g. Iyango *et al*. 2005; Langan *et al*. 2018). Transitioning to papyrus biomass for fuel has great potential to supply domestic energy requirements by more than 80% while reducing forest logging pressure for wood and charcoal production. Another potential cross-cutting use of papyrus for sustainable livelihoods is the fabrication of biodegradable sanitary pads from papyrus in Uganda, which is promising for poverty alleviation and promoting women's health and wellbeing with a ready supply chain (see Fig. 3.7 on the value chain; Licero-Villanueva 2022).

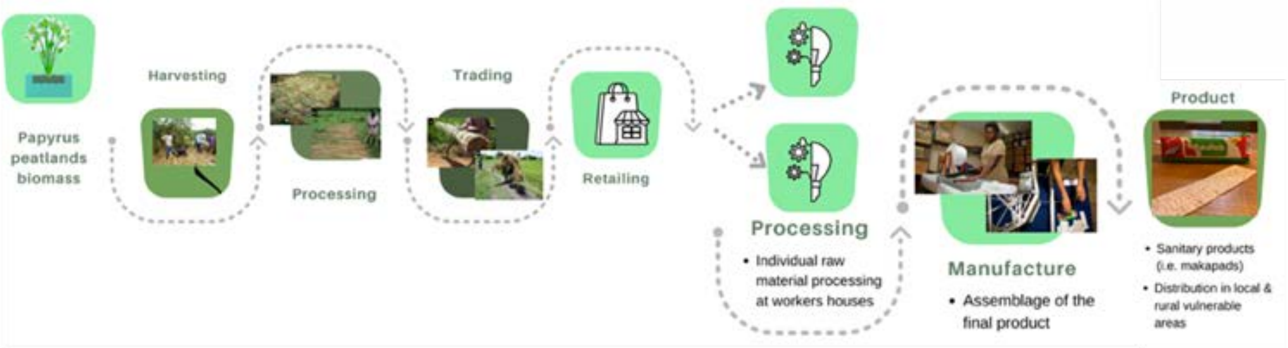

Figure 3.7 Exemplary papyrus value chain for sanitary products
Source: Licero-Villanueva 2022.

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Intact peatlands in Uganda provide community-wide benefits. They supply land for bee keeping, provide a source of medicinal plants, support eco-tourism, provide fish for food and provide plant materials that are used widely in baskets mats, rope and roofing. These peatlands also help with water retention (Iyango *et al*. 2005). Similarly, the Tonga people of the Tembe Tribe in South Africa use the indigenous plants from the swamp forests for various purposes. For instance, they use the palm *Raphia australis* for construction material. The leaf is light and strong and therefore an excellent component for building canoes, ladders, roofs and even walls. Many indigenous swamp forest plants are also used as medicines and food resources (Silva *et al*. 2004). Therefore, it is unfortunate that most of these peat swamp forests are being drained for cultivation.

3.3.2.1. Hydrology and African Peatlands

Several major river systems arise from mountainous areas with headwater peatlands, such as the Okavango, Orange and Zambezi in Southern Africa, the Congo and the Nile in Eastern Africa (Balek 2006) or the Rufiji and Malagarasi river systems in Tanzania (Hughes and Hughes 1992).

Headwater wetlands in western Ethiopia feed all major rivers in the Horn of Africa and are responsible for 90% of the water supply of the main Nile River (Wood *et al.* 2001; Wood 2003; Kebede *et al.* 2017). A small area of these headwater wetlands is made up of fen peatlands. Preliminary studies have revealed the presence of peatlands in the headwater areas of the Blue and the White Nile in the western highlands of Ethiopia, totalling approximately 110,000 hectares (Dresen *et al*. 2015; Elshehawi *et al*. 2019a).

The Angolan Highlands is a central water source region for three major river basins of sub-Saharan Africa, contributing to the Congo Basin to the north, the Zambezi Basin to the east and the Okavango Basin to the south (Lourenco *et al.* 2022). The source waters originating in the Angolan Highlands are dominated by peatland environments. The highland peatlands are diverse in that they form at lake margins, on river floodplains and on relict river terraces. The peat accumulating in the river channels is the control valve between groundwater flow and the river (Lourenco *et al*. 2022).

3.3.2.2. Coastal Organic Soils

Africa's coastline is richly endowed with mangroves which are important for protecting shorelines from storm damage and floods. However, the proportion of mangrove forests on peat soils is not known (Ewel 2010). Various studies confirm the presence of peat in mangroves of the African east coast.

Studies in the Rufiji River Delta mangrove ecosystem confirm high organic carbon content both from aboveground and belowground carbon (roots). In Mozambique, the most extensive mangroves occur on the estuarine and swampy coast in the centre of the Mozambican coastline, dominated by mud rich in organic matter (Odum and Heald 1975; Campira *et al*. 2021) with an almost continuous mangrove forest from the Zambezi River delta to Beira and further south to the Save River estuary (Campira *et al*. 2021). South African mangroves are confined to the intertidal zones along the east coast, at 14 important localities from Kosi Bay in the north on the Mozambique border, to Kabonqaba north of East London in the south (Smuts 1996).

3.3.3. Hotspots of Value

There is limited information on the value of African peatlands and the ecosystem services they provide. The better studied peatlands of the Cuvette Centrale, the Nile Basin, South Africa and Tanzania have been shown to have value for climate change mitigation, carbon storage and water purification. They also serve as essential habitat for a wide range of fauna and flora.

The peatlands of the Cuvette Centrale and the Nile Basin (with its sub-basins the Nile Equatorial Lakes and the Sudd) store the highest known amount of carbon within soil and biomass in African peatlands. They play a major role in climate change mitigation and help to achieve the Sustainable Development Goals on health, water and life on land (Page *et al*. 2011). As an example, the peatlands of the Nile Basin store approximately 4,200–10,000 Mt of carbon, equivalent to 5–10% of the known tropical peat carbon stock (Elshehawi *et al*. 2019a). The central Congo Basin peatlands are a globally important carbon stock of 28,900 Mt of carbon, with about two-thirds of this peat carbon in DRC and one-third in Congo (Crezee *et al*. 2022). Therefore, it is imperative that these peatlands are protected because degradation by anthropogenic disturbances can convert these peatlands from carbon sinks to carbon sources and exacerbate the already existing climate crisis.

South African peatlands are critical for water purification. The Gerhard Minnebron Peatland in South Africa was found to efficiently remove and filter out uranium from upstream mining activities (Winde 2011). The Klip River Peatland in Johannesburg was also found to have accumulated heavy metals from industrial pollution and sewage treatment plants over time (McCarthy and Venter 2006). The ability of these peatlands to filter and accumulate pollutants is important. The loss or degradation of these ecosystems would compromise water quality for many surrounding catchments.

Peatland can provide insight into a wide range of historical events, such as human records and volcanic eruptions. It also can reveal historic levels of key chemicals in the atmosphere and of past climate change events (Malmer *et al*. 1997; Barber *et al*. 2000). Peat deposits from peatlands such as the Mfabeni mire in South Africa, which is older than 45,000 years, and the Maua mire of Tanzania have been used as historical archives to provide insight into past conditions (McCarthy *et al*. 2010; Strobel *et al*. 2019; Courtney-Mustaphi *et al*. 2021). Climatic reconstruction with information collected from peatlands in Africa is particularly important because there are little to no historical records of past climatic events in Africa.

For southern Africa the 14C-derived accumulation rates yielded information on past environmental changes affecting southern African peatlands together with the observed changes in 13C. The data showed two peaks indicating favourable moist peat accumulating conditions prior to the Late Glacial Maximum (LGM) and during the Mid-Holocene (Elshehawi *et al.* 2019b), e.g the Angolan Highland peatlands accumulating since of 7000 years B.P. (Lourenco *et al.* 2022). Peatlands in valleybottoms of the interior plateau showed optimal accumulating conditions from after the LGM to the Early-Holocene whilst Coastal peatlands, although some of Late Pleistocene age, showed mostly optimal conditions during the Holocene, with maximum humid conditions occurring ca. 6000-3000 years ago (Elshehawi *et al.* 2019b).

3.4. Status of Peatlands, Drivers of Change and Hotspots of Change

3.4.1. Status of Peatlands

Although Africa has only about 10% degraded peatlands the situation is desperate in such countries as Chad, South Africa and Mali with 70 to 95% degraded peatlands (see Fig. 3.8). Peatlands in the Nile Basin are degrading at an alarming rate due to multiple factors such as agriculture, extractives, infrastructure development and climate change (NBI 2020). Peatland extraction on an industrial scale is ongoing in Rwanda and Burundi (See § 3.4.2.4. Peat Extraction). These damaged lands are losing carbon, flora, and fauna. Their destruction is harming livelihoods through the disruption of critical ecosystem services. However, there are still largely intact peatlands in Africa such as the Sudd and the Cuvette Central peatland complex (Cole *et al*. 2022). For the Cuvette Centrale peatland complex, several initiatives are announced or planned associated with logging, oil and gas exploration, dam building and infrastructure development (Dargie *et al*. 2019).

Peatland degradation has been reported for all countries. In 13 countries, it is observed that approximately 50% of the peatlands have been degraded (Fig. 3.8). Greenhouse gas emissions from degraded peatland are estimated at just over 130 Mt CO_2e per year, with ten countries alone being responsible for 59% of those emissions (Fig. 3.9).

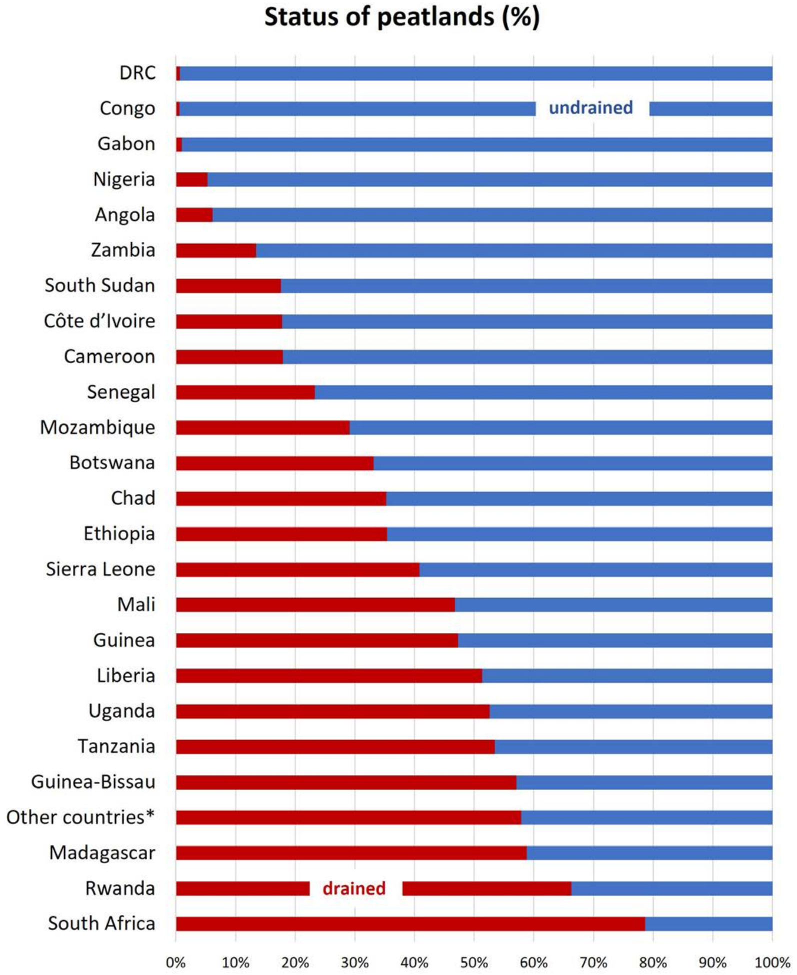


*Figure 3.8. Proportion of drained (red) and undrained (blue) peatlands in Africa per country (partly including organic soils). Calculations are based on the drained area for forestry, agriculture and peat extraction. *Sum of African countries with less than 100,000 hectares of peatland area.*

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

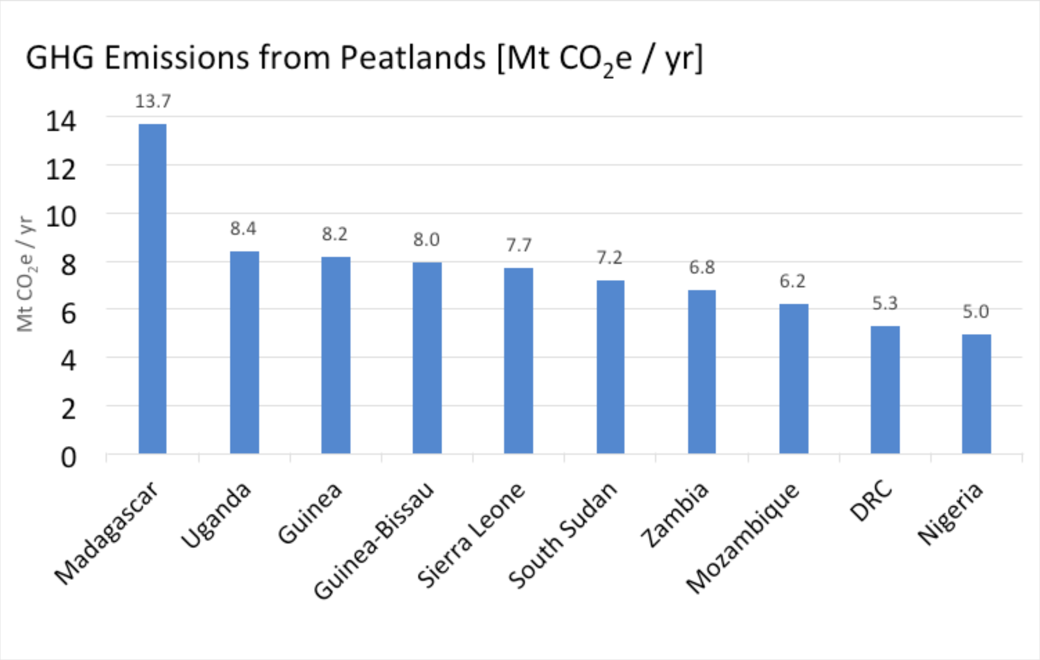


Figure 3.9. Top 10 countries emitting GHG from peatlands in Africa, representing 59% of total peatlands emissions in the region. Calculations are based on the peatland drained area for forestry, agriculture and peat extraction and IPCC (2014) emission factors including CO_2, CH_4, N_2O, DOC, and emissions from ditches. Includes only net, on-site GHG emissions. Wildfire emissions are not included.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

3.4.2. Drivers of Change

Drivers of change include, but are not limited to, agriculture and commercial logging, peat extraction, water extraction and urbanization. Key drivers vary by subregion. Agriculture is the largest driver for peatland conversion and drainage, such as rice and potato production in Uganda (Elshehawi *et al.* 2019a; Farmer *et al*. 2022). In Kenya, sugar cane is grown in peatlands like the Yala Swamp near Lake Victoria (Maua *et al*. 2022).

Peatlands in Africa have been reported to be altered through peat extraction, burning, housing construction and other infrastructure development, deforestation and drainage for agriculture, grazing, fishing ponds, and tourism (Namaalwa *et al*. 2013; Hakizimana *et al*. 2016; Langan *et al*. 2019). In many rural communities, women and girls are tasked with collecting water and fuel for domestic use. When peatlands are drained and degraded, water sources are increasingly threatened and so women and girls may need to walk further jeopardising their personal safety and reducing the amount of time that might be invested in pursuing economic activities or education (UNEP and IUCN 2018).

Despite conservation efforts, both forested and non-forested peatlands in South Africa are suffering continuous degradation. In 2006, a target was set to protect all South Africa's forested peatlands (Mucina and Rutherford 2006). This target was not met as only 47 % of remaining forested peatlands in South Africa could be classified as natural by 2019 (Van Deventer *et al.* 2021). Large parts of the Maputaland Coastal Plain have been included in the iSimangaliso Wetland Park, a National Park, Wetland of International Importance and World Heritage Site in South Africa. In a red list assessment of the subtropical-temperate coastal forested wetlands as an ecosystem, these forested wetlands have been assessed as critically endangered, with a total collapse possible within the next fifty years (Van Deventer *et al*. 2021).

3.4.2.1. Agriculture and Forestry

Van Deventer *et al.* (2021) showed that 53 % of the areal extent of subtropical-temperate coastal forested wetlands are included in iSimangaliso Wetland Park (South Africa), but that transformation to subsistence crop production occurred both inside and outside the park boundaries. In Kenya, sugar cane is grown in the peatlands fringing Lake Victoria such as the Yala Swamp (Maua *et al*. 2022). Conversion to various types of land use from Rwanda, Tanzania and Uganda is shown in Fig. 3.10. For instance, increasing rice cultivation is a severe threat, because of the change of the traditional low-intensity and peat-conserving use of mainly papyrus in the peat-filled valleys, to a high intensity and peat degrading crop.

The peatlands of South Africa are highly affected by exotic timber plantations in their vicinity, which causes a draw-down of the water table and makes the land more accessible. This makes it easier for people to access and transform this land for crop production.

Figure 3.10 Examples of land use of peatlands in the Nile Basin: a-c) road construction; d, e) developing rice fields from papyrus swamps; f) fish pond; g) freshly burned papyrus; h) burned papyrus and peat; i) peat extraction; j, l) cropland on former Raphia palm stand; k) grazing; m) multiple times burned peat; n) abandoned land with mineralised peat and dense weed cover; o) domestic transport and bird watching and tourism.

Source: Elshehawi et al. 2019a.

3.4.2.2. Burning Peatlands

As a result of water removal through drainage, extraction of water or other impacts to their hydrology, for example through road construction, peatlands become prone to fire, also in Africa. Abandoned, drained peatlands used e.g., for fishing or hunting have an especially high risk of burning (FAO 2014). Clearing the land during droughts further increases the risk of desiccated peatlands to burn (Gabriel *et al*. 2017). In the Nile Basin, prolonged drier periods likely lead to the burning of peat (image 'm' in the Fig. 3.10) that was previously drained for cultivation.

It is estimated that almost a third of the substrate of non-forested peatlands on the Maputaland Coastal Plain that has been affected by fires, have been lost in the past 30 years (Grundling *et al*. 2021), where an upsurge in the number, frequency and duration of peat fires has taken place (Fig. 3.11).

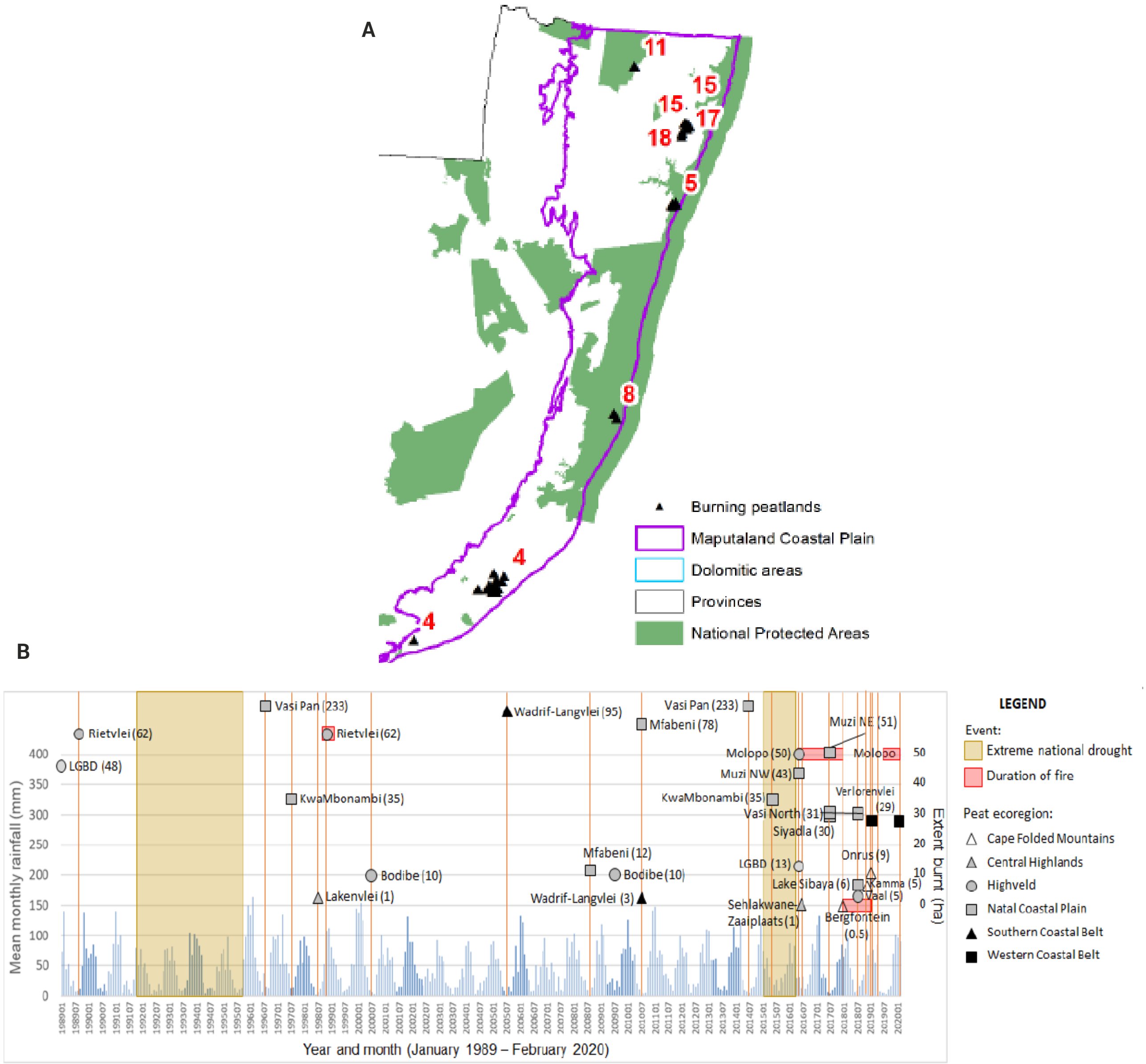


Figure 3.11 (a) Location of peatland fires on the Maputaland Coastal Plain of South Africa. (b) Peatland fires (plotted per peat ecoregion) in South Africa as a whole and mean monthly rainfall for the period January 1989 to February 2020. The areal extents (hectares) of the fires are shown in brackets. The extreme decadal droughts which affected >25 % of the areal extent of South Africa (Malherbe et al. 2016) are also shown.

Source: Figure adjusted from Grundling et al. 2021.

3.4.2.3. Greenhouse Gas Emissions

Land use is expanding throughout most of the deepest peatlands of the Nile Basin and resulting in very high GHG emissions (Elshehawi *et al*. 2019) (See Fig. 3.12). In Uganda the drainage of peatlands, which cover less than 25% of all the wetlands in Uganda, have been leading to GHG emissions of about 8 Mt CO_2e annually since 2015 and are expected to continue doing so until 2035 in a business-as-usual scenario (Fig. 3.12). Potato cultivation in the deep peatlands of the Kigezi highlands in southwest Uganda is widespread (See Fig. 3.4) and can provide income of up to $3,000 ± 1,000 US Dollars per hectare per year to farmers (Langan *et al.* 2018). Yet, this potato cultivation is causing huge carbon losses that are estimated at 98.79 ± 1.7 t CO_2e per hectare per year (Farmer *et al*. in press). Such emissions equal about 10% of the total annual national emissions of Uganda (Elshehawi *et al*. 2019a) equating to more than 50% of the national consumption of fossil fuels and cement (see Fig. 2.14 in Chapter 2) (Joosten 2009).

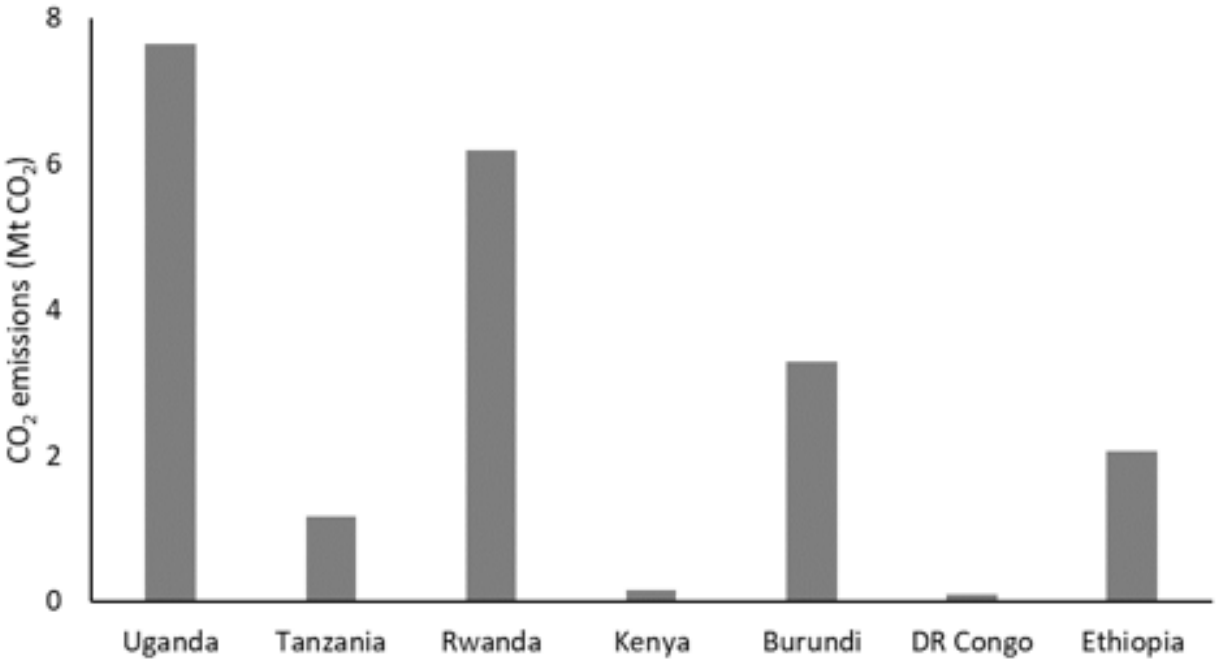


Figure 3.12 Average annual CO_2e emissions from drained peatlands within various Nile Basin countries in a business-as-usual scenario for the period 2015-2050. Note: Countries outside the Nile Basin are not included. Additionally, information for South Sudan, Sudan, and Egypt is currently unavailable.

Source: Elshehawi et al. 2019a.

Box 3.2. A Quaking Peatland – the Ondiri Bog in Kikuyu, Kenya

Ondiri bog is Kenya's largest known highland quaking bog, estimated at 30 hectares, with a perimeter of 3.3 km (Fig. 3.13) (Macharia *et al*. 2010; Mwangi *et al*. 2018). The peatland is the source of the Nairobi River that drains into the Athi River Basin and eventually into the Indian Ocean (Ogondo 2008; Njuguna *et al*. 2017).

In the past, the local people had named it 'kahenia' meaning 'shining body of water' (Mwenda 2016). The Maasai and Kikuyu people would come and graze their livestock around the peatland. For the past two decades, the peatland's fertility and rapid urbanization of its environs attracted investors to initiate unregulated agricultural practices around it, due to its lack of formal protection status (Macharia *et al*. 2010; Karangi 2017). This led to its continuous degradation particularly from pollution, water abstraction, infrastructure development, encroachment, overgrazing and planting of non-native *Eucalyptus* trees on its riparian reserve (Mwangi *et al*. 2018; National Environment Management Authority [NEMA] 2022).

Figure 3.13 Ondiri peatland, Kenya. Photo: Eva Ntara/@FAO 2021.

To mitigate the environmental challenges facing the wetland, a community-based organization of like-minded individuals called "The Friends of Ondiri Wetland Kenya (FOWK)" was formed in 2016 by David Wakogy. The aim of the organization was to promote public participation in the conservation and eco-tourism initiatives of the peatland (Macharia *et al*. 2010).

Since its establishment, various groups have partnered with the FOWK to preserve the Ondiri ecosystem and the benefits it provides (NEMA 2022). Some of the joint work done includes: the construction of a 3.7km perimeter fence around the peatland, the construction of a Wetland Information Centre that serves as a repository for information on wetlands countrywide, the development of a nature-trail and an eco-toilet to encourage eco-tourism activities such as bird watching at the swamp, establishment of the Kikuyu Organic Farmers Market through a training program for local farmers around the peatland on organic farming, and planting of native tree species (*Olea africana*, meru oak, vetiva grass, bamboo, croton trees, etc.) and the painting of an environmentally themed art mural near the peatland to create community awareness on the importance of conserving the wetland.

Figure 3.14. Peat-powered electricity plant in Gisagara, Rwanda. Photo: Hans Joosten

3.4.2.4. Peat Extraction

Peat extraction at industrial scale in Africa is currently only known from Burundi and Rwanda (Elshehawi *et al*. 2019a). Peat extraction was once conducted in South Africa, mainly for horticulture, but was stopped in 2011. The problem is likely only going to get worse as the Government of Rwanda has built and is operating an 80 MW peat power plant to produce electricity from peat extracted from the South Akanyaru peatland in Gisagara in its Southern Province (Fig. 3.14).

3.4.2.5. Water supply and Urbanization

One example of extraction of water from peatlands for urban water supply comes from the Molopo Eye (a spring) in South Africa, where water was diverted for urban water supply to the city of Mafikeng. When this water was diverted, the peatland downstream of the spring dried out and eventually burned. The peat was lost, and along with it, all its ecosystem services. This resulted in dangerous levels of air pollution locally, as well as the loss of cultural ecosystem benefits like fishing, boating and swimming (Rebelo *et al*. 2019).

Urbanization is another driver of change and recorded in various places. For example, urbanization and road infrastructure expansion are some of the main causes of peatland degradation in Uganda. Urban landscape expansion around Kampala has led to widespread eutrophication, due to waste-water disposal in the swamps. Also, many roads lead to drainage of the swamps due to a lack of accounting of the special nature of peat soils in the construction plans (Elshehawi *et al*. 2019a). Water transfer schemes servicing cities might also impact on the hydrology of wetlands with higher base flows and increased storm flows from hardened surfaces resulting in erosion of peatlands.

3.4.2.6. Climate change

Ongoing changes in the climate are another driver expected to cause significant changes in peatland condition in the longer term, especially when human impact is combined with changes in rainfall and temperature (Cook *et al*. 2020; Cole *et al*. 2022). Some evidence of increasingly longer dry seasons in the Central Congo Basin in the last forty years shows that an increase in peatland fires could be expected (Cook *et al*. 2020; Cole *et al*. 2022). On Fig. 3.15, the global distribution of peatlands in arid and subarid climates can be seen, with increased heat and aridity in North Africa.

At the same time an increase in aridity can also decrease the accumulation of peat, which in the future can lead to a reduction of the carbon sink capacity of the region (Cole *et al*. 2022). These climatic conditions, if combined with an increase in land-use threats (such as deforestation), have the potential to make peatlands much less resilient and progressively more vulnerable to future changes (Roucoux *et al*. 2017; Page *et al*. 2022). It is good to note that conservation and maintaining peatlands wet supports their resilience to changes.

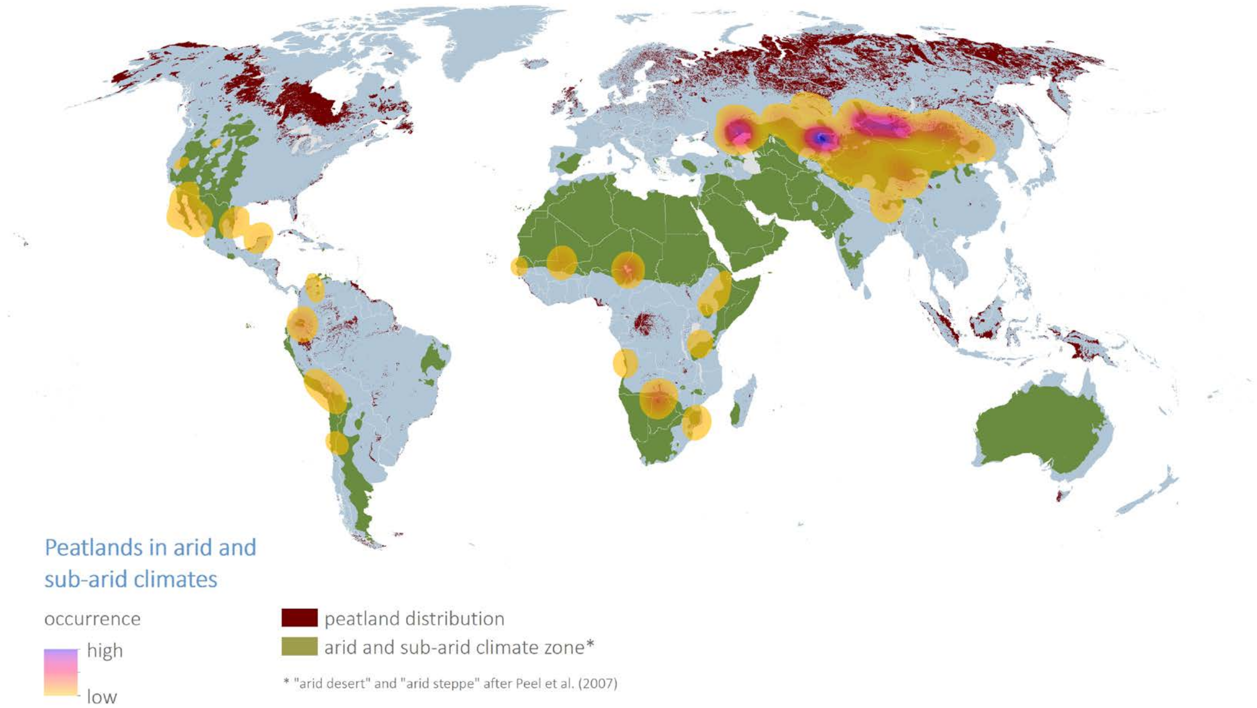


Figure 3.15 Global distribution of peatlands in arid and subarid climates.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III.3 Production of Thematic Maps.

3.5. Policy Context, Options for Action and Hotspots of Response

This section presents hotspots of response in specific regions. Responses reflect either best management practices on the ground or collaborative and participative processes leading to a better protection of peatlands.

3.5.1. Policy Context

Policies for the conservation, restoration or sustainable management of peatlands across Africa are limited partly due to limited awareness of the location, extent and condition of peatlands in the region. So, while most African countries have wetland policies, the majority make no specific reference to peatlands. This is notable since 51 countries in Africa have ratified the Convention on Wetlands providing an important policy framework for the sustainable and non-destructive use of wetlands. This has led to the designation of Wetlands of International Importance at national and transboundary levels but details on peatlands are not included. The total number of Wetlands of International Importance in Africa stands at 422 sites (according to www.ramsar.org, as of July 2022), many of which contain substantial areas of peatlands. Assessments of peatlands have only been undertaken in a limited number of these Ramsar sites.

A resolution reporting effort for UNEA, Convention on Wetlands and IUCN in 2019 attempted to identify peatland policies and strategies in six countries with significant peatland resources, carbon stocks and/or emissions (Uganda, Congo, DRC, Sudan, Zambia, Angola). This review only received information for the Congo and DRC (detailed below), with additional information being supplied by Lesotho (which had water resources policies and a wetland strategy under development) and South Africa (described below) (Reed *et al*. 2019). Similarly, The Nile Basin Initiative (NBI) has supported the inclusion of wetlands (including peatland) in the Eastern African policy frameworks, however, a deeper analysis on the results cannot be covered at the time of writing. In general terms, further analysis is needed on the policy context in the continent, i.e., on laws, regulations, procedures, administrative actions, incentives, or voluntary practice of governments and other institutions.

The inclusion of peatlands into climate commitments, such as the NDCs as well as the long-term low GHG emission development strategies (LTSs) will enable African countries to respond to the global climate action call (UNFCCC 2021; Global Peatlands Initiative [GPI] 2022). Several African countries have included peatlands in their NDCs, including Uganda, DRC and Congo (for more information on policies, see Chapter 9).

There are a number of new policies, strategies and plans under development for the Congo basin. These aim to promote ongoing mapping and monitoring of peatlands (cf. Barthelmes and Joosten 2018), stop peatland drainage, avoid conversion and destruction of intact peatlands, secure the livelihoods of local communities that live in and around peatland ecosystems, create an enabling environment for obtaining climate finance and restore and sustainably manage degraded peatlands. Regional policy initiatives related to the conservation and sustainable management of Central Congo Basin peatlands include:

- The Brazzaville Declaration
- The Central Africa Forest Initiative (CAFI) and the DRC-CAFI Letter of Intent 2021-2031
- The Lake Tele-Lake Tumba memorandum of understanding
- The memorandum of understanding between the Congo and Indonesia.

The Brazzaville Declaration is an international transboundary agreement signed by the governments of the Congo, the DRC and Indonesia during the 3rd meeting of the GPI in May 2018. The Declaration commits the key peatland countries to work together through South-South Cooperation and with support of the Global Peatlands Initiative to protect the Cuvette Centrale Congo Basin peatlands from future drainage and providing greater protection from unregulated agriculture, oil and gas mining and logging concessions (UNEP 2018). After signing the Brazzaville Declaration, in order to encourage its implementation, Indonesia, the Republic of the Congo, and the Democratic Republic of the Congo came together to declare their support and establish the International Tropical Peatlands Center (ITPC). During its launch, the GPI partner countries signed MoUs and inter-institutional agreements, committing to work together on peatlands globally and encouraging the implementation of the Brazzaville Declaration, showing the effectiveness of South-South and Triangular Cooperation by building regional and global impact through collaboration.

3.5.1.1. Democratic Republic of the Congo

The DRC has a number of forest policies which have a strong bearing on its peatlands. This includes its National Forestry Policy, Reducing Emissions from Deforestation and Forest Degradation (REDD) National Plan, its REDD National Strategy, the National Development Plan, the National Land Use Scheme and the Land Law Reform. The DRC's REDD National Strategy was adopted by the Council of Ministers in 2018 and explicitly considers forests in the Congo basin to contribute to their protection. The strategy includes undertaking an inventory of important areas of peatlands and forests to provide information on carbon stocks, their emissions and their wider environmental benefits. This policy builds on a network of parks and reserves covering more than 12% of the country's forests, many of which are on peatlands.

In the Global Peatlands Pavilion at the COP26 UN Climate Change Conference, the ministerial representatives from DRC particularly highlighted that DRC is in the process of developing a national peatland strategy (GPI 2022). The DRC is also developing a readiness project that will support peatland management in the country through the development of sustainable peatland plans and policies. Furthermore, the DRC has included peatlands in its NDC.

To inform policy making, several studies are underway in the field to improve knowledge of these tropical peatlands. In addition to the attention given to peatlands in northern Congo, important sites in the south of the country are receiving attention from local authorities. The goal is to arrive at a national definition of peat and elucidate its implications at the national level.

The national Peatland Management Unit has consulted interested people for the national vision on peatlands, has set a road map forward, and is, at the time of writing, planning a national peatland strategy, starting with consultations with peatland communities.

3.5.1.2. Republic of the Congo

The Republic of the Congo has paid particular attention to peatlands in the central Grande Cuvette basin since they were first mapped (Dargie *et al*. 2017). Before this, peat was included in the mining code of the country. In 2018 (March 21-23), to demonstrate its commitment, the Republic of Congo co-hosted the Third meeting of the Global Peatlands Initiative members together with the DRC and UNEP. Indonesia shared their lessons on peatland management which supported the countries to formulate and sign the Brazzaville Declaration (UNEP 2018). The political commitment of the Congo continued with the signing of the Central African Forest Initiative (CAFI) letter of intent between Presidents Sassou Nguesso and Emmanuel Macron of France. This letter emphasizes the need to properly manage and conserve areas of high ecological importance and high carbon potential.

The Congo briefly mentions peatlands in its NDC (2021), however it has not set goals for improved mapping and inventory nor other activities which could support further resource mobilization for setting e.g., measurable goals for adaptation or mitigation (FAO 2022). The country is aiming to attract private finance through initiatives such as the Blue Fund that could facilitate the protection and sustainable management of wetlands in general, and peatlands specifically. The Congo has 5 wetland resource centres, known as "wetland relay poles", with one dedicated specifically to peatlands, and managed by the Federation of Conservatories of Natural Spaces.

3.5.1.3. South Africa

South Africa has a reasonably supportive policy framework, but enforcement remains a major issue as mandates pertaining to the legislation discussed below are fragmented. The mandated authority for peatland management is the Department of Forestry, Fisheries and the Environment. In the past three decades peatland conservation was expanded with the enforcement of wetland related provisions in (1) the Conservation of Agriculture Resources Act (No 43 of 1983) (CARA); (2) the National Environmental Management Act (No 107 of 1998) with related Environmental Impact Assessment policy (especially Listing Notice 2 Activity 24, a peat focused intervention); and (3) Water Use Licence Authorisations (WULA) into regulations 21 c) and i) of the National Water Act (No 36 of 1998).
This regulatory framework has resulted in: (1) limited granting of commercial wetland cultivation authorisations, with Environmental Impact Assessments (EIAs) and WULA regulations enforced on peatlands, resulting in a decrease development and dams being built in peatlands, or upstream, (2) no granting of peat extraction authorisations, and (3) a decrease in afforestation and mining authorisations in peatland areas.

The intervention effort through legislation, policy and enforcement in South Africa is critical, as peatlands are part of catchments and cannot be managed in isolation (Grundling and Grundling 2019). A further positive development pertaining to wetland management in the country was the recent formulation in 2021 of a national wetland policy for the three national departments mandated to manage wetlands in terms of the three pieces of legislation listed above.

In southern Africa two wetland restoration programmes aim to protect water sources: Within the ambit of the South African Expanded Public Works Programme the Working for Wetlands and Working for Water programmes (within the Department of Forestry, Fisheries and the Environment) are actively involved in wetland restoration. Working for Water targets control of alien invasive species in wetlands and catchments, whilst Working for Wetlands pursues wetland restoration and wise use in a manner that maximises employment creation, supports small emerging businesses, and transfers skills to its beneficiaries with particular emphasis on women, youth and people with disabilities. About 40 % of the programme’s wetland restoration projects are taking place in peatlands and catchments of peatlands controlling erosion and rewetting peatlands.

In the Kingdom of Lesotho, the Departments of Environment and Range Resources Management play a leading role in controlling invasive alien species in the catchments of wetlands. Meanwhile, the Ministry of Water is responsible for planning the rehabilitation of wetlands, and the Department of Soil Conservation focuses on rehabilitating degraded land. The Protection of the Orange-Senqu River Water Sources ('Sponges' Project) for example focused on the application of a holistic approach towards the protection and conservation of mires in the upper Orange-Senqu River Catchment, while demonstrating a methodological approach for sustainable wetland management.

Box 3.3. Nile Basin Initiative (NBI)

The area of peatlands and organic soils in the Nile Basin represents about 10% of the total tropical peatland carbon stock (NBI 2022). However, Nile Basin peatlands are under increasing land use threats. These include draining, burning and clearing for agriculture and settlements, the arrival of invasive species, the extraction of peat for energy and drainage for infrastructure and plantation forestry. The Nile Basin Initiative (NBI) was born as a response to tackle these challenges. The NBI is an intergovernmental partnership between Burundi, DRC, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania and Uganda (Eritrea participates as an observer). Established in 1999, it provides a forum for consultation and coordination among the Basin States for the sustainable management and development of the shared Nile Basin water and related resources. Work is being done to map the extent and status of peatlands, quantifying their carbon storage, and on transboundary management plans and shared options for sustainable livelihoods for the communities that rely on them. The Nile Basin Initiative promotes socioeconomic development as well as gender equality and equity at the local, regional, and international levels. This is in line with the Paris Agreement and the SDGs and remains a crucial ingredient for sustainable development.

3.5.2. Options for Action

On the basis of the challenges and opportunities reviewed in this chapter, there are a number of options for policy and practice that could be considered to help protect, restore and sustainably manage African peatlands:

- At the political level, disseminate the findings from this assessment and future research to sensitize decision makers to the state of peatlands in their jurisdiction, the value of ecosystem services (and cost of losing these services) and options for protecting, restoring and sustainably managing their peatlands.
- As academia, continue to train young researchers, build capacities for practitioners and fund research across African peatlands to fill gaps in knowledge around the extent and condition of peatlands, the carbon stocks and other ecosystem services they provide.
- Mobilize funds to improve peatland monitoring to provide information to policy-makers about important changes and their implications for climate, people, and the planet.
- Engage local women and men and indigenous communities in the preservation and sustainable management of peatlands across Africa, drawing on local knowledge and social innovation to sustain livelihoods alongside the preservation and management of intact and restored peatlands. Promoting gender-responsive approaches is crucial for a just transition that takes into account the needs of everyone in society.
- Create an Africa group of specialist peatland researchers to create and enact a research agenda to better understand drivers of change, degradation processes and identify appropriate options to conserve, restore and sustainably manage these habitats.

3.5.3. Hotspots of Response

This chapter does not include information on responses across Africa due to the unavailability of comprehensive data. Acknowledging this limitation, this assessment serves as a call to all actors to contribute their knowledge and information. Building a collective repository of information and knowledge will support future decisions regarding peatlands.

3.6. Knowledge Gaps

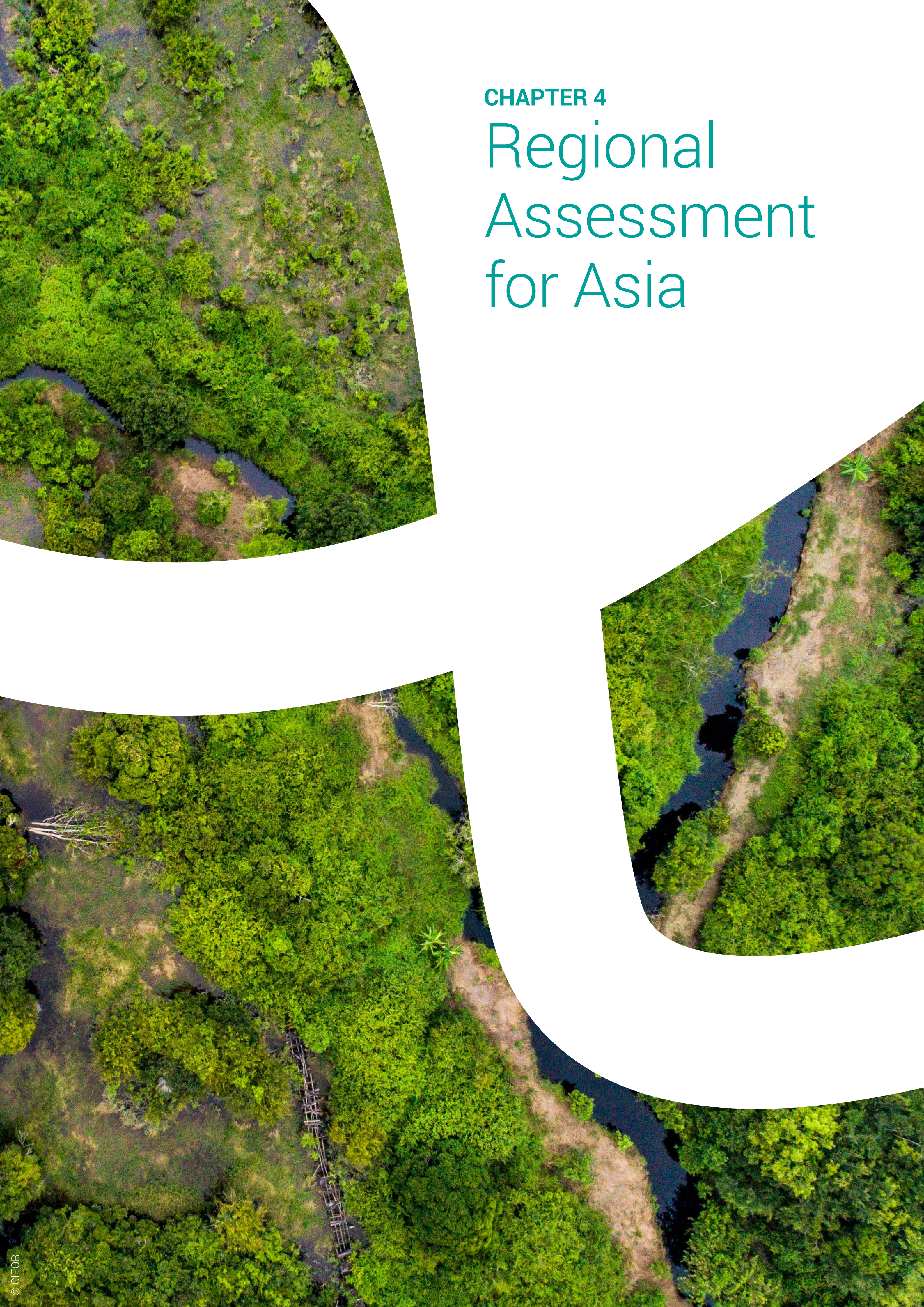
Peatlands in Africa are under-researched with policy peatland-specific plans in most countries absent and coherent wetland policies and legislation generally lacking. Despite this situation, some countries such as Nile Basin Countries, DRC, Congo and South Africa are working to fill these gaps and improve understanding of peatland distribution, key ecosystem services and drivers of change. Partners are working together to develop policies and management plans at site, national and regional levels. As such, more research is needed to better assess how local communities, mostly those living in rural areas, use and value peatlands today (as a source of bushmeat and other foods, fuel, and medicinal plants) where future threats may emerge (Dargie *et al*. 2019; Cole *et al*. 2022).

One study suggests that peatland areas may be larger than typically reported, including large peatland systems such as (1) the Niger River Delta; (2) the Sudd in South Sudan; (3) the Cuvette Centrale; (4) the central Angolan highlands and connected lowland riverine systems; and (5) the Zambezi basin peatlands (Gumbricht *et al.* 2017). However, no field data is included in the study. Peatlands of Western Africa are some of the least researched on the continent with very few research papers available on these peatland areas or their carbon stocks.

3.6.1. Regional Initiatives bridging knowledge gaps

The National Geographic Okavango Wilderness Project (NGOWP) has identified extensive peatlands in the Angolan Highlands in south-western Africa, which are the only water source for the Okavango Delta (Conradie *et al*. 2016; Goyder *et al*. 2018). Despite the highland peatlands' hydrological and ecological significance, they had remained poorly studied. The NGOWP has undertaken the most widespread scientific research in the highlands over the last decade with a vision to preserve the greater Okavango Basin in its current near-pristine state by establishing a network of new protected areas (National Geographic Society [NGS] 2022). Field-based studies are currently underway to provide more information on the peatland and peat characteristics.

The Nile Basin Initiative (NBI) is a transnational River Basin Organization (RBO) that offers an exemplary case study on RBO engagement on peatlands conservation in north-eastern Africa (see also Box 3.3. above). The NBI focus on peatlands ecosystems is anchored in a 10-year strategy (2017-2027) on environmental sustainability that calls for actions to protect, restore and promote sustainable use of water-related ecosystems across the basin, including peatlands. The NBI undertook specific studies to understand peatland extent, content and associated land-use changes. They also worked to raise awareness and explore the ways in which peatland analyses can be better integrated into climate policy making (Elshehawi *et al*. 2019). In the frame of the NBI, management plans and Conservation Investment Plans (CIPs) have been developed for the Sio-Siteko, Sango-Bay-Minziro and Semliki Transboundary Wetlands. The economic valuation studies included peatlands ecosystems in Sio-Siteko (Kenya and Uganda), Rweru-Bugesera (Burundi and Rwanda), Machar Marshes (South Sudan), Sudd Wetlands (South Sudan) and Lower Baro Wetlands (South Sudan and Ethiopia) for Green Infrastructure Planning and the development of Wetland Conservation Investment Plans.



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CHAPTER 4

Regional Assessment for Asia

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Regional Highlights

Key Facts

KEY REGIONAL DATA PRODUCED FOR THE GLOBAL PEATLANDS ASSESSMENT 2022[1]	
Total peatland area (hectares)	161,030,209 ha
Peatland cover over total region surface area (%)	3.7%
Degraded peatlands (%)	13.0%
Annual GHG emissions from peatlands (Megatons of carbon dioxide equivalent emissions per year)	1,020.9 Mt CO_2e / yr
Undegraded peatlands (%)	87.0%
Peatlands within protected areas (%)	10.3%
Top 5 Countries with largest peatland area (hectares)	1. Asian Russia (118,500,000 ha) 2. Indonesia (20,949,000 ha) 3. China (12,885,443 ha) 4. Mongolia (2,700,000 ha) 5. Malaysia (2,530,100 ha)
ADDITIONAL DATA	
Total peatland carbon stock[2] (Megatons of carbon)	182,417 Mt C
Threatened peatland species[3] (VU = vulnerable; EN = endangered; CR = critically endangered)	Flora: 20 VU, 25 EN, 13 CR Fauna: 135 VU, 144 EN, 56 CR
Ramsar Wetlands of International Importance with peat[4]	71 sites (18.2% of total Ramsar sites in Asia)

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[1] Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

[2] Joosten, H. (2009). The Global Peatland CO_2 Picture. Peatland status and drainage associated emissions in all countries of the World. Wetlands International, Ede, 10 p. + tables.

[3] Data extracted from the IUCN Red List of Threatened Species.

[4] Data extracted from the Ramsar Sites Information Service.

Asian peatlands are under threat, and a source of significant GHG emissions. It is estimated by the Global Peatlands Assessment that around 15% of Asia's peatlands are degraded. Drivers of change are exacerbated by climate change, and include overgrazing by livestock in Central Asia, permafrost thawing in Northern Asia, conversion for agriculture and plantations in Northeast China, and illegal logging, drainage for plantations and wildfires in Southeast Asia, a region that lost more than half of its peat swamp forests between 1990-2010. As examples, Indonesia reported average annual emissions of 513.4 Mt CO_2e per year from peat decomposition and fires, and Malaysia reported 28.6 Mt CO_2e per year in carbon losses from drained organic soils. However, few other countries in the region include peatlands as a key category of emissions in their National Communications to the UNFCCC.

Rewetting of managed peatlands for paludiculture with wetland species may be particularly pertinent in this region, given its potential to facilitate more sustainable use of degraded and carbon-rich peatland ecosystems. In addition to providing relatively immediate greenhouse gas mitigation, paludiculture may help sustain livelihoods for local populations, providing a socially acceptable pathway to achieve the goal of carbon neutrality on large land areas.

Subregional and transboundary agreements to tackle peatland haze are vital and provide a good example for coordination mechanisms that could help scale up impact also in other regions. The Association of Southeast Asian Nations (ASEAN) Agreement on Transboundary Haze Pollution signed in 2002 is a commitment of 10 country members to work together to monitor and tackle the problem of Haze Pollution in the sub-region. Collaboration on implementing the agreement has enabled countries affected by the degradation of peatlands to work together to reduce haze and GHG emissions.

Countries in the Southeast Asian region in particular have strong lessons to share for other tropical peatland countries. For example, Indonesia has pioneered a number of South–South collaboration initiatives, including the International Tropical Peatlands Centre's facilitation of the implementation of the Brazzaville Declaration. There is a need to further document and share lessons from policy and practice to help other tropical peatland countries, as they weigh up the importance of peatlands in the development of their development trajectories.

Only a small fraction of Asian peatlands falls within protected areas (10.3% according to the data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre). Asian governments have started recognizing their importance in recent years and enacted various laws and policies supporting peatland conservation outside of protected areas. Despite the large opportunity to restore degraded peatland areas and growing political will to do so, the extent of peatland restoration in the region is still relatively small. It has been reported that Asia's peatlands cover an area of 162 million hectares (Xu *et al*. 2018). Of those, 15% are degraded, 5% are protected and less than 5% have been restored (Dinerstein *et al*. 2017).

With such a wide latitudinal span, the fauna of Asian peatland is diverse with some highly charismatic species, like the Bornean Orangutan (*Pongo pygmaeus*) and the Sumatran Tiger (*Panthera tigris* ssp. *sumatrae*) (Cheyne *et al.* 2008; Wich *et al.* 2008; Quinten *et al.* 2010; Erb *et al*. 2018). Many of these species are classified as critically endangered on the IUCN Red List.

With a significant proportion of Asian peatlands degraded, research and capacity-building are needed to help scale-up peatland conservation and restoration efforts. If this were done, it would contribute towards the recovery of endangered species. Additionally, ensuring that both women and men are included in conservation and restoration activities drives progress towards achieving the SDGs. The under-representation of women should be addressed with specific efforts to overcome barriers and challenges that women face in peatlands-related fields.

4.1. Biomes and Ecological Zones

Spanning from tropical to polar, and from humid to arid regions, Asian peatlands are distributed in thirteen Global Ecological Zones (GEZ). These are summarized in Table 4.1.

Fig. 4.1 shows the distribution of Asian peatlands in aggregated FAO GEZ based on the Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. In the region, nearly half of peatlands (about 47%) are in the boreal ecological zone whereas 26% are located in the temperate zone.

Characteristics of peatlands in tropical zones are different from those of peatlands in temperate, boreal and polar zones. In tropical ecological zones, peat accumulation started earlier than in temperate and boreal zones and peat deposits are formed and maintained by continuous large litter inputs mainly from evergreen trees into water-saturated peat (Biancalani and Avagyan 2014).

Southeast Asian peatlands are mostly ombrogenous and thus poor in nutrients (Omar *et al*. 2022). The oldest reported initiation date for lowland ombrotrophic peat formation in Southeast Asia was around 26,000 years B.P. (Page *et al*. 2004). In general, however, the development of peat domes in the lowlands of Peninsular Malaysia, Sumatra and Borneo started with the onset of the Holocene as a response to rapid post-glacial sea-level rise over the Sunda Shelf and intensification of the Asian monsoon (Dommain *et al*. 2011).

Table 4.1 Distribution of peatlands in major peatland countries under respective Global Ecological Zones
Source: Global Ecological Zone: FAO (2012); Countries of peatland distribution: Global Peatland Map 2.0.

Global Ecological Zones	Countries of peatland distribution
Tropical rainforest	Bangladesh, Brunei Darussalam, India, Indonesia, Malaysia, Myanmar, Philippines, Sri Lanka, Thailand, Vietnam
Tropical moist forest	Bangladesh, Indonesia, Myanmar
Tropical dry forest	Cambodia
Tropical mountain system	Indonesia
Subtropical humid forest	China, Japan
Subtropical mountain system	China
Temperate continental forest	China, Japan
Temperate mountain system	China, Japan, Mongolia
Temperate steppe	Mongolia
Boreal coniferous forest	China, Russia
Boreal tundra woodland	Russia
Boreal mountain system	Russia
Polar	Russia

Peat accumulation results when the rate of organic matter deposition is higher than the decomposition rate and peat accumulation rates diverge with the general tendency of fast accumulation in coastal areas (Dommain *et al*. 2011; Takada *et al*. 2016). Dommain *et al*. (2011) estimated, for example, that mean rates of Holocene carbon accumulation in coastal Sumatra and Borneo were 77 g C m^{-2} per year, in contrast to 31.3 g C m^{-2} per year in inland Central Kalimantan.

In temperate and boreal biomes, the accumulation of peat is due to waterlogged conditions and peat forming mosses, sedges, dwarf shrubs and trees. Peat accumulation rates vary widely and are linked to the peatland's geographical location, age and type (Biancalani and Avagyan 2014). A mean long-term apparent carbon accumulation rate in Northeast China, for example, is reported as 33.66 g C m^{-2} per year while the average of the worldwide boreal peatlands is 18.6 g C m^{-2} per year (Yu *et al*. 2010; Xing *et al*. 2015). In the polar zone, cold conditions (permafrost) play an important role in peat formation (see § 2.2.).

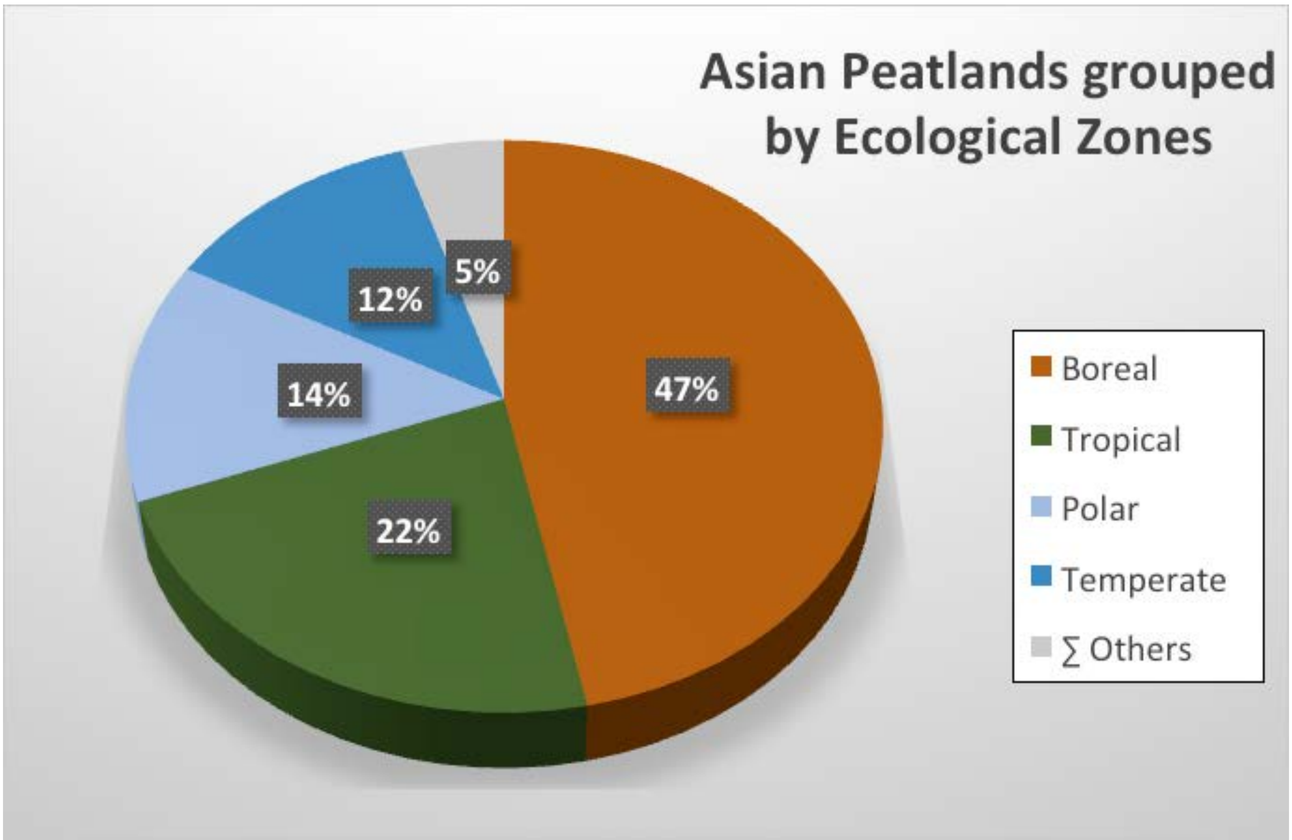


Figure 4.1 The distribution of Asian peatlands in aggregated FAO Global Ecological Zones.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

4.2. Peatland Distribution and Extent

As explained in Chapter 2, differing definitions and classifications combined with a range of approaches to estimate distribution and extent of peatlands has led to variations in the numbers. This is particularly true in Asia. The estimates of peatland area in Asia conducted by different groups are summarized in Table 4.2. Discrepancies among area estimates are due to inherent assumptions, varying peatland definitions, spatial scales and mapping biases. Also, the timing of the estimates affects the extent, especially for countries where degraded peat layers have been depleted, reducing the total area.

Through the Global Peatlands Assessment process and its Global Peatland Map 2.0, the distribution and extent of peatland in the Asian region are summarized in Figs. 4.2 and 4.3. Based on the data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre, peatlands in the region cover an area of 161 million hectares, representing 33% of global peatlands.

Table 4.2 Comparison between peatland areas (hectares) estimation from six global, tropical and subtropical databases. Source: Global Ecological Zone: FAO 2012; Countries of peatland distribution: Global Peatland Map 2.0.

Country	**Global Peatland Database (2022)**	**IMCG-GPD (Joosten 2009)**	**Page *et al.* (2010)**	**HWSD v1.2 (FAO 2012)**	**Gumbricht *et al.* (2017)**	**PEATMAP (Xu *et al.* 2018)**
Asian Russia	118,500,000	117,628,000	N/A	87,970,000	N/A	118,035,800
Indonesia	20,949,000	26,550,000	20,695,000	19,400,800	22,452,222	14,833,100
China	12,885,443	3,349,900	N/A	523,800	8,392,857	13,696,300
Others	4,765,666	4,374,600	N/A	73,680	24,738,277	13,513,200
Malaysia	2,530,100	2,668,500	2,588,900	2,148,000	2,952,318	2,239,800
Kazakhstan	1,000,000					
India	400,000					
Total	**161,030,209**	**154,571,000**	**N/A**	**117,410,600**	**58,535,674**	**162,318,200**

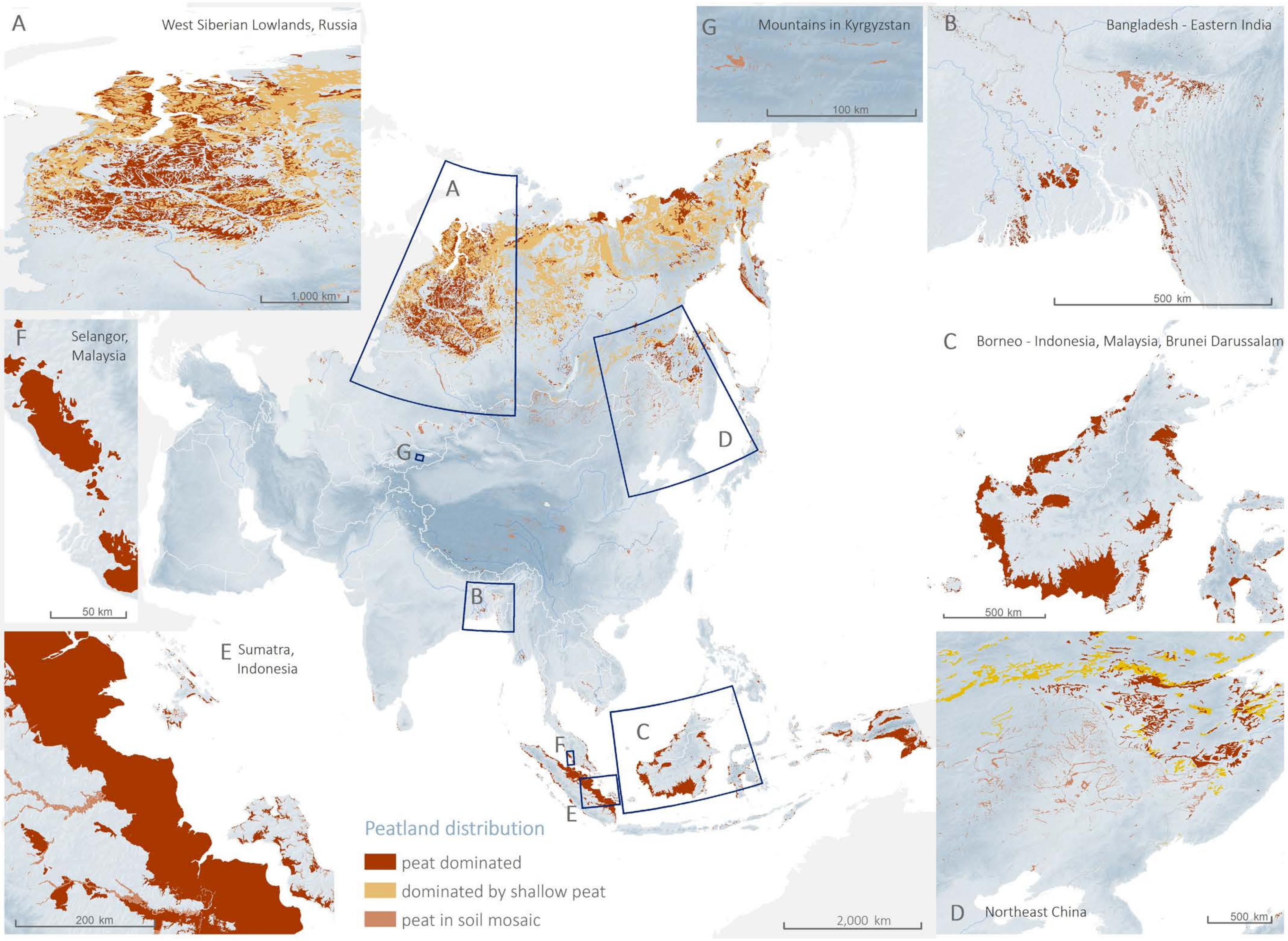
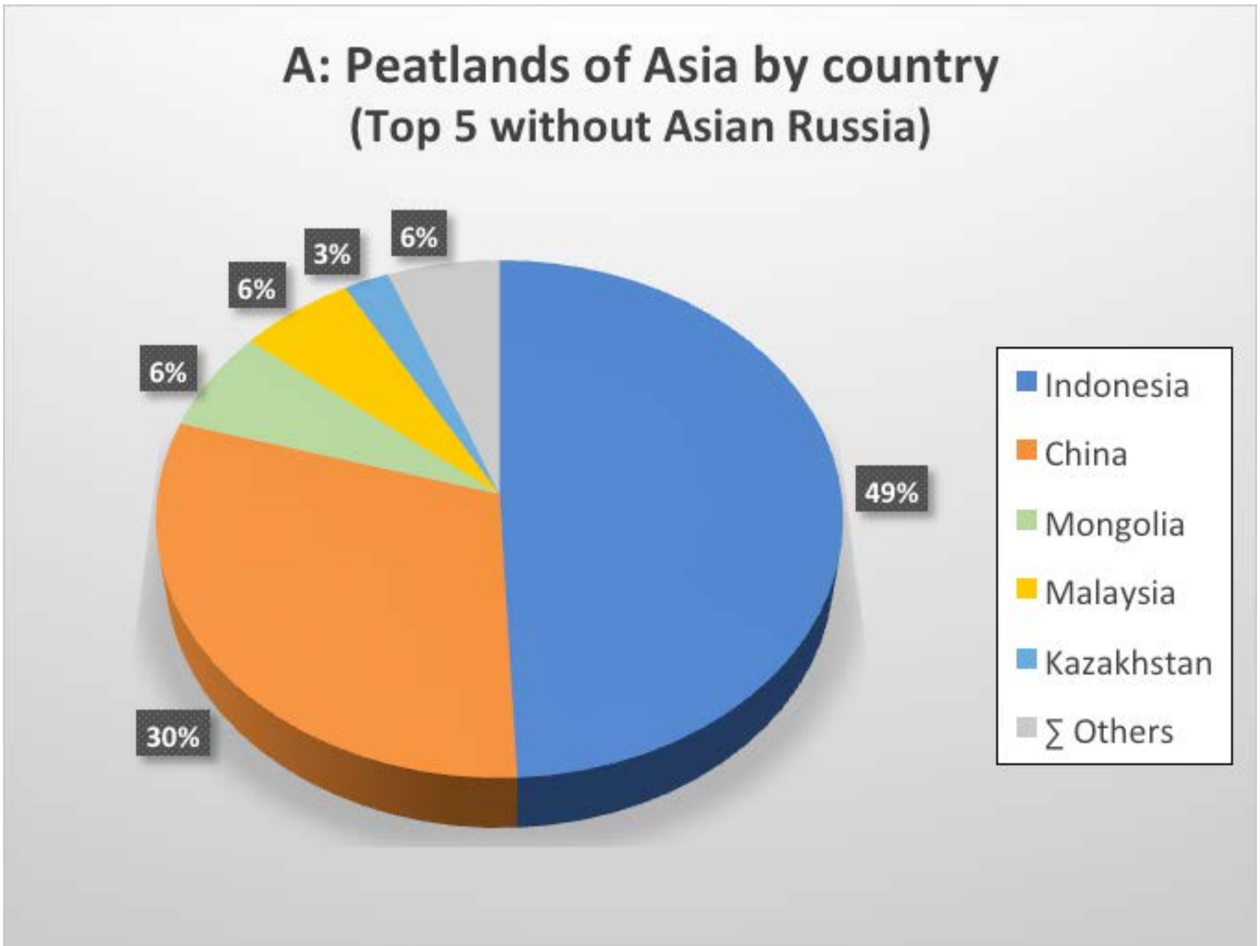


Figure 4.2. Peatland distribution in Asia (partly incl. organic soils).

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III. Production of the Global Peatland Map 2.0.



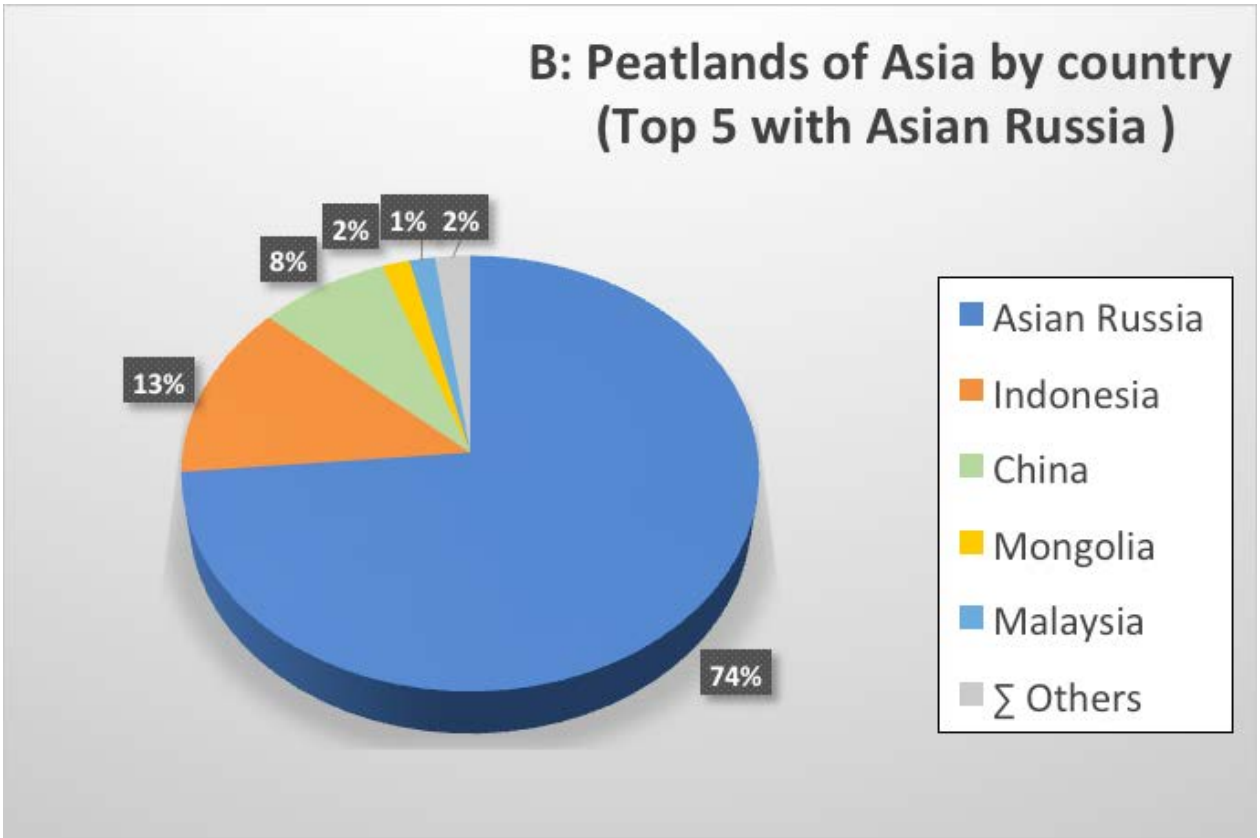


Figure 4.3. (A) Top-5 countries/group of countries holding the largest area of peatlands in Asia (without Asian part of Russia) and (B) Top-5 countries holding the largest area of peatlands in Asia.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

4.3. Biodiversity, Nature's Contributions to People and Hotspots of Value

4.3.1. Biodiversity

Peatlands in the region support rich biodiversity. In Southeast Asia, tropical peat swamp forests and associated marshes are the most common natural peatland ecosystems (Prentice 2011). Tropical peat swamp forests, home to at least 1,524 plant species and an extensive number of bryophyte, fern and fungal species, are the most extensive in Southeast Asia. They have the highest floral diversity globally when compared with other peatland ecosystems (Posa *et al*. 2011; Rieley 2016). This diverse flora maintains a substantial percentage of the fauna recorded in the region (Posa *et al*. 2011), including 123 mammals, 268 birds, and 219 freshwater fish species alongside an unreported number of invertebrates (Rieley 2016). As an example, peat swamp habitats are responsible for supporting 23% to 32% of all species of mammals and birds in Peninsular Malaysia and Borneo (Posa *et al*. 2011). Blackwater fish communities including endemic species, which are not found in other types of habitats, are also supported by these ecosystems (Prentice 2011).

Table 4.3 Species that are globally threatened (either vulnerable, endangered or critically endangered) found in Southeast Asian tropical peatlands.

Source: Prentice 2011.

Animal species	Orangutan (*Pongo pygmaeus*), Proboscis Monkey (*Nasalis larvatus*), Leopard (*Panthera pardus*), Tiger (*Panthera tigris*), Flat-headed Cat (*Prionailurus planiceps*), Otter Civet (*Cynogale bennettii*), Hairy-nosed Otter (*Lutra sumatrana*), Sumatran Rhinoceros (*Dicerorhinus sumatrensis*), Malayan Tapir (*Tapirus indicus*), Asian Elephant (*Elephas maximus*), Malayan False Gharial (*Tomistoma schlegelii*), Asiatic Softshell Turtle (*Amyda cartilaginea*), Painted Terrapin (*Callagur borneoensis*), Bornean River Turtle (*Orlitia borneensis*), Storms Stork (*Ciconia stormi*), Lesser Adjutant (*Leptoptilos javanicus*), Wrinkled Hornbill (*Aceros corrugatus*), White-winged Wood Duck (*Cairina scutulata*) and Asian Bonytongue (*Scleropages formosus*)
Plant species (trees)	*Shorea platycarpa, Dipterocarpus chartaceus, Hopea mengerawan, Shorea albida* and *Gonystylus bancanus*

Figure 4.4 Secondary tropical peat swamp forests, important habitats for Sumatran Elephants (Elephas maximus sumatrensis) which are critically endangered. Photo: Faizal Abdul Aziz/CIFOR.

4.3.2. Nature's Contributions to People

Even though they are small, covering just 3.7% of Asia's land surface area, peatlands make many contributions to people. Local communities living in and around peatlands are those who benefit the most. For example, an average of 104 people per km^2 live in or around peatlands in Indonesia, with small areas of peatlands in Sumatra and Kalimantan reporting more than 500 people per km^2 (Lilleskov *et al*. 2019), reflecting the importance of peatlands to local communities. However, peatlands in Asia are increasingly threatened by unsustainable land use changes, resulting in a decline in their contribution to human well-being.

To date, research on the contributions peatlands provide in the Asia region is disproportionately concentrated in Indonesia, contributing to the undervaluation and omission of peatland NCPs in other parts of the region. Improved knowledge and more holistic valuation of peatland NCPs in Asia can contribute to better awareness of peatland benefits and assessments of the impacts of different management policies.

4.3.2.1. Material Contributions (Including Provisioning Services)

Indigenous peoples and Local Communities (IPLCs) have long valued peatlands for the material resources that they supply. For example, peat swamp forests in Southeast Asia provide important habitats for freshwater fishes, the harvest of which constitutes a major protein source for local communities. Over 1,376 plant species have been identified in Southeast Asian peat swamp forests, ~39% of which are used for timber, medicine, food and other purposes (Giesen 2015), highlighting the high economic potential of native peat swamp products. These products have been a source of local women's economic empowerment especially where other livelihood options have not been available to them. For instance, in Indonesia, local women weaving and selling mats from purun, a sedge plant in peat swamps, has helped women to supplement their household income by catering for their family's needs as well as their own. Such empowerment has also improved women's position in household decision making (Goib *et al.* 2018).

These ecosystems produce valuable timber, such as meranti, and non-timber forest products, such as sago (*Metroxylon sagu*) and illipe nuts (*Shorea* spp.) (Fig. 4.5). However, technical and socioeconomic challenges, such as the lack of market and knowledge regarding the cultivation of native peat swamp forest species, preclude the widespread use of native peat swamp forest biomass. Instead, peat swamp forests in Southeast Asia are often cleared for monoculture oil palm, timber and pulpwood plantations (see § 4.4), and may be further used to cultivate rice and vegetables. More recently, efforts to reconcile biomass production and peatland conservation have created interest in paludiculture, the production and use of biomass on wet and rewetted peatlands (Fig. 4.5 and Box 4.1).

Similarly, in boreal and polar regions peatlands provide populations with berries, mushrooms, reindeer herding areas as well as fishing and hunting grounds (Joosten *et al*. 2012).

Box 4.1. Paludiculture in Indonesia

Multiple pilot studies in Indonesia are currently underway to investigate the feasibility and sustainability of paludiculture systems, including fish and other aquatic species' production. Scenario analyses comparing rattan (*Calamus rotang*), jelutung (*Dyera costulata*), and oil palm (*Elaeis guineensis*) monoculture production on peatlands in South Sumatra showed that while oil palm generated the highest benefits, these were negated by the social costs of peatland fires (Tarigan *et al*. 2021), let alone the high carbon emissions.

Analyses conducted in Central Kalimantan comparing timber, oil palm, rattan, and paddy rice production on peatlands yielded similar findings, where oil palm and paddy rice production incurred high carbon emission costs due to the drainage involved during land use conversion (Sumarga *et al*. 2015; 2016). With further work on value chains, the benefits of paludiculture production using native peatland species, may exceed those of oil palm (Sumarga *et al*. 2016). Further research on the gender dimension of oil palm and paddy rice production is required. So far, indications are that productive opportunities outside the home often tend to benefit men, further widening the gender gap.

Figure 4.5 (A) Trunks of mature Sago Palm (Metroxylon sagu) transported through the canal for milling the starch in Riau Province, Indonesia. (B) Peat moss paludiculture nearly cover all the landscape suitable for peat moss cultivation in Jiading Town, Guizhou Province, China.(C) Peat mosses in paludiculture being carried back for wind-drying at the backyard in Jiading Town, Guizhou Province, China.

Photos: A - Daniel Murdiyarso; B, C - Zhao-Jun Bu

4.3.2.2. Non-material Contributions (Including Cultural Services)

Traditionally, IPLCs living in and around peatlands have depended on the ecosystem for their livelihoods. Many of these communities developed place-based knowledge (i.e., traditional or local ecological knowledge) and beliefs about peatlands (Box 4.2), which regulate and inform community use of peatland resources. The loss of peatlands represents a gradual erosion of traditional/local ecological knowledge and cultural identities, which is often accompanied by the unsustainable exploitation of peatland resources.

4.3.2.3. Regulating Contributions (Including Regulating Services)

Peatlands are globally significant terrestrial carbon reservoirs that play a key role in climate change mitigation by storing tremendous amounts of organic carbon in vegetation and waterlogged soils (Hergoualc'h and Verchot 2011; Warren *et al*. 2017; Ribeiro *et al*. 2021). One of the largest peat carbon pools in Asia is found in the boreal peatlands of Asian Russia, storing an estimated 20,100 Mt and 96,200 Mt as dead wood and soil carbon, respectively (Alexeyev *et al*. 2000). In comparison, Indonesia accounts for the largest area of tropical peatlands in Southeast Asia (see § 4.1) with estimates of belowground carbon in Indonesian peatlands ranging from 13,600 – 40,500 Mt of carbon (Warren *et al*. 2017).

Peatlands are also important archives of past environmental conditions. Analyses of peat cores can reveal insights on past vegetation changes, hydrological and climate conditions, and the impacts of human activities. Radiocarbon dating of peat cores extracted from peatlands in West Kalimantan, Indonesia, revealed varying rates of peat formation and carbon accumulation between inland and coastal regions throughout the Late Pleistocene and Holocene, respectively. Such findings further highlight the role of peatlands as major, and very old terrestrial carbon sinks (Ruwaimana *et al*. 2020).

Box 4.2. Dayak Communities on Peatlands in Central Kalimantan

Indigenous Dayak communities in the Sebangau peat swamp forest of Central Kalimantan, Indonesia, rely on peatland resources for subsistence. For example, fish catching constitutes a key source of protein and income for some communities (Thornton *et al*. 2020). The Dayak communities living in the area possess traditional ecological knowledge of their landscape, such as the locations, timing, and methods to maximize fish catch. Additionally, they have developed close cultural ties with peatlands, which govern their use of the resources.

Taboos ('pali') surrounding the types of fish to avoid consuming and offerings to spirits for fishing permission reflect the many ways that Dayak communities relate to and manage peatlands. However, rapid land use changes in the surrounding areas and the modernization of fishing technology pose challenges for indigenous communities, including women and girls, to continue managing peatlands in traditional ways that are compatible with the natural functions of peatlands.

When intact, domed peatlands are essentially hydrologically self-regulating, maintaining high water table level during drought seasons and preventing floods during the rainy seasons (Dommain *et al*. 2010; Evers *et al*. 2017; Lupascu *et al*. 2020). They retain and release waters into the surrounding landscape and aquifers. They are instrumental to maintaining the base flows of nearby rivers and streams (Hooijer 2005; Ishii *et al*. 2016). They are also important for regulating regional water quality and quantity (Xu *et al*. 2018). Hydrology also partially determines the rate of carbon accumulation or loss (i.e., in the form of peat oxidation and emissions) in peatlands. Impairments to the self-regulating functions of peatlands following land use conversion or fires can therefore exacerbate flood and drought risks (Evers *et al*. 2017; Lupascu *et al*. 2020).

In addition to carbon and hydrological regulations, pristine peatlands host a variety of highly specialized plant and fish species that are adapted to the acidic and low-nutrient environment (Posa *et al*. 2011; Giam *et al*. 2012; § 4.3.2). They are also important refuges for threatened species, such as orangutans and tigers (Posa *et al*. 2011; Giam *et al*. 2012; Husson *et al*. 2018). The conservation of rare and endangered species is crucial for supporting other ecosystem services that support food security and ecotourism.

4.3.3. Hotspots of Value

Not all peatlands of the region are studied with similar detail. The list below contains a few examples, and reflects the knowledge and experience of the writers to this chapter.

4.3.3.1. Northeast China

Northeast China holds the largest peatland area in the country (8,287,000 hectares, Xing *et al*. 2015). Northeast China peatlands are mainly distributed in the mountain regions of Great Hinggan, Small Hinggan and Changbai Mountains from northwest to southeast, as seen in Fig. 4.6, the mountain peatlands distribution map by elevation. Although most of the peatlands originated and developed in the Holocene, peat depth and peatland age tend to increase from northwest to southeast. In the Changbai Mountains, the maximum peat depth is 9.6 m with a basal age of 13,685 yrs B.P. (Zhang *et al*. 2019). The peatlands in Northeast China play an important carbon sink role with a total carbon stock of ~ 4,340 Mt (Yu *et al*. 2010; Xing *et al.* 2015). Peatlands in Northeast China not only play key ecological functions but also provide important socio-economic resources. The people in the peatland region regularly pick wild fruit and collect natural vegetables every summer. *Vaccinium uliginosum, V. vitis-ideae, Lonicera caerulea, Osmunda cinnamomea* and *Pteridium aquilinum* plants provide indispensable economic benefits for the rural community residents (Lang 1999).

4.3.3.2. Southeast Asia

Traditionally, peatlands were perceived as marginal lands from a production standpoint. Application of the NCP framework enables the valuation of both material and non-material contributions and an improved assessment of trade-offs and co-benefits under different peatland uses. Identification of valuable NCPs can thus also contribute towards the conservation of peatlands.

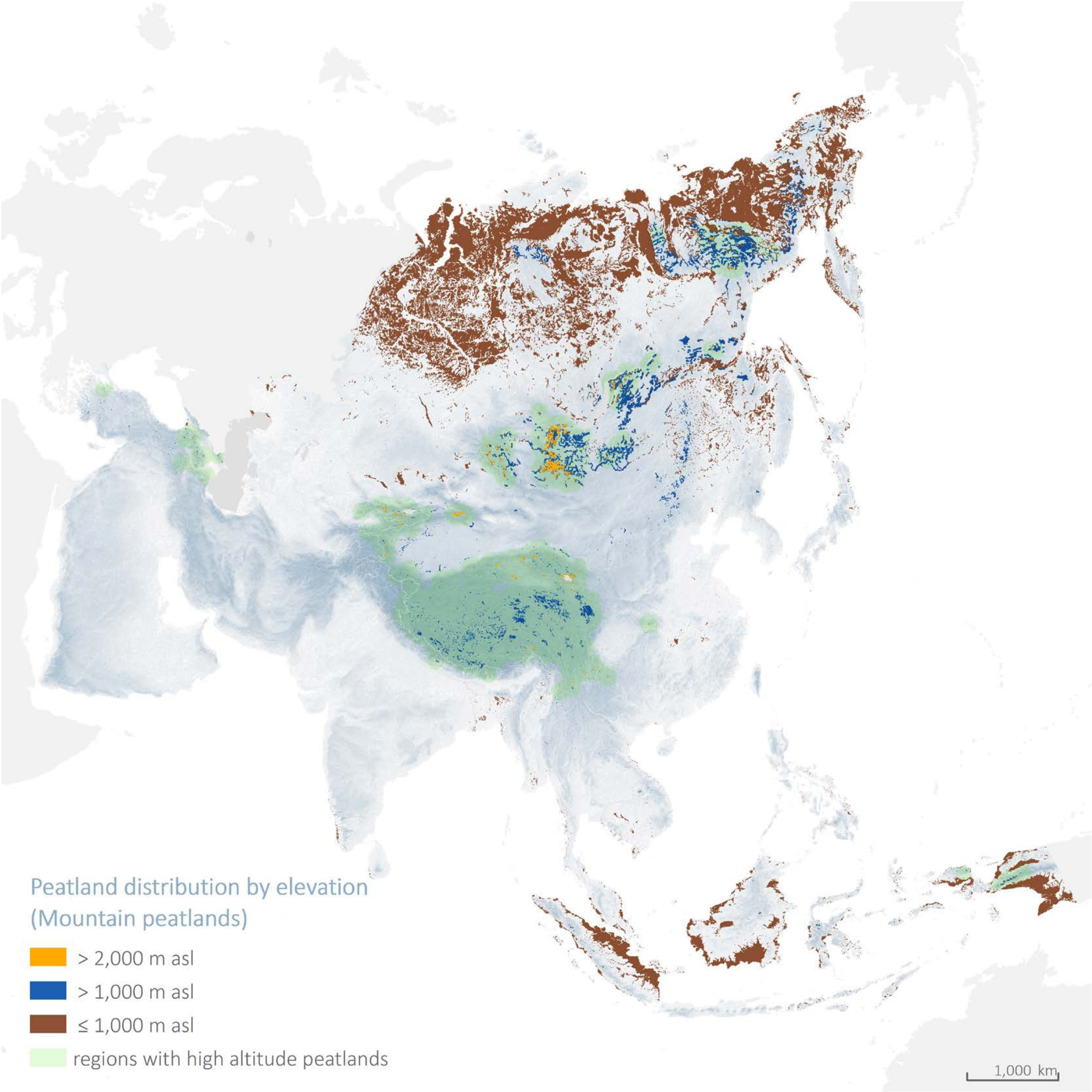


Figure 4.6. Distribution of Asian Mountain peatlands by elevation (in meters above sea level).

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III.3 Production of Thematic Maps.

Across the region, peatlands are conserved within the boundaries of at least 26 protected areas located in Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand, and Vietnam (Association of Southeast Asian Nations [ASEAN] 2021). Though the estimated area of peatlands within protected areas represents only a small fraction (4.4%) of the total peatland extent in Southeast Asia (ASEAN 2021), these conserved peatlands store massive amounts of carbon in their biomass and peat soils and provide critical habitat for rare and endangered species, hosting significant biodiversity. For example, more than 50 new peatland fish species have been identified, including the smallest vertebrate in the world (*Paedocypris*), which lives in the peat swamp forests of Sumatra, Indonesia and Malaysia (ASEAN 2021). Many rare and endemic plant species have also been recorded in peatlands in the region, such as the Caimpugan peat swamp forest in Philippines (ASEAN 2021). Within existing protected areas, peatlands have been newly documented in Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, and Thailand. Unique peatland ecosystems in the region have been documented for the first time in the last decade, including calcareous mound spring peatlands in Myanmar and mangrove peatlands in Cambodia.

Sites of importance for the conservation of peatland biodiversity have been identified, but relatively few new protected areas have been designated. Given the large areas of high carbon stocks combined with high conservation values found in peatlands, Indonesia should continue to promote the protection of conservation areas. Examples include the Wetlands of International Importance, National Parks, such as the Berbak-Sembilang National Parks in Sumatra (3,819,837 hectares) with their water birds, Sebangau and Tanjung Puting National Parks (983,700 hectares) in Kalimantan with their Orangutan, and Wasur National Park (413,800 hectares), dubbed as the Serengeti of Papua. Avoiding deforestation and drainage will not only protect the habitat of wildlife but also prevent emissions of GHGs, provide resilience against climate change and support sustainable development for local communities. Wetlands of these conservation areas may store carbon by as much as 1,200-1,300 tons per hectare (Murdiyarso *et al*. 2010; Murdiyarso *et al*. 2015) depending on the peat depth.

4.3.3.3. South Asia

Peatlands in South Asia extend from coastal areas surrounding the Bay of Bengal and the Arabian and the Laccadive Sea to the foothills of the Himalayas in Bangladesh, India, Pakistan and Sri Lanka (Khan and Arshad 2014; Ratnayake 2020; Paul *et al*. 2022). In Bangladesh, peat soils are seasonally flooded, often not drained or partially drained, very dark greyish brown to black organic soil (Huq and Shoaib 2013). Peat soils occur in the low-lying areas of the Gopalganj-Khulna region (Rahman and Khan 2022). These soils include alternate layers of peat and muck, with sometimes peat and mineral layer at the top of the profile (Masud *et al*. 2011). Peat resources in the Gopalganj-Khulna region have been seen as a potential source of energy (Rahman and Khan 2022).

In South-West India, the high rainfall and massive floods coupled with a rising sea level during the Middle Holocene must have inundated large areas of coastal lowlands and river basins and converted forest ecosystem into peatland with accumulation of peat almost to 2.0—3.0 m thickness (Kumaran *et al*. 2016). This is one of the youngest tropical peatlands which has operated as long term carbon sink. In the North-Eastern states of India, peat deposits are prominent in areas of elevated and domeshaped lands and shallow basins and peat thickness is reportedly reaching to 4-10 meters (Paul *et al*. 2022). Bangladesh peat has also been seen as a possible source of energy.

4.4. Status of Peatlands, Drivers of Change and Hotspots of Change

4.4.1 Status of Peatlands

It is estimated by the Global Peatlands Assessment that around 13% of Asia's peatlands are degraded. Fig. 4.7 shows the proportion of drained and undrained peatlands in Asia per country (partly including organic soils), based on the data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. More than 80% of peatlands in North Korea, India, and Bangladesh have been drained for forestry, agriculture or peat extraction.

Greenhouse gas emissions from degraded peatland are estimated at close to 1,021 Mt CO_2e per year. Fig. 4.8 shows the annual GHG emissions from organic soils drained for forestry, agriculture and peat extraction in key Asian countries. For example, Indonesia is responsible for GHG emissions of nearly 668 Mt CO_2e per year, followed by China, whose drained organic soils are responsible for GHG emissions of approximately 230 Mt CO_2e per year. The two countries contribute to 80% of the total GHG annual emissions in the region from organic soils drained for forestry, agriculture and peat extraction.

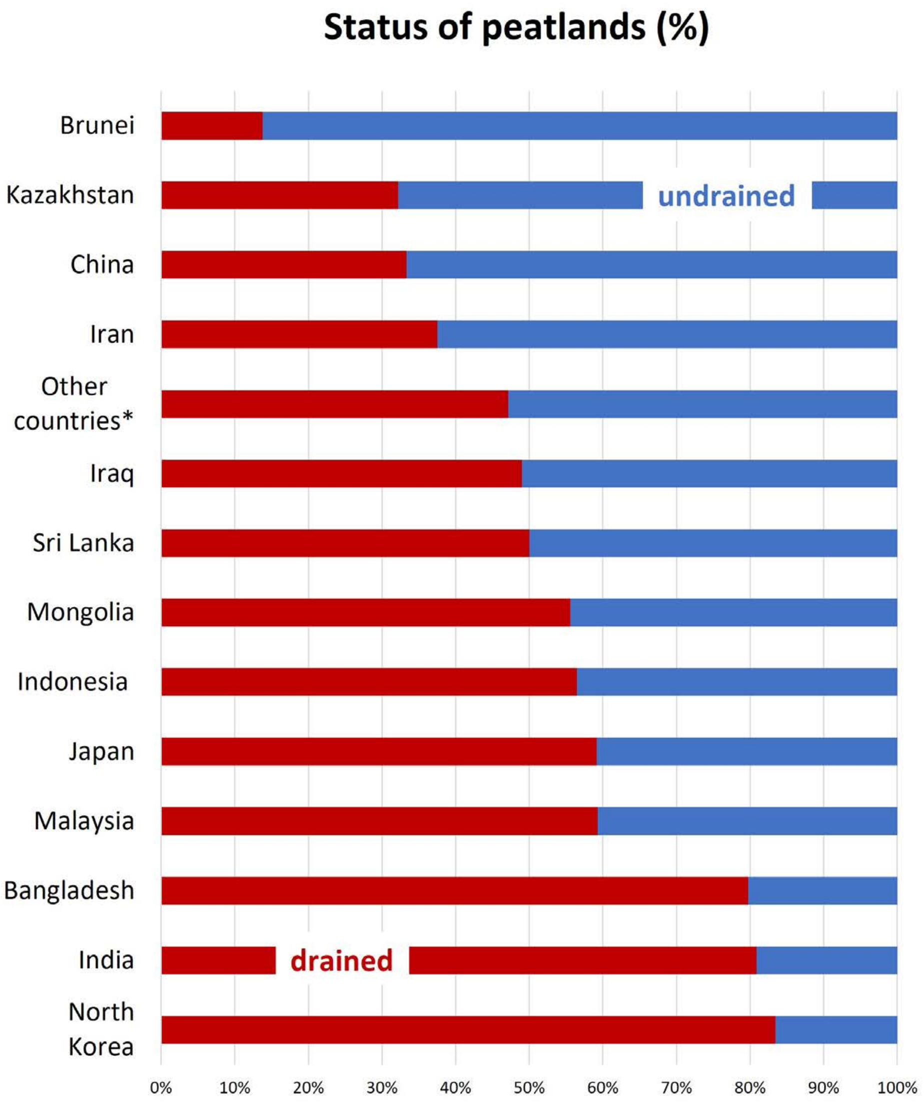


*Figure 4.7. Proportion of drained (red) and undrained (blue) peatlands in Asia per country (partly including organic soils). Calculations are based on the drained area for forestry, agriculture and peat extraction. *Sum of Asian countries with less than 100,000 hectares of peatland area.*

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

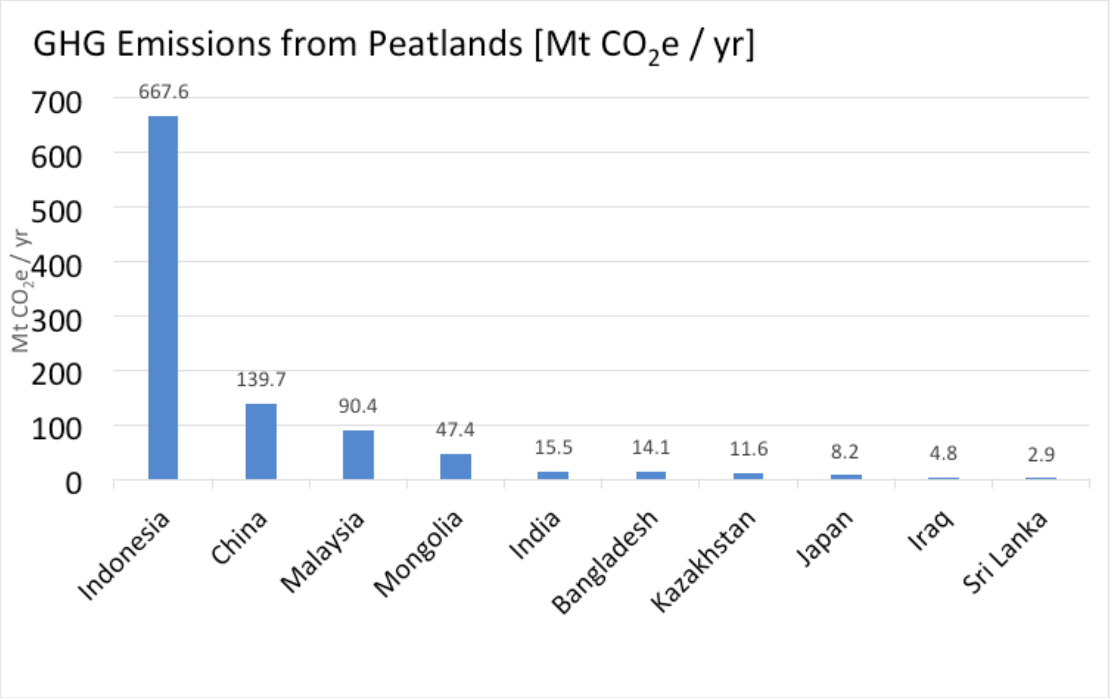


Figure 4.8. Top 10 countries emitting GHG from peatlands in Asia, representing 98% of total peatlands emissions in the region. Calculations are based on the peatland drained area for forestry, agriculture and peat extraction and IPCC (2014) emission factors including CO_2, CH_4, N_2O, DOC, and emissions from ditches. Includes only net, on-site GHG emissions. Wildfire emissions are not included.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

4.4.1.1. Southeast Asia

Southeast Asian peatlands have historically been used by humans for slash-and-burn agriculture, logging, grazing, cut-and-carry practices, harvest of non-timber forest products and fishing, causing small-scale disturbances (Anshari *et al*. 2004; Yulianto *et al*. 2005; Cole *et al*. 2015; Hapsari *et al*. 2018). However, in the past 30 years, Southeast Asian peatlands have undergone dramatic changes with large areas being converted into plantations or agriculture or degraded by intensive logging, drainage and fire (ASEAN 2021). Managed land-uses in converted peatlands are dominated by industrial and smallholder oil palm and pulpwood plantations (Koh *et al*. 2011; Miettinen *et al*. 2012; Miettinen *et al*. 2016). The majority of remaining peat swamp forest cover has been affected by logging. A large proportion of peatlands are covered by open undeveloped areas and secondary regrowth (Miettinen *et al*. 2016), an intermediary stage between pristine peat swamp forest and managed land (Miettinen *et al*. 2012). The estimated area of peatlands included in protected areas is approximately 1.1 million hectares or about 4.4.% of the peatlands in the region (ASEAN 2021). Nevertheless, the protected areas also face challenges from illegal logging, encroachment and fire.

4.4.1.2. Northern Asia

In the heavily swamped regions of the Asian part of Russia, peatlands are changing indirectly due to the construction of roads and infrastructure for oil and gas production. In the southern part of the taiga zone in the Asian part of Russia (south of Western Siberia, in the Far East, e.g., Sakhalin) some peatlands have become an object of interest for drainage-based agriculture and forestry, and in places, driven by the local need for fuel or growing media, for peat extraction (Minayeva *et al*. 2009). In highland (forest-steppe and steppe) areas (Mongolia, Ruoergai Plateau in China etc.), use of mires for pasture is increasing while pasture productivity on mineral soils decreases because of a more arid climate.

4.4.2. Drivers of Change

4.4.2.1. Central Asia

The key threat to highland peatlands of Central Asia (Mongolia, Qinghai-Tibet Plateau of China, etc.) is overgrazing by livestock. This is rapidly increasing due to the growing numbers of animals and the decreasing productivity of pastures on mineral soils in the current warming and drying climate (Joosten *et al*. 2012).

4.4.2.2. Northern Asia

Throughout Northern Asia, peatlands are affected by climate change, especially at high latitudes. The remains of permafrost peatlands from previous colder paleoclimate epochs can be found up to the highlands of Mongolia and maritime northern Sakhalin. In the Asian part of Russia alone, permafrost peatlands occupy more than 20 million hectares (more than 13 million hectares are palsa, the rest are polygonal) and more than 50 million hectares are represented by shallow peatlands on permafrost (primarily tundra) (Vompersky *et al*. 2005).

Permafrost thawing is widespread from the Arctic to eastern Siberia and the uplands of Mongolia. When dry, peat serves as an insulator. When wet, it serves as a conductor of heat. Warming has an ambiguous effect on permafrost peatlands, such as polygonal and palsa mires, as well as shallow peat tundra. Human impact increases the vulnerability of peatlands. Roads and drainage change the water regime in tundra and taiga, overgrazing in steppe and forest steppe disturbs the vegetation cover that protects the peat from water and wind erosion and from permafrost thawing. Humans are responsible for most of the peat fires that occur in all natural areas where there are peatlands (Minayeva *et al*. 2013).

4.4.2.3. Northeast China

In Northeast China, especially the Changbai Mountains, rice and corn cultivation in peatlands has been widespread since the 1980s. A smaller area of peatlands was drained both for forestry and croplands since the 1960s in the Great Khingan Mountains (Chai 1990). Even in the Sanjiang Plain, where marsh is dominant, peatlands are still being developed in some waterlogged areas. Since the 1950s, nearly 270 million hectares of wetlands, including some peatlands, have been opened-up for rice, soybean and corn cultivation (Ma *et al*. 2015).

4.4.2.4. Southeast Asia

Logging, drainage and conversion to industrial plantations and agriculture and recurrent fires are the main direct drivers of peatland degradation in Southeast Asia (Fig. 4.9). Legal and illegal logging activities also contribute to peat swamp forest degradation and loss, through tree removal as well as the construction of logging roads and drainage canals (Franke *et al*. 2012). Infrastructure and housing development, oil production, peat mining, intensive agriculture, charcoal production and hunting also pose threats to peatlands in the region (ASEAN 2021). Conversion of peat swamp forest to industrial and small-scale plantations entails drainage of soils, land-clearing fires, drastic changes to vegetation cover and fertilizer application. All these activities dramatically increase GHG emissions (Yule 2010; Hergoualc'h and Verchot 2014).

The degradation and drainage of peatlands is commonly associated with heightened fire and flood risks, and results in potentially irreversible changes to the function of the ecosystem. One of the biggest threats to peatland hydrology is drainage using canals, leading to peat loss and subsidence.

Comparisons of peat subsidence between *Acacia* plantations and native peat swamp forests in Indonesia showed an average subsidence rate of 4.3 centimetres per year in plantations been drained with these effects extending into nearby forests (Evans *et al*. 2019). In areas near the coast, continual subsidence can lead to saltwater intrusion that results in the land being lost and or becoming unproductive.

Drained peatlands are more susceptible to fires. These fires are particularly serious when the region experiences dry climatic conditions (Field *et al*. 2016). Once a peatland is burned, it also burns easily again (Joosten *et al*. 2012). For example, the drainage and conversion of peat swamp forests in Southeast Asia to oil palm and *Acacia* plantations render the ecosystem susceptible to fires and promote the growth of non-woody vegetation conducive to repeated burning.

These direct drivers are themselves influenced by complex socio-economic, policy and climatic factors. Heavy reliance on natural resource extraction, drainage-based plantations and agriculture, e.g., attempts to cultivate rice on peat, combined with government policies permitting peatland use have played a role in the rapid conversion and degradation of peatland in Southeast Asia over the past three decades (Brockhaus *et al*. 2012; Lilleskov *et al*. 2019; Naylor *et al*. 2019).

Figure 4.9. Examples of disturbed peatlands in Southeast Asia. (A) Oil palm plantation on a tropical peatland in Sarawak, Malaysia. (B) Drainage canal in converted tropical peat swamp forests in South Sumatra, Indonesia.

Photos: A - Susan Page; B - Faizal Abdul Aziz

Table 4.4. Peat swamp forest cover and cover change (hectares) in Southeast Asia from 1990 to 2010. Numbers in brackets indicate percentage of loss in 2010 compared to 1990.

Source: Miettinen et al. 2012.

	1990	2000	2010	Change
Peninsular Malaysia	379,700	280,800	229,900	149,800 (39)
Borneo	4,926,100	3,636.900	2,746,500	2,179,600 (44)
Sumatra	4,921,600	3,078,500	1,806,900	3,114,700 (63)
Total	**10,227,400**	**6,996,200**	**4,783,300**	**5,444,100 (53)**

4.4.3. Hotspots of Change

Peat swamp forests in Southeast Asia have been subject to conversion for plantations, agriculture and infrastructure development. As shown in Table 4.4, the region has lost more than a half of its peat swamp forests during the period between 1990-2010. During the same period, the GHG emissions from peat swamp deforestation and degradation (including peat decomposition and fires) in Indonesia were reported to be as much as 650 Mt CO_2e (Indonesian Government 2016).

4.5. Policy Context, Options for Action and Hotspots of Response

The following section displays some recent examples of peatland related policies, actions and needs in the countries and within subregions.

4.5.1. Policy Context

In the People's Republic of China, the Wetland Managing Department of the National Forestry and Grassland Administration is responsible for managing peatlands and their services. Its major duties are to draft laws and regulations and departmental rules for wetland protection and management. The Department also formulates national and regional wetland protection policies and plans, organizes and implements wetland ecological restoration and ecological compensation, and supervises and guides the protection, development, and utilization of wetlands. It also organizes and carries out national wetland resource monitoring and evaluation, among other duties. In June 2022, China introduced the Wetland Protection Law stipulating that local governments shall formulate special protection plans for peatlands and take effective measures to protect peatlands. According to the law, local governments at or above the county level where peatlands are located must formulate special plans and take effective measures to protect peatlands. Peatlands with important ecological significance should be included in the list of national important wetlands. It is forbidden to mine peat, exploit underground water and discharge water stored in peatlands without authorization.

As an example of a regional-level framework, in Southeast Asia, the ASEAN Peatland Management Strategy (APMS) is guided by the ASEAN Agreement on Transboundary Haze Pollution (AATHP). ASEAN Member States are encouraged to develop respective National Action Plans on Peatlands (NAPP) with reference to the APMS as a guiding document for actions to support management of peatlands in the region. The APMS was prepared in response to the pressing need recognized by both local and international communities for wise use and sustainable management of peatlands as well as the threat of peatland fires and its associated haze to the economy and health of the region, and its contributions to GHG emissions and climate change. Six out of ten ASEAN Member States have National Action Plans (NAPP) - Brunei Darussalam, Indonesia, Malaysia, Philippines, Thailand and Vietnam - each at different levels of development and implementation. An ASEAN Task Force on Peatlands (ATFP) was established to oversee implementation of the NAPP and APMS by the ASEAN Member States for national level activities and at ASEAN level through regional cooperation.

4.5.1.1. Indonesian Example

The Indonesian peatland management has been regulated with a large number of laws and regulations, public policies, including regulations coming from different decision-making bodies, and with different levels of duration (see Fig. 4.10). As in all countries, policies are balancing between interests and needs. Harmonization and alignment of the policy framework so that it will lead to the achievement of the ambitious long-term climate goals, is an ongoing effort (Indonesian Government 2021).

On 20 May 2011, the government of Indonesia released Presidential Instruction (Inpres No. 10/2011) on ‘The postponement of issuance of new licences and improving governance of primary natural forest and peatland’. The instruction follows Indonesia’s cooperation under the Letter of Intent (LoI, from 2010) with the government of the Kingdom of Norway. The Inpres, which was later known as “Forest Moratorium”, effectively imposed a 2-year moratorium on new forest concession licences on primary forests and peatlands (Murdiyarso *et al*. 2011). After being renewed three times, a permanent moratorium was declared in 2019 with certain exceptions and based on a map (referred to as PIPPIB for its acronym in Bahasa Indonesia) that is updated every six months. While this is a step in the right direction, the decree has encountered difficulties due to a lack of law enforcement at the levels where most of these decisions occur, i.e., at the village, district, and provincial scales (Uda *et al*. 2017).

The reported effect of the Forest Moratorium was a significant reduction of primary forest loss of 856,000 hectares in 2012 to 667,000 hectares in 2015. Later, it was reported that the rate of forest loss has been declining from 2015 to 2018. Deforestation of 440,000 hectares was reported in 2018, slightly lower than the 2017 number of 480,000 hectares (Wijaya *et al*. 2019). Deforestation of 462,500 hectares took place in the period 2018–2019, plummeting to just 115,500 hectares in 2019–2020 period, i.e., dropping drastically by 75.03%. With such impressive reductions two years in a row, Indonesia seems to be moving in the right direction to achieve the forestry sector’s goals for the country’s Nationally Determined Contribution (NDC) stipulated in the Paris Climate Agreement. In its Long-Term Strategy (LTS) Indonesia aims to reach net zero emissions by 2030 in the forest and other land use sector, including peatlands (Indonesian Government 2021).

Immediately after the Paris COP-21 in December 2015, the President of the Republic of Indonesia released a Regulation (Perpres No. 1/2016) to restore 2.4 million hectares of degraded peatlands by establishing the Peatland Restoration Agency (known as BRG until the end of 2020). This is in line with a stronger Government Regulation (PP No. 57/2016) on Peatland protection and management released in the same year.

The tasks of the BRG were not completely accomplished when the regulation expired in 2020. As part of the lessons learned, the work on monitoring successful peatland restoration building on a baseline and including a consistent set of criteria and indicators was started with a delay, and its implementation carries on. The BRG's mandate was continued to restore 1.2 million hectares of degraded peatland in addition to rehabilitation of more than 600,000 hectares of mangroves. Subsequently, BRG was renamed as the Peatland and Mangrove Restoration Agency (BRGM) and legalized (Perpres No. 120/2020). These ambitious targets and policies, together with the improvement of the monitoring systems for forests, peatlands and fire risk, highlight the commitment of Indonesia to scale up peatland protection and restoration. Further refinement of peatland restoration, deepening the understanding of full rewetting and other capacity development combined with law enforcement will support Indonesia in the coming years with meeting its climate commitments.

Recognizing the hydrological connectivity of peatlands, the Indonesian Government has also legally defined Peatland Hydrological Units (PHU) as peatland areas that are bounded by at least two waterbodies and which would serve as the basis for peatland governance and management (Regulation No. 57/2016). Indonesia has made the choice that at least 30% of each PHU needs to be allocated for conservation. In a more recent regulation (Ministry of Environment and Forestry regulation no. 10/2019), where a PHU has >30% conservation areas and at least one peat dome peak, existing plantation operations are only allowed to continue until the end of their concession licenses (Tan *et al*. 2022).

4.5.1.2. Rest of Southeast Asia

Peatlands in **Thailand** are distributed mainly in the southern part of the country, in Nakhon Si Thammarat and Narathiwat Districts. Agricultural use of peatlands, which began in the late 1960s, was not successful, necessitating reclamation through government intervention. Three management zones were then established: a development zone (for specific uses), a conservation zone (for rehabilitation), and a protected zone (for climax peat swamp forests).

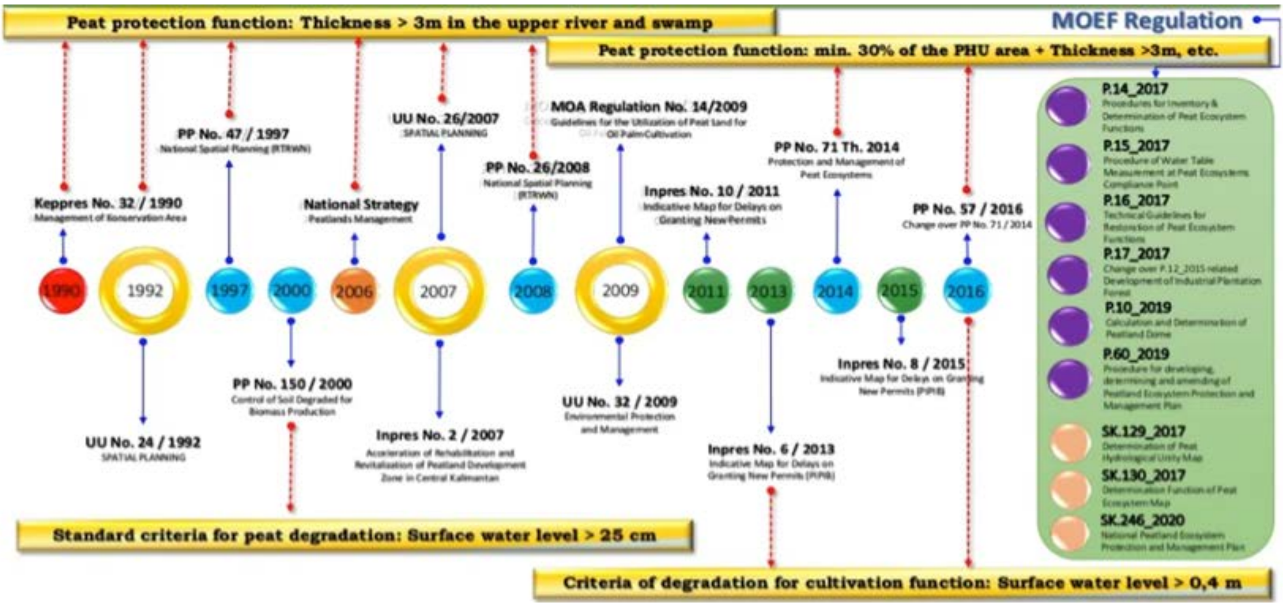


Figure 4.10. Three decades development of Indonesian peatland regulations for their protection and sustainable management. Source: Budisusanti 2022.

Narathiwat district, where the Princess Sirindhorn or Pru To Daeng Wildlife Sanctuary is located, has approximately 42,000 hectares of peatlands. A total of 48% of these peatlands have been designated as a protected zone (Vijarnsorn 2021) and are being managed by the Royal Forest Department and Department of National Park, Wildlife and Plant Conservation. The conservation zone was established for restoration and reforestation. The development zone occupies 39% of peatlands and is an area designated for drainage-based agriculture. However, cultivators that have tried to farm on peatland soils have had significant problems (Vijarnsorn 2021).

In **Vietnam**, the peatland area is very small and mostly located along the Mekong River Delta. U Minh peat swamps located in Kien Giang and Ca Mau provinces are the main remaining peatland with an area of 12,666 hectares (Le and Le 2021). Peat swamps in the U Minh region used to be more than 60,000 hectares but have decreased due to conversion for agriculture and peat mining. Some were also lost due to peat fires (Le and Le 2021). The government took conservation actions during the 1980s by establishing nature reserves for small patches of these peatlands. Nature reserves were then upgraded to national parks for 9,174 hectares of U Minh peat swamps during the 2000s, i.e., U Minh Thuong and U Minh Ha National Parks (Le and Le 2021). In order to prevent encroachment by local people into national park areas, the government introduced a community-based peat management approach called a “Green Contract” in buffer zone areas. Under the Green Contract, respective households are supported by public associations for the development of economic activities. Because of the Green Contract, the number of illegal peatland exploitation events has decreased significantly, and no human-caused forest fires have been reported since 2010 (Le and Le 2021).

In **Malaysia**, the government has been undertaking some initiatives to improve peatland management. These include developing and implementing the National Action Plan for Peatlands (NAPP), the National Policy on Biological Diversity 2016-2025, the National Physical Plan and the Malaysian Sustainable Palm Oil (MSPO) Certification Scheme. In addition, an Integrated Management Plan (IMP) and several site-specific Management Plans were developed and are being implemented.

In 2019, the **Lao People's Democratic Republic** was developing a wetland conservation framework in 2019-20 under a draft Wetland Decree to be included under the Water Law that includes peatlands (Reed *et al*. 2019). District and provincial authorities and local communities have been working on an action plan for two globally important wetland landscapes in Savannakhet and Champasak provinces. Protection and restoration of floodplains, wetlands, native fisheries and peatlands is being undertaken in an integrated manner by the government with international support and is designed to inform national policy. This work has also enabled the establishment of two Wetlands of International Importance. A peatland inventory is also underway and leads to the design of specific peatland-habitat management regimes in collaboration with local communities, including for example, artificial canal blocking and weir repair to rewet wetlands and extend lakebed flood periods. Measures are under development to encourage farmers to avoid intensive use of flood plains, lakes, wetlands and peatlands, in an effort to reduce flood losses and enable landscape restoration, management and sustainable use (Reed *et al*. 2019).

4.5.2. Options for Action

1. Advance with more detailed peatland mapping and assessment efforts to document current management and allow for holistic land-use planning.
2. Ensure that the needs and aspirations of local communities are reflected in land-use planning and decision-making, by concrete mechanisms in which they can take part of the process from the beginning. Ensuring that both local women and men are included as key stakeholders is crucial; as much as possible, specific efforts should be made to build women's capacity and to include them in leadership and decision-making roles.
3. Halt further conversion of peatlands through protection measures and investment.
4. Develop and scale up full rewetting of peatlands in restoration sites, combined with drainage-free livelihood options such as paludiculture, combined with harmonized and supportive policies and development of sustainable products and value chains.
5. Document and share knowledge and lessons learned globally on regional and south-south collaboration initiatives that have been successful (e.g., ASEAN joint work on haze and fire, Brazzaville Declaration to protect peatlands, GPI South South Exchanges, etc).
6. Look at including REDD+ as a tool to promote and complement other existing international frameworks to advance the conservation of peatlands in the region, while stressing the importance of transparency for accessing finance and capacity development.
7. Promote the transparency and clear criteria for the assessment of the results of peatland restoration and sustainable management such as GHG emission accounting, and peatland restoration success criteria.

4.5.3. Hotspots of Response

Protecting remaining intact peat swamp forests in Southeast Asia from degradation is important for sustaining the important services that these ecosystems provide. The fact that peatland degradation is extensive should be seen as a priority and an opportunity to restore peatlands and regain their functioning (e.g., Miettinen *et al*. 2016) and for achieving important greenhouse gas emission reductions. In Indonesia alone, 2.6 million hectares of degraded peatland have been identified as priorities for restoration (ASEAN 2021).

Due to the hydrological connectivity of peat ecosystems, large-scale efforts that restore entire peat domes are needed to re-establish peatland function (Wong *et al*. 2009) and have been supported since 2017 through ministerial regulations and/or sub-regulations. Research on effective design of large-scale restoration intervention and monitoring (Urzainki *et al*. 2020) as well as supportive land-use policies (Indriatmoko *et al*. 2014; Dohong *et al*. 2018) are critically needed to support full rewetting at landscape level. In tropical peat swamp forest ecosystems, following a single and low-intensity fire, natural regeneration back to forest requires a much longer recovery period compared to other tropical forest ecosystems. Where the disturbance is more extreme, the forest does not return, and the landscape becomes dominated by fern and shrub communities. Regeneration barriers that prevent the re-establishment of woody species, such as limited seed dispersal, low soil nutrient availability and seasonal flooding, can be ameliorated through human assistance (FAO 2020; Convention on Wetlands 2021).

Market-based schemes are being tested and may become increasingly widespread in Southeast Asia. An example is the voluntary carbon market, which enables actors to offset emissions by purchasing standards-certified carbon credits generated from carbon-saving projects. Countries that wish to participate in the voluntary carbon market need to have strong policies and a highly transparent registry system that avoids double counting of GHG emissions. The system also should facilitate the application of corresponding adjustments against domestic mitigation targets in case carbon credits are sold to other countries. Although the carbon credit market for peatlands is under discussion in Indonesia, pilot projects are currently underway (see Box 4.3.).

From 2010-2022, significant responses have been implemented by the Government of Indonesia to reduce emissions from the land-use sector. Among the efforts made was the enaction of a forest harvesting moratorium that resulted in receiving REDD+ payments. In 2014-2016, Indonesia has reported a reduction of land-based emissions by as much as 20.3 Mt CO_2e and payment was made by the Green Climate Fund following independent verification (Indonesian Government 2016).

Paludiculture has been applied to restore degraded peatlands in Southeast Asia. Key paludiculture plant species are already identified from various commodity categories such as food, medicines, other non-timber forest products and a range of wood products (FAO n.d.). Case studies, although still limited in number, show that hydrological management is often insufficient so that the potential of reducing GHG emissions is not fully realized.

In China, there is a history of 20 years or more of extraction of peat moss in Southwest China where annual precipitation is high. At present, peat moss production is rather successful and common in Guizhou province, where many peatlands are degraded and croplands are transformed to paludiculture. This also can be found in central China, but the area is not as vast as that in Guizhou.

Box 4.3. Katingan Peatland Restoration and Conservation Project

The Katingan Project is protecting and restoring 149,800 hectares of peatland ecosystems with the objective of offering local communities sustainable sources of income and contributing to global climate change mitigation. The project lies within the districts of Katingan and Kotawaringin Timur in Central Kalimantan and covers one of the largest remaining intact peat swamp forests in Indonesia. The project has been certified against the Verified Carbon Standard and the Climate, Community and Biodiversity Standards. It is projected to reduce around 10 Mt CO_2e per year to the atmosphere (Sills *et al.* 2014). The project also seeks to bring direct benefits to local communities by promoting the livelihoods of the most vulnerable groups including women, the poor, elderly and people living with disabilities.

The Katingan Project applied for an Ecosystem Restoration Concession license covering an entire peat dome, but to date, only half of the peat dome is protected. This could in the project area lead to negative impacts from downstream degradation, due to the hydrological link between downstream areas at the edges of the peat dome and upstream areas at the centre of the peat dome where the project is located. The Katingan Project demonstrates both the enormous potential of peatland conservation and restoration for ecosystem service provisioning, as well as the need for institutional frameworks that facilitate large-scale interventions in peatlands.

4.6. Spotlight Country Cases

4.6.1. Indonesia

Indonesia holds the deepest and largest continuous areas of peatland in the tropics, contributing 13% and 18% of pantropical peatland area and volume, respectively (Gumbricht *et al*. 2017). Indonesian peat carbon storage is estimated to be between 13,600 – 40,500 Mt of carbon (Warren *et al*. 2017). These carbon stocks are under threat from decomposition and from fires in drained peatlands.

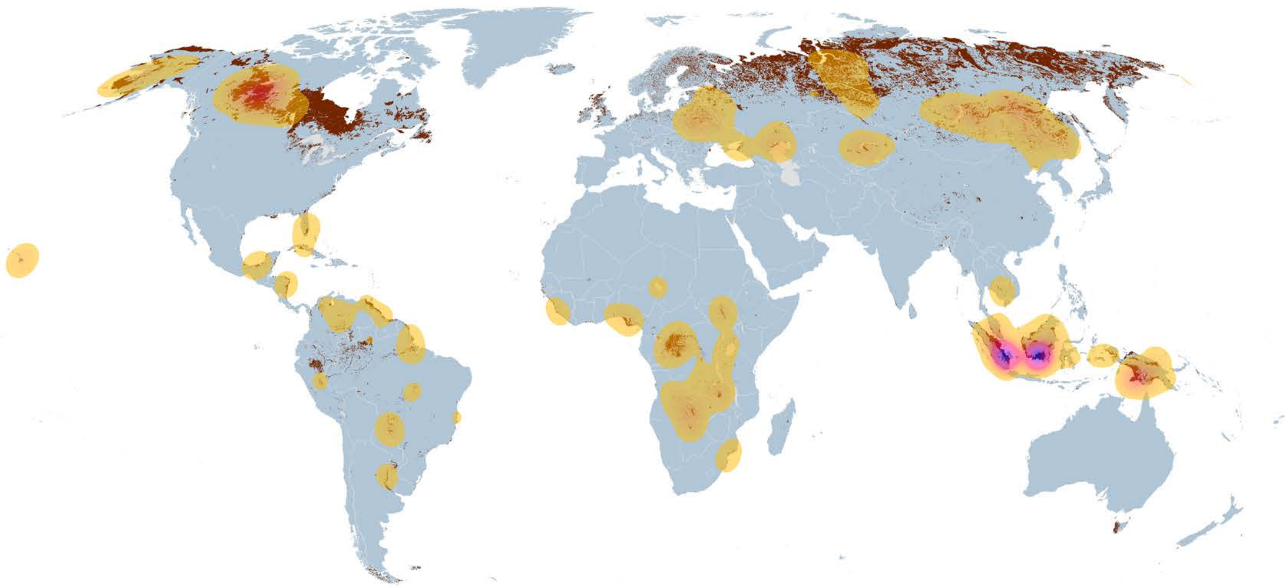
Although fire regimes in the last three decades have changed over time, forest and land fires in Indonesia are almost entirely related to the conversion of peatland for pulpwood plantations and expansion of agricultural land, including oil palm. Fig. 4.11 shows the global hotspots of fire on peatlands, having a severe impact in Southeast Asia, especially on Indonesia during strong El Niño Southern Oscillation (ENSO) years. The large fires in 1997-1998 occurred coincidently with the worldwide economic downturn and strong ENSO. The inter-decadal extreme weather events reoccurred with fire episodes of different Southern Oscillation Index (SOI) that burned large areas of peatlands, causing immense emissions of greenhouse gases and economic loss that are summarized in Table 4.4.

Moreover, it is better documented now that peat fire incidences are closely associated with hydrological drought or peat dryness rather than climatological drought. The steady increase of the affected area over the last century may be well associated with the increasing temperature (Fig. 4.9). However, without drainage and man-made fire, peat fires are extremely rare.

Table 4.5. Indonesia's fire episodes, area burned, greenhouse emissions and economic loss in the past three decades.
Note: Numbers in brackets indicate the percentage of peatland burned.

Year	Burned area (Mha)	Southern Oscillation Index	Estimated emission (Mt CO_2e)	Economic loss (Billion US Dollars)	Reference
1997-1998	11.6 (75)	-2.7	1,500	9.3-20.1	Barber and Schweithelm 2000; Varma 2003; Murdiyarso and Adiningsih 2006
2006	N/A	-1.3	2,000	N/A	NASA/NCAR/Univ. Toronto
2015	2.6 (52)	-2.2	1,200	16.1	Harris *et al*. 2015; Glauber *et al.* 2016; Parker *et al.* 2016;; Wooster *et al.* 2018
2019	2.6 (44)	-1.2	700	5.2	https://dataalam.menlhk.go.id/karhutla/2019; World Bank 2019

2015 - strong El Niño year



2020 - moderate La Niña year

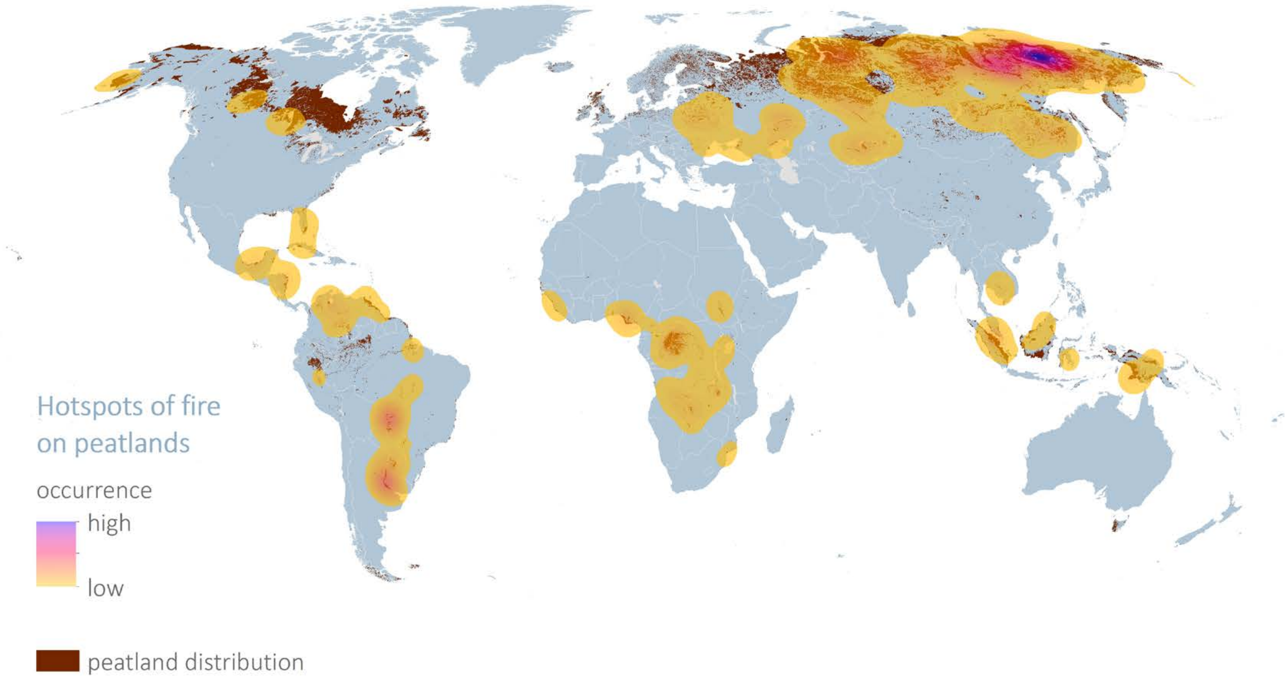


Figure 4.11. Hotspots of fire on global peatlands during a strong El Niño (2015) and a moderate La Niña year (2020).

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III.3 Production of Thematic Maps.

4.6.2. Malaysia

Peatlands in Malaysia are mainly lowland bogs, formed as peat swamp forests that are dome-shaped with ombrogenous peat occupying the centre of the dome (Tie 1990; Ten and Murtedza 2002; Zulkifley *et al.* 2016). Minerotrophic peatlands have been recorded in various locations such as Tasek Bera in Pahang State. Malaysia also has upland peats located on top of mountains, e.g., the Cameron Highlands, Mount Kinabalu and other high-altitude areas. The area of peatlands in Malaysia has been estimated at 2.56 million hectares (Table 4.5) based on an analysis undertaken in 2019 with reference to data from the State Agricultural Departments of Peninsular Malaysia, Sabah and Sarawak (DOE 2019a, b). This study estimated that Malaysia has 2,560,341 hectares of peatlands of which 714,156 hectares is in Peninsular Malaysia, 200,600 hectares in Sabah and 1,645,585 hectares in Sarawak.

Due to their fragile nature, any disturbance of these peatlands is expected to change their natural ecological balance. Therefore, many environmental issues ranging from loss of biodiversity, loss of habitats, loss of biomass and increased carbon emissions can be expected if they are damaged. This damage will then make floods worse and fires more frequent.

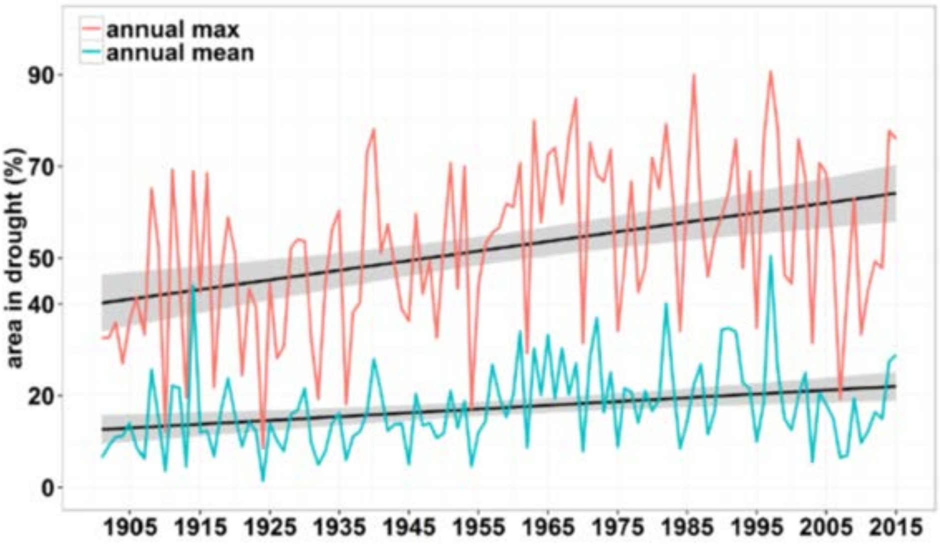


Figure 4.12. Time series of hydrological drought for 1901-2015 across Borneo.
Source: Taufik et al. 2017.

Table 4.6. Peat distribution in Malaysia (adapted from DOE 2019).
*Note: * Data of 2017 from Department of Statistics, Malaysia **DOE (2019)*

State	Land Area (ha)*	Peat soils in State (ha)**	% peat soil (State)	% peat soil (country)
Johor	1,916,600	187,151	9.76	7.31
Kelantan	1,504,000	7,692	0.51	0.30
Negeri Sembilan	665,600	6,220	0.93	0.24
Perak	2,097,600	75,124	3.58	2.93
Pahang	3,596,500	196,050	5.45	7.66
Sabah	7,390,400	200, 600	2.71	7.83
Sarawak	12,445,000	1,645,585	13.22	64.27
Selangor	795,100	173,198	21.78	6.76
Terengganu	1,305,200	68,338	5.24	2.67
Wilayah Persekutuan (Putrajaya)	10,429	383	3.67	0.01
Total Malaysia Land Area	**33,062,100**	**2,560,341**	**7.74**	**100.00**

CHAPTER 5

Regional Assessment for Europe

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CHAPTER 5

Regional Assessment for Europe

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Regional Highlights

Key Facts

KEY REGIONAL DATA PRODUCED FOR THE GLOBAL PEATLANDS ASSESSMENT 2022[1]	
Total peatland area (hectares)	58,755,644 ha
Peatland cover over total region surface area (%)	6.0%
Degraded peatlands (%)	46.4%
Annual GHG emissions from peatlands (Megatons of carbon dioxide equivalent emissions per year)	582.0 Mt CO_2e / yr
Undegraded peatlands (%)	53.6%
Peatlands within protected areas (%)	19.7%
Top 5 Countries with largest peatland area (hectares)	1. European Russia (20,800,000 ha) 2. Finland (8,313,381 ha) 3. Sweden (6,797,032 ha) 4. Norway (4,865,000 ha) 5. Belarus (3,014,298 ha)
ADDITIONAL DATA	
Total peatland carbon stock[2] (Megatons of carbon)	43,620 Mt C
Threatened peatland species[3] (VU = vulnerable; EN = endangered; CR = critically endangered)	Flora: 6 VU, 10 EN, 5 CR Fauna: 32 VU, 12 EN, 8 CR
Ramsar Wetlands of International Importance with peat[4]	456 sites (40.5% of total Ramsar sites in Europe)

[1] Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

[2] Joosten, H. (2009). The Global Peatland CO_2 Picture. Peatland status and drainage associated emissions in all countries of the World. Wetlands International, Ede, 10 p. + tables.

[3] Data extracted from the IUCN Red List of Threatened Species.

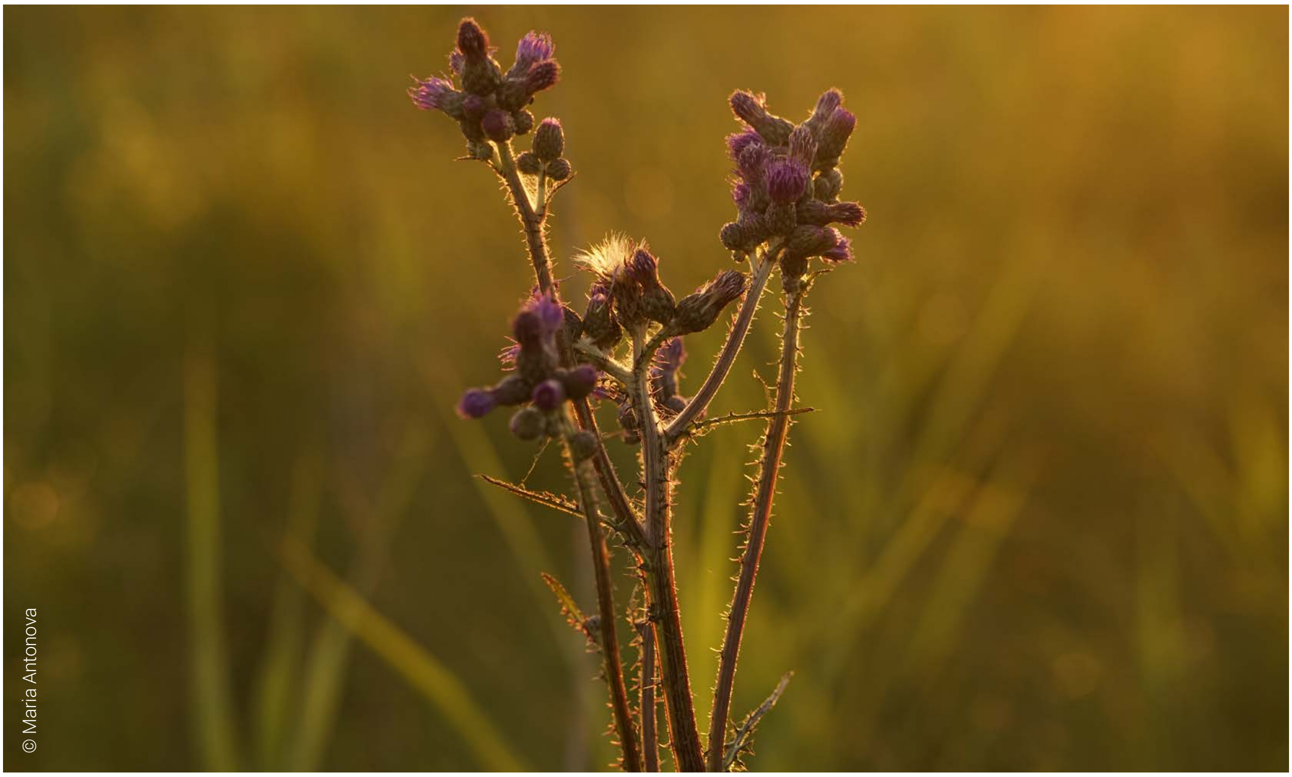
[4] Data extracted from the Ramsar Sites Information Service.

Peatlands in Europe are distributed unevenly with a higher density in the northern areas, highlands and coastal areas. They are sparsely distributed in steppe and broadleaved forest zones. Europe is the continent with the largest proportional losses of actively accumulating peatlands (mires) in the world. Even so, it still comprises significant mire diversity. The economic use of peatlands began in Europe over a thousand years ago and includes a wide range of uses from food, timber and energy production to collection of medicinal plants, reeds, hunting and ecotourism. However, economic use of peatlands damages their biodiversity, reduces their ability to clean water and hampers their potential to store carbon.

About 10% of the former European peatland area has already been completely lost through drainage for agriculture, forestry and peat extraction and about 46% of the current European peatland area is classified as degraded, in the EU even 50%. This makes Europe the world's second largest greenhouse gas emitter from drained peatlands. Climate change also induces peat loss from undrained peatlands as a result of extensive droughts and/or heatwaves, fire, vegetation change, and permafrost degradation. The large and rapid losses of old permafrost carbon have only recently commenced and will increase in the future. The problems associated with unsustainable peatland management (incl. drainage for agriculture and forestry) in Europe have not been fully addressed in land-use and climate policies. Furthermore, the EU and national agricultural policies with established subsidy systems do not support development of sustainable peatland management practices.

Peatland protection and restoration towards natural functioning is essential for cost-efficient climate change mitigation and for maintaining biodiversity and water related services. Both raising the water level in managed peatlands for more sustainable use in forestry and agriculture, and restoration for protection, should be considered across the region.

Inclusive engagement of, and support to, local communities (especially women and girls from lower socioeconomic status, minorities and Indigenous Peoples) in making use of new policies and initiatives for sustainable peatland use are relevant for enabling transition to a climate-neutral and resilient society.



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5.1. Biomes and Ecological Zones

The most comprehensive analysis of mire regions in Europe delineates ten main regions and 52 sub-regions (Moen *et al*. 2017; Tanneberger *et al*. 2021a; Fig. 5.1). Traditionally European mire regions have been also distinguished according to ecological zones. We apply this distinction here for ease of discussion (Fig. 5.2).

- The **Arctic seepage and polygon mire region (I; 6% peatland cover)** covers northernmost Europe, mainly in the Russian Federation, including the Russian arctic islands and Svalbard. The region has a dry and cold climate with permafrost and little snow. Tundra seepage and polygon fens are characteristic, and the degree of degradation is low (1%). However, infrastructure projects and vehicle travel are increasingly threatening these highly vulnerable Arctic peatlands, which is potentially more damaging under current climate change conditions (Minayeva *et al*. 2016). Only a relatively small proportion of these mires are protected (Sirin *et al*. 2017).
- The **Palsa mire region (II; 13%)** covers large areas in the Russian Federation and in northern Finland, Sweden and Norway (including mountainous areas). The characteristic mire type is the palsa mire (high palsa more in the western part, and flat palsa on the eastern plateaus). The degree of degradation is low (6%). There is no drainage. There are only roads and other linear structures that are currently affecting negligible areas compared to the total peatland cover. However, the average figures do not reflect the concentration of impacts in individual regions. And, as for the rest of the Arctic region, these growing threats occur against the background of climate change.
- The **Northern fen region (Aapa mire region) (III; 27%)** covers large areas in the boreal vegetation zones in northern Europe. String-flark mires are very common in the central and continental parts (Sweden, Finland, Russia), with sloping fens in the more oceanic areas (Norway). About one quarter of the peatlands are degraded through drainage intended to improve forest productivity. On average, 13% of the peatland area is within protected areas. In European Russia, the Republics of Karelia and Komi have a particularly highly developed system of federal, regional and local protected areas (Sirin *et al*. 2017).
- The **Typical raised bog region (IV; 31%)** is found in Fennoscandia, the Baltics and northern Russia. Characteristic mire types are typical raised bogs and wooded raised bogs. This region is densely populated and about one quarter (or without European Russia: one half) of the peatlands are degraded. Raised bogs themselves have suffered losses and degradation to a lesser extent than fens. This is especially true for those in river valleys, which are of greater economic interest and cover smaller areas. Some 10% of the peatlands are within protected areas, which is a low overall proportion, yet a large absolute area given the high peatland coverage of the region.
- The **Atlantic bog region (V; 6%)** is located along the oceanic coast of western Europe, from Portugal to Ireland, the northwestern parts of the United Kingdom of Great Britain & Northern Ireland (GBR) and western Norway. The region is characterised by Atlantic raised bogs and blanket bogs. For centuries, these peatlands have been heavily impacted by agricultural drainage, afforestation, peat extraction for fuel, and over-grazing by domestic animals (the latter two causing effects mainly since the 1970s) (Moen *et al*. 2017). Today, the majority of these (former) mires (68%) are damaged. More than half of the peatland area is located in protected areas but this does not change the fact that the peatlands are already degraded.

- The **Continental fen and bog region (VI; 12%)** stretches from the Polesie (eastern Poland, southern Belarus, northern Ukraine) to large parts of Central European Russia. The region is characterized by mosaics of fens and bogs. Most of these are wooded raised bogs in the north and percolation fens in the south. The long land use history of this region combined with its more southern location has led to a high degree of peatland degradation (52%). The degree of protection is low (15%).
- The **Nemoral-submeridional fen region (VII; 3%)** comprises large parts of England, France, Germany, and other Central European countries and extends as a narrow belt towards the Ural Mountains. Flat fen is the most characteristic mire type, while plane bogs and percolation fens occur. The majority of these peatlands are degraded (63%). Although half of the total peatland area is located in protected areas, here and in other regions this ‘protection’ has neither effectively protected nor restored these peatlands.
- The **Colchis mire region (VIII; <1%)** is the smallest mire region and located at the Black Sea coast in Georgia, i.e., in the sub-meridional vegetation zone and highly oceanic vegetation section. The region is characterized by percolation bogs, which are unique to this region. Only 5% of the peatland area is degraded. Almost half of the peatlands lie within protected areas.
- The **Southern European marsh region (IX; 2%)** comprises wetlands of southern Europe from the Iberian Peninsula to Azerbaijan, around the Mediterranean and Black Sea. The region stretches from west to east over the warmest and driest parts of continental Europe. Most wetlands are located in river deltas and floodplains, coastal lagoons and alongside freshwater lakes. The peatlands often have only a thin peat layer and most of them are heavily influenced by drainage (52%) or have already disappeared. Protected areas cover 43% of the peatland area.
- The **Central and southern European mountain compound region (X; <1%)** is different from other regions, as it relates to the vertical distribution of mire types. It occurs in the mountain areas of central and southern Europe. Flat fens and percolation fens are most common, but also sloping fens and bogs occur, and about one third is degraded. More than half of the peatland area is located in protected areas.

Fig. 5.3 shows some examples of peatlands in the region.

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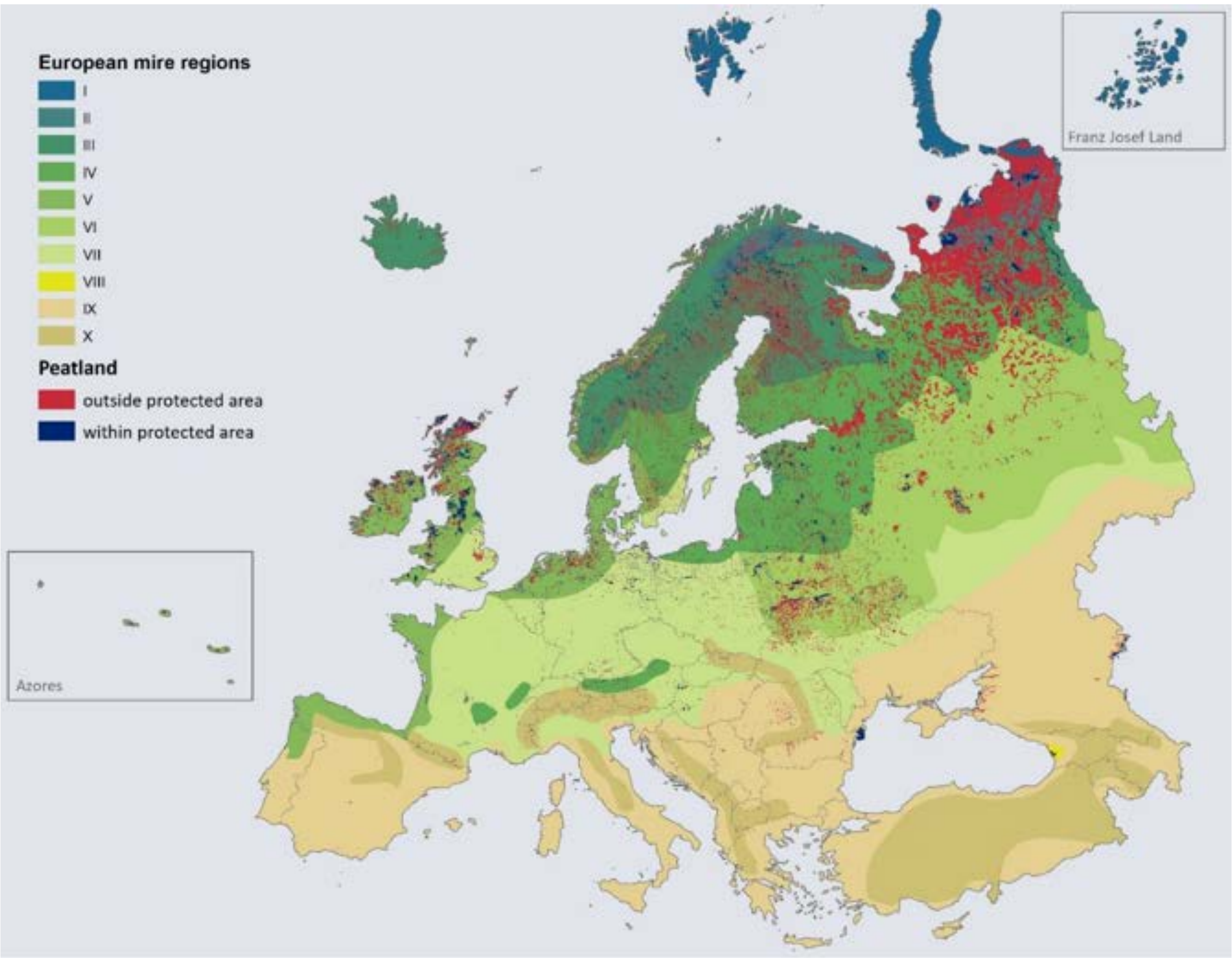

Figure 5.1. European mire regions (see text above) and peatland distribution inside and outside protected areas.
Source: Tanneberger et al. 2017.

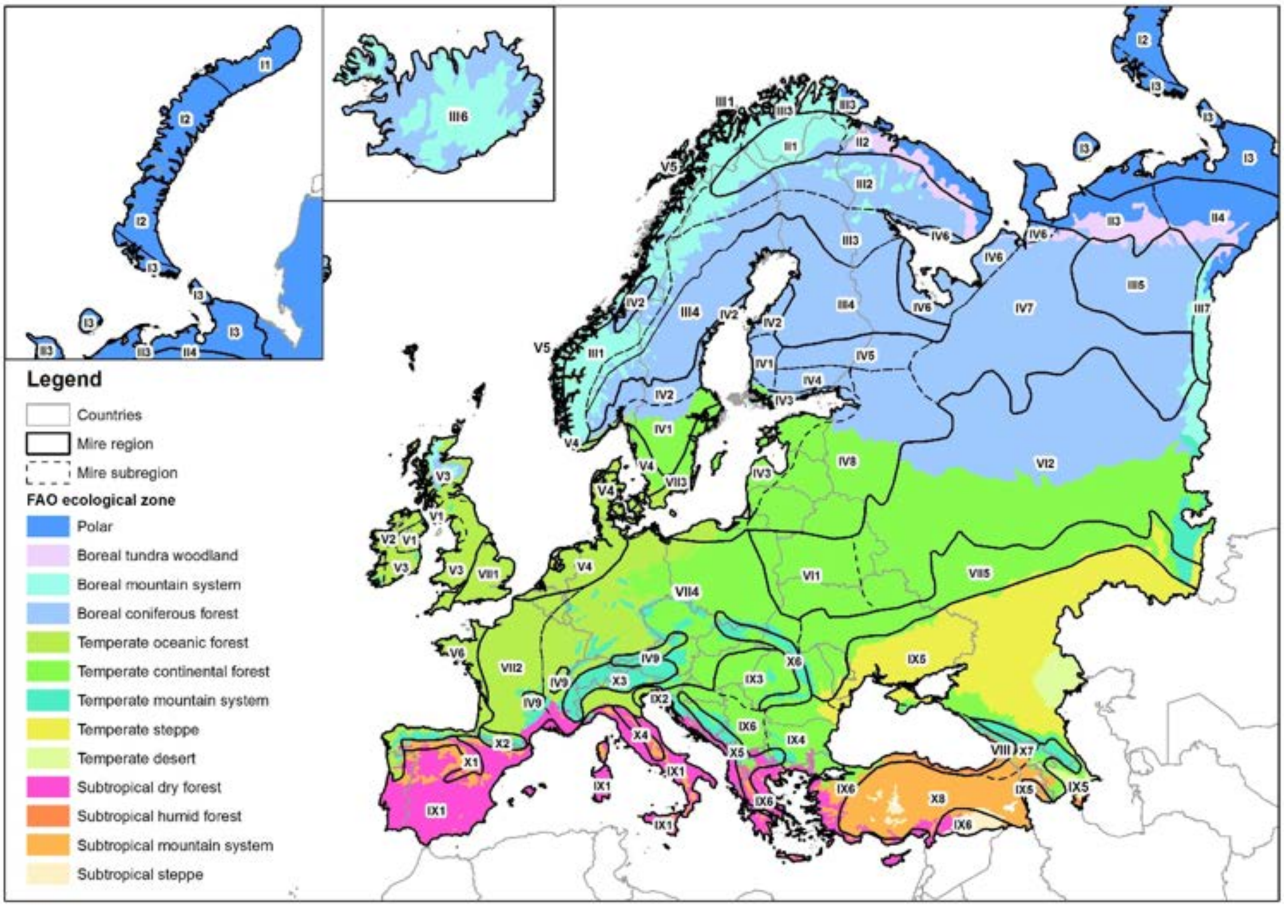

Figure 5.2. FAO ecological zones in relation to European mire regions and subregions according to FAO and Moen et al. 2017, respectively European mire regions and subregions: ***I Arctic seepage and polygon mire region*** *(I1 Northern, I2 Middle, I3 Southern),* ***II Palsa mire region*** *(II1 Fennoscandian, II2 North-Kola, II3 Lower Pechora, II4 East-Nenets),* ***III Northern fen (aapa mires s.l.) region*** *(III1 Northwestern, III2 Northern, III3 Main, III4 Southern, III5 Northeastern, III6 Northwestern alpine, III7 Ural),* ***IV Typical raised bog region*** *(IV1 Fennoscandian plateau bog, IV2 Fennoscandian eccentric bog, IV3 Baltic plateau bog, IV4 Finland/Karelia concentric bog, IV5 Finland/Karelia eccentric bog, IV6 White Sea, IV7 Northeastern, IV8 East-Baltic, IV9 Central European upland),* ***V Atlantic bog region*** *(V1 Ireland-Britain raised bog; V2 Western Ireland blanket bog; V3 Ireland-Britain blanket bog; V4 Northwestern lowland; V5 Boreal (Norway); V6 Southern, V7 Azores),* ***VI Continental fen and bog region*** *(VI1 Polesia, VI2 East-European),* ***VII Nemoral-submeridional fen region*** *(VII1 British lowland, VII2 West-European lowland, VII3 Danish and Baltic Sea lowland, VII4 Central European lowland, VII5 Central Russian)****, VIII Colchis mire region, IX Southern European marsh region*** *(IX1 Western, IX2 Po delta, IX3 Pannonian (Hungarian) plains, IX4 Lower Danube, IX5 South-Russian, IX6 Eastern),* ***X Central and southern European mountain compound*** *(X1 Cantabrian mountains, X2 Pyrenees mountains, X3 Alps, X4 Western mediterranean mountains, X5 Mountains of the Balkan peninsula, X6 Carpathian mountains, X7 Humid Caucasus mountains, X8 Semi-arid Caucasus and Turkey mountains.*

Table 5.1. European mire regions in relation to FAO ecological zones.

Notes: FAO ecological zones that cover a major area of the respective mire region are in bold. Azores and Franz Josef Land omitted from the map but included in the classification of mire regions. For peatlands in Greenland, please see Chapter 7.

European mire regions	FAO ecological zones
I Arctic seepage and polygon mire	**Polar**
II Palsa mire	**Polar / Boreal tundra woodland / Boreal coniferous forest / Boreal mountain system**
III Northern fen (aapa mires s.l.)	**Polar / Boreal tundra woodland / Boreal coniferous forest / Boreal mountain system** / Temperate oceanic forest
IV Typical raised bog	**Boreal coniferous forest / Temperate continental forest**/ Polar/ Boreal mountain system / Temperate oceanic forest / Temperate mountain system
V Atlantic bog	**Boreal mountain system / Temperate oceanic forest** / Temperate continental forest / Temperate mountain system / Subtropical dry forest / Subtropical mountain system
VI Continental fen and bog	**Boreal coniferous forest / Temperate continental forest** / Boreal mountain system / Temperate mountain system / Temperate steppe
VII Nemoral-submeridional fen	**Temperate oceanic forest / Temperate continental forest** / Temperate mountain system / Temperate steppe / Subtropical dry forest / Subtropical mountain system
VIII Colchis mire	**Subtropical humid forest**
IX Southern European marsh	**Temperate continental forest / Temperate steppe / Subtropical dry forest / Subtropical mountain system** / Temperate oceanic forest / Temperate mountain system / Temperate desert / Subtropical steppe / Subtropical humid forest
X Central and southern European mountain compound	**Temperate mountain system / Subtropical mountain system / Subtropical steppe**/ Temperate oceanic forest / Temperate continental forest / Temperate desert / Subtropical dry forest / Subtropical humid forest

Figure 5.3. Peatland diversity in Europe (A) Aapamire in the Oulanka National Park (Finland); (B) Dikoe fen mire (Belarus) (C) Pristine patterned peatland in the Flow Country of northern Scotland (UK) (photos: A - Elisabet Rams-Beltrán; B – Maria Antonova; C – Susan Page)

5.2. Peatland Distribution and Extent

Peatland maps of Europe show mire regions (e.g., Kats 1971), the general occurrence of peatlands (e.g., Lappalainen 1996) or peat soils based on topsoil organic carbon and the European Soil Database (Montanarella *et al*. 2006). The first comprehensive peatland map for the whole of Europe as a composite map of national datasets was published in 2017 (Tanneberger *et al*. 2017) along with the book “Mires and Peatlands of Europe” (Joosten *et al*. 2017). All maps of Europe in this GPA are based on this map with some data updated. Peatlands in Europe cover an area of almost 59 million hectares, representing 12% of global peatlands. They are distributed unevenly with higher density in the northern areas, highlands and coastal areas (Fig. 5.4), and sparsely distributed in steppe and broadleaved forest zones (Moen *et al.* 2017; Tanneberger *et al.* 2017).

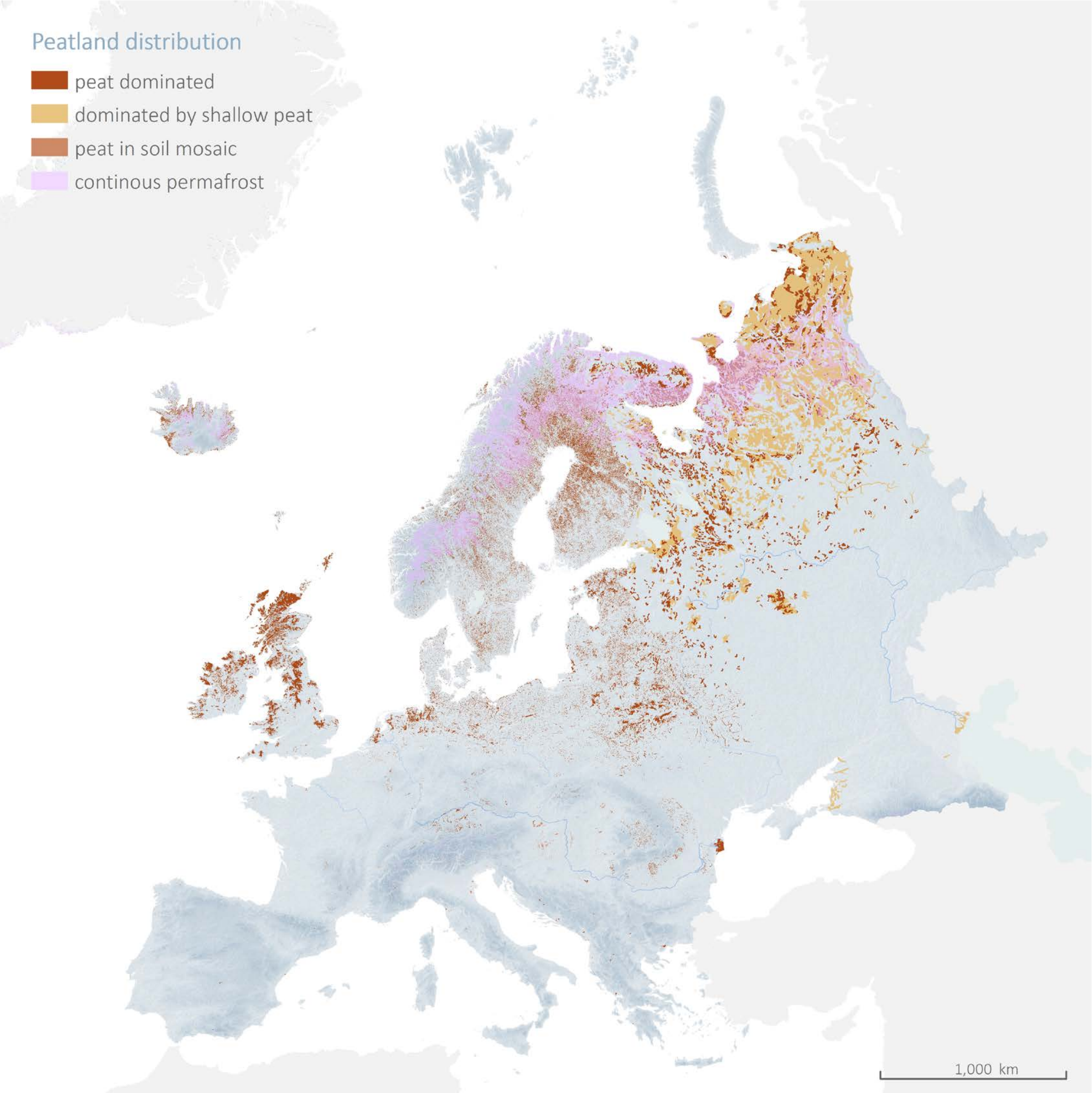

Figure 5.4. Peatland distribution in Europe (partly incl. organic soils).

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III. Production of the Global Peatland Map 2.0.

The largest mire systems in Europe are the mire "Ocean" (178,000 hectares) in the Republic of Komi and Polisto-Lovatsky mire (96,000 hectares) in northwest Russia (Bogdanovskaya-Guiheneuf 1969). The smallest mires are in the highlands and in the steppe zone (a few square meters). Across Europe, the average peat depth is 3 to 4 m, maximum peat depths are usually 10-12 m (Moen *et al*. 2017; Tanneberger *et al*. 2017). The deepest peatland in Europe is Philippi peatland (Greece) with up to 190 m depth, offering the unique opportunity for studying the transition from peat to coal at a depth of c. 120 m (Melidonis 1981). Fig. 5.5 shows the proportion of Europe's total peatland area per country.

The degree of peatland degradation increases from arctic to temperate regions. Due to the large area of drained peatlands, the EU is the world's second largest emitter of GHG from drained peatlands. In many European countries, National Inventory Submissions to UNFCCC substantially underestimate peatland GHG emissions (Barthelmes 2018). Consequent implementation of the IPCC Wetlands Supplement does increase annual EU wide emissions from agriculture on organic soils from 92 Mt reported in national submissions to UNFCCC to 167 Mt CO_2e (Martin and Couwenberg 2021) based on Global Peatland Database.

The European mire regions (see Fig. 5.1) with the least degraded peatlands are the A*rctic seepage and polygon mire region* (1%) and the *Palsa mire region* (6%). The proportion of degraded peatlands is particularly high in the *Atlantic bog region* (68%) and the *Nemoral-submeridional fen region* (63%), followed by the S*outhern European marsh region* (53%) and the *Continental fen and bog region* (37%). If excluding European Russia, the third most degraded region is the *Continental fen and bog region* (58%), followed by the T*ypical raised bog region* (49%) and the S*outhern European marsh region* (47%; (Tanneberger *et al*. 2021a). The degradation status in highland peatlands is not specifically estimated and demands special attention. It is critical also to include peatland loss and indirect degradation caused by human induced climate change, such as permafrost thaw in polar and boreal zones.

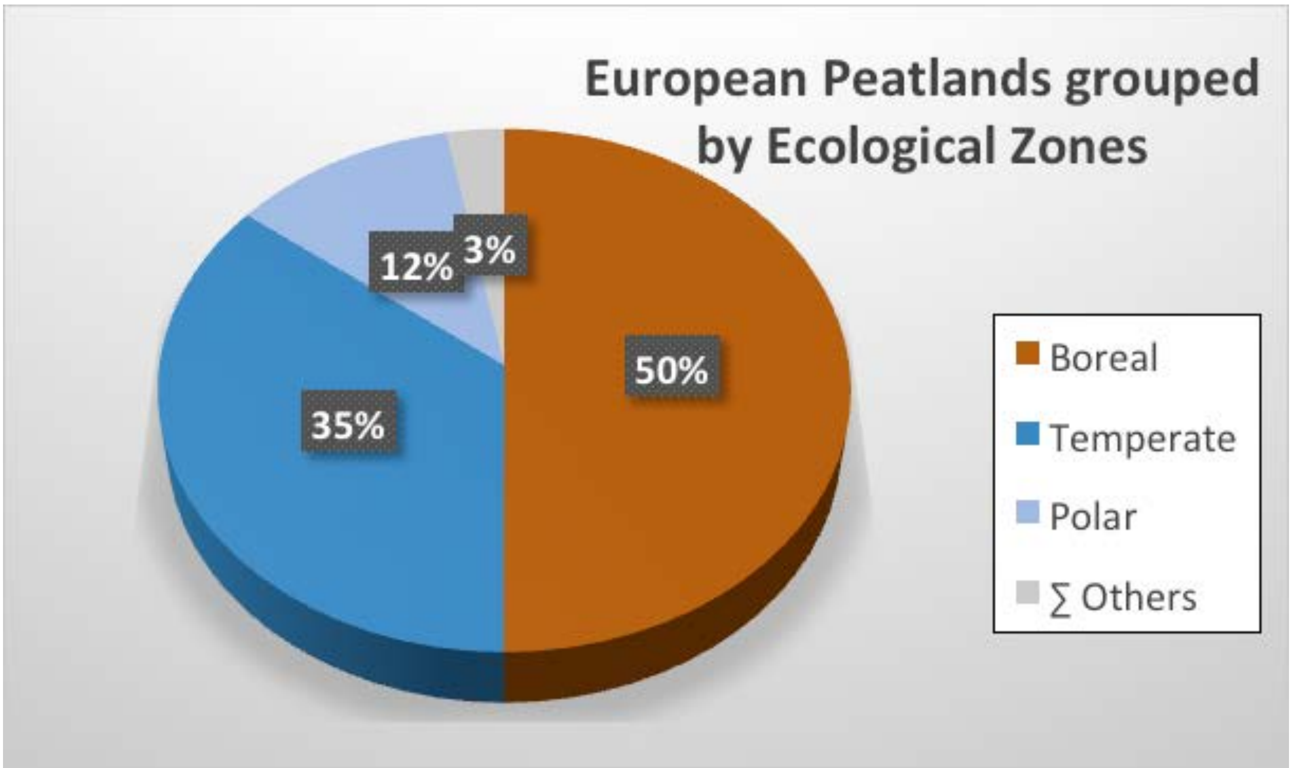

Figure 5.5. The distribution of European peatlands in aggregated FAO Global Ecological Zones.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

5.3. Biodiversity, Nature's Contributions to People and Hotspots of Value

5.3.1. Biodiversity

In more than half of Europe's mire regions, less than 17% of the peatland area is inside protected areas (Fig. 5.1; Tanneberger *et al*. 2021a). Fig. 5.6 shows the peatland protection in the region. The EU European red list of habitats (European Environment Information and Observation Network [EIONET] Forum 2016; Janssen and Rodwell 2016) contains thirteen treeless mire habitats, three of which are listed as endangered and one as critically endangered.

Peatlands (or peat/peaty soils) are also recorded in other rare habitat categories. These include freshwater habitats, grasslands, heathland and scrub as well as forests (Fig. 5.7). Due to a reduction of traditional land use practices, anthropogenic mire habitats (grassland on peat, Fig. 5.7) are also endangered. Taking the non-EU countries into consideration, the list of rare mire habitats would appear differently. Raised bogs and spruce dominated peatlands are not endangered within the Carpathian and Ural Mountains, or the Russian part of East European Plain.

Mire species usually comprise not more than 15% of local flora and fauna (Minayeva *et al*. 2016). The proportion of endangered species in mires is often higher than in other ecosystems. The IUCN Red List contains nine species of European mire vascular plants and five species of birds. Key umbrella or flagship species for European fen mires are the Aquatic Warbler (*Acrocephalus paludicola*) (Tanneberger and Kubacka 2018), the Fen Orchid (*Liparis loeselii*) and (for European bogs) the Golden Plover (*Pluvialis apricaria*). In raised bogs, the Wood Sandpiper (*Tringa glareola*) is a key species.

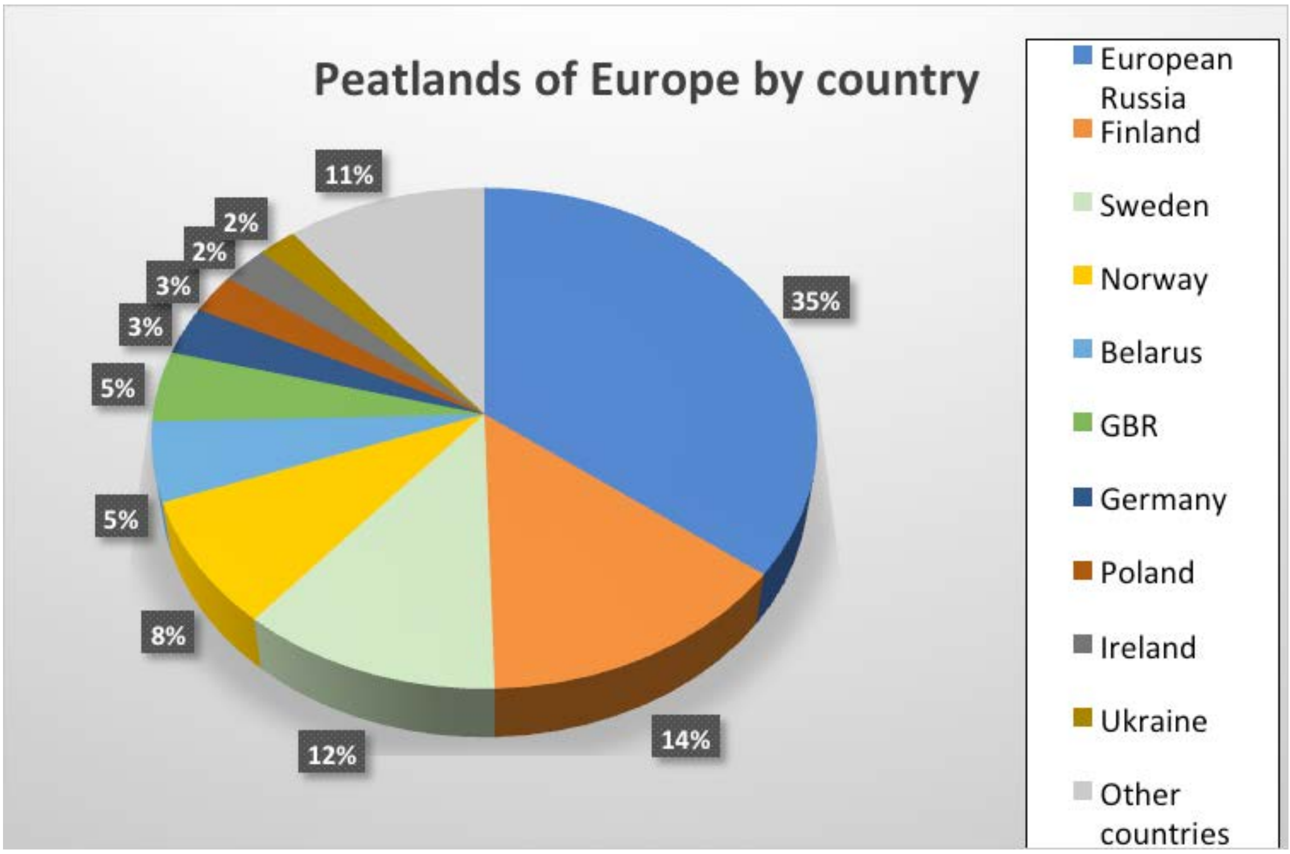

Figure 5.6. Top-10 countries holding the largest area of peatlands in Europe (including European part of Russia).
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

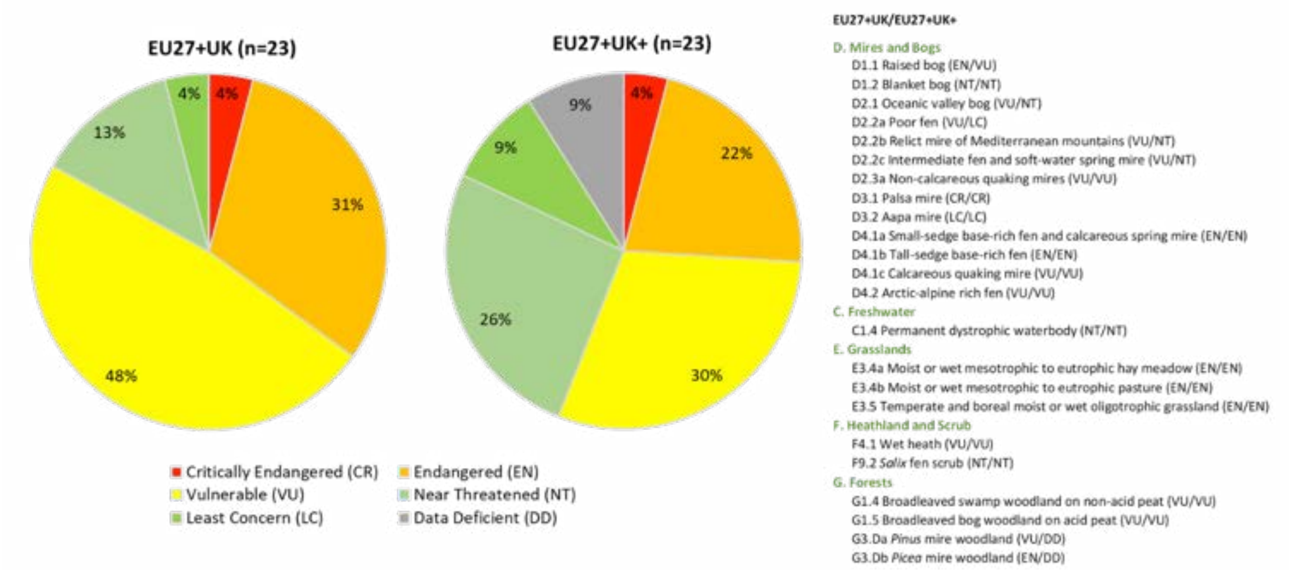

Figure 5.7. European red list of mires and mire-related habitat types and percentage of threatened habitat types at two geographic levels: across the EU27+UK (EU and the United Kingdom) and EU27+UK+ (including Norway, Switzerland, Iceland, and the Balkan countries). n – number of habitats. Source: Modified after Eionet Forum 2016 and Janssen et al. 2016.

5.3.2. Nature's Contributions to People

Peatlands' contributions to people have been well assessed in Europe and the resulting information is increasingly being applied. Such assessments are an important tool for planning sustainable peatlands management based on an understanding of the economic value of biodiversity and ecological processes. In many cases, these assessments are based on the "cascade" approach (Haines-Young and Potschin 2010), in-line with guidelines by Bouma and Beukering (2015). The approach suggests a flow from the status of biophysical features of the site to ecosystem functions, services and values. This opens the possibility to link European legislation on biodiversity conservation and ecosystem services management to people through interested parties and market analysis. One of the more widely used decision-making tools is cost-benefit analysis. The 'public good' nature of many ecosystem services poses a challenge for delivering them through markets - but attempts are being made to apply these mechanisms, such as payment for ecosystem services (PES). For peatlands, three components of biophysical features for peatlands – biota, water and peat - should be considered, with further interpretation of them into ecosystem functions and ecosystem services (Martin-Ortega *et al*. 2014). The site-level ecosystem service assessment could be an effective peatland management tool. Its application will require good coverage of data on peatland sites, interested parties' analysis and an understanding of regional specific features and land use, including driving factors of land use that are beyond the control of local people. For example, for the Arctic and highland peatlands, the role of peatlands in the protection of permafrost and regulation of global climate should be considered as a key ecosystem service. In arid, semiarid and highland areas the water supply related ecosystem services provided by peatlands are crucial. Peatlands along migratory corridors also contribute to global biodiversity (Minayeva *et al*. 2016). Interested parties' analysis requires a site appropriate design in areas where Indigenous Peoples and Local Communities (IPLCs) directly depend upon peatlands. Both simple bioindication and more sophisticated modelling approaches are available and should be developed further for quantitatively assessing the benefits of peatland restoration (Joosten *et al*. 2015).

It is also important to incorporate indigenous knowledge systems when considering all the contributions peatlands provide to people. Throughout Europe, harvesting of reed for thatch is a sustainable way of using wet peatlands, and a traditional type of paludiculture (Wichmann and Köbbing 2015). Lack of awareness for indigenous knowledge is particularly the case when considering non-material contributions to people, including cultural ecosystem services, or groups who depend on peatlands for their livelihoods. For example, peatland dominated landscapes in West Siberia host vast areas of biodiversity and are home to different groups of Indigenous Peoples who are partly maintaining their traditional lifestyle and who have both livelihoods and identities that are directly related to the status of the surrounding ecosystems (Minayeva *et al*. 2021). In a case study on ecosystem services, respondents belonging to Nenets and Khanty Peoples pointed out traditional provisioning land use that is critical to indigenous people working in reindeer herding, raising animals on pastures, fishing and hunting. They also revealed how this land use is tightly bound to their spiritual and cultural identity (Minayeva *et al*. 2021). A study from Sápmi outlined that peat-accumulating mires with willows and sedges provide important forage for reindeer in the summer. Where reindeer grazing is an important form of land use, grazing on deciduous shrubs can inhibit shrub expansion that is driven by climate change (Olofsson *et al*. 2009).


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There are trade-offs between human activities and peatland ecosystems. An example from low-productive drained peatland forests reveals strong trade-offs between biodiversity, water quality, climate and economy (Juutinen *et al*. 2020). Optimal land use/ management on these low-productive peatlands depends on which target is considered: a focus on biodiversity and water quality requires cost-efficient active restoration measures but climate benefits in these nutrient poor peatlands could be reached even with no active measure (the current low-productive drainage state will continue net carbon sequestration without any human intervention, also because the stands will gradually rewet by itself (Juutinen *et al*. 2020). In practice, land use decisions can optimize many targets (biodiversity, water quality, climate and economy) at the same time, but the decisions are confounded by the time perspective relevant to land users and how different uses depend on each other spatially.

5.3.3. Hotspots of Value

5.3.3.1. Country case Belarus

The original extent of mires in Belarus was at least 2,560,500 hectares (12.3% of the country area) (Council of Ministers of Belarus 2015). Some 946,000 hectares of mires were drained for agriculture and 299,100 hectares for peat extraction (Tanovitskaya and Bambalov 2009; Council of Ministers of Belarus 2015). The current extent of mires is 863,000 hectares (Kozulin *et al*. 2012), including peatlands that have been slightly drained for forestry. Until the 1990s, peatlands were a strategic resource for agriculture and energy production and peat still plays a substantial role for the energy and economic security in Belarus. In 2011-2015, 1.7—3.2 Mt of peat was extracted annually mainly for use as energy. The peat industry employs more than 5,000 people. There are many towns and villages with the peat industry as the main employer (Kozulin *et al*. 2017). This use of peatlands for extracting peat as fuel conflicts with the other ecosystem services that these peatlands provide. The pristine mires sequester about 0.25 Mt of carbon from the atmosphere annually and the peatlands store about 500 Mt (Council of Ministers of Belarus 2015). They also maintain a favourable regional hydrological regime for natural ecosystems. This freshwater storage ensures the conservation of water resources and a steady water supply for rivers and lakes. Belarusian mires host considerable biological resources such as cranberry bushes (*Vaccinium oxycoccos*), medicinal plants and game.

Ecotourism in Belarus largely revolves around the recreational potential of mires (Council of Ministers 2015). Mires also provide habitats for rare and endangered wildlife species. More than 40% of birds, 35% of insects and 15% of wild plant species listed in the Red Data Book of the Republic of Belarus inhabit mires. Among these are globally endangered bird species including about 40% of the global population of the Aquatic Warbler (*Acrocephalus paludicola*), 10% of the global population of the Greater Spotted Eagle (*Clanga clanga*) and 3% of the global population of the Great Snipe (*Gallinago media*) (Bambalov *et al*. 2017). The key issue for peatlands governance in Belarus is finding the balance between conflicting interests in the use of peatland ecosystem services. The recently developed National Peatland Wise Use and Conservation Strategy and Law on the Protection and Use of Peatlands is aimed at this task.

5.4. Status of Peatlands, Drivers of Change and Hotspots of Change

5.4.1. Status of Peatlands

In Europe, the degree of peatland degradation clearly increases from arctic to temperate regions. The total proportion of degraded peatlands in Europe is 46%; within the EU it is 50% (12 million hectares; Tanneberger *et al*. 2021a). Peatland degradation is caused by artificial drainage, most often for agriculture, forestry or peat extraction. Fig. 5.8 shows the proportion of drained and undrained peatlands in Europe per country (partly including organic soils), as per the Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. Countries such as Germany, the Netherlands, Denmark, Poland, and Ireland have more than 80% of their peatlands drained for agriculture, forestry or peat extraction.

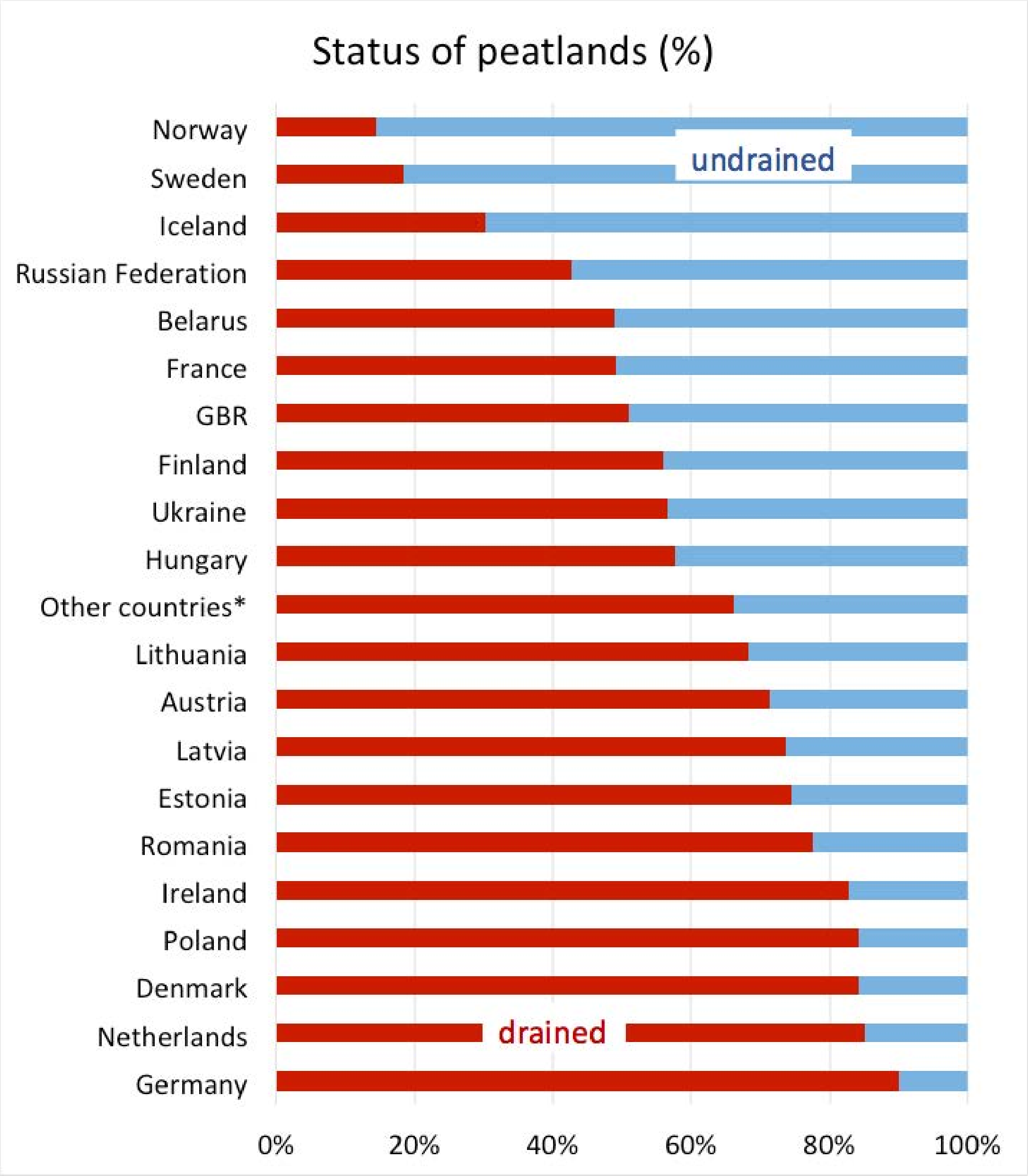


*Figure 5.8. Proportion of drained (red) and undrained (blue) peatlands in Europe per country (partly including organic soils). Calculations are based on the drained area for forestry, agriculture and peat extraction. *Sum of European countries with less than 100,000 hectares of peatland area.*

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Because of the multiple types of environmental damage caused by peatland drainage, these lands are today at the centre of Europe’s key environmental problems with drained peatlands in the EU alone generating close to 25% of the total agricultural GHG emissions while only making up 3% of the agricultural land area (Tanneberger *et al*. 2021b). Drained, agriculturally used peatlands are also a strong source of nitrate (through peat mineralization; Tanneberger *et al*. 2021b). This results in a substantial impact on ground and surface water quality, drinking water provision and biodiversity. Last but not least, typical peatland biodiversity, in particular that of groundwater-fed fens in temperate Europe, has been devastated by drainage (Joosten *et al*. 2017). Greenhouse gas emissions from degraded peatland are estimated at 582 Mt CO_2e per year. Fig. 5.10 shows the annual GHG emissions from organic soils drained for forestry, agriculture and peat extraction in key European countries. The Russian Federation (RUS) alone is responsible for 231 Mt CO_2e per year, representing 40% of the total GHG annual emissions in Europe, while the top 10 countries represent 84% of total peatlands emissions.

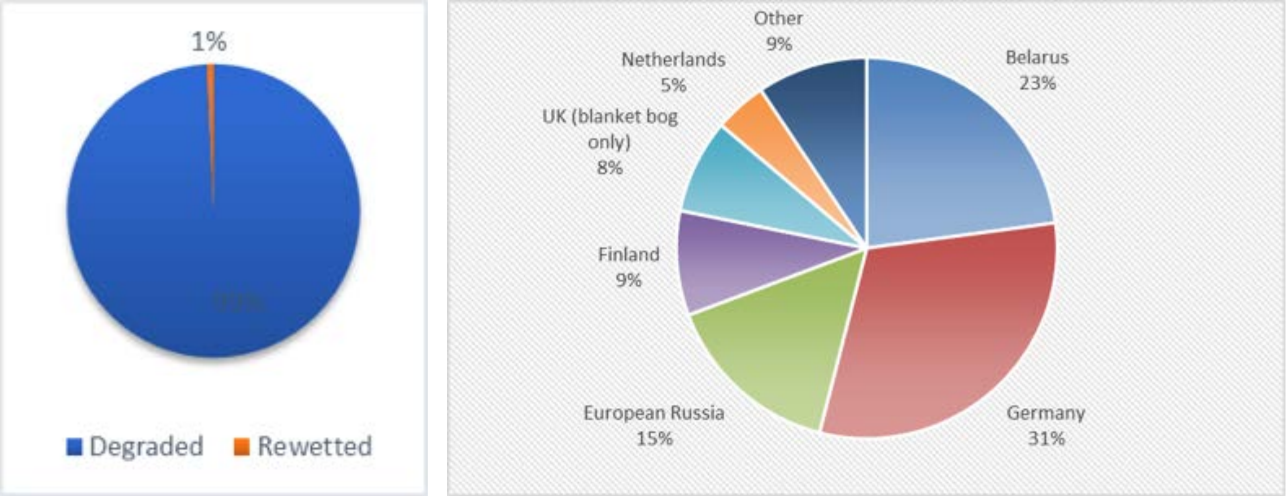


Figure 5.9. Total degraded and rewetted peatland area in Europe, and rewetted area by country in percentage of the total rewetted peatland area in Europe (c. 250,000 hectares in 2017, based on national chapters in Joosten et al. 2017, partly extended by interviews with national experts, as of 2017).

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

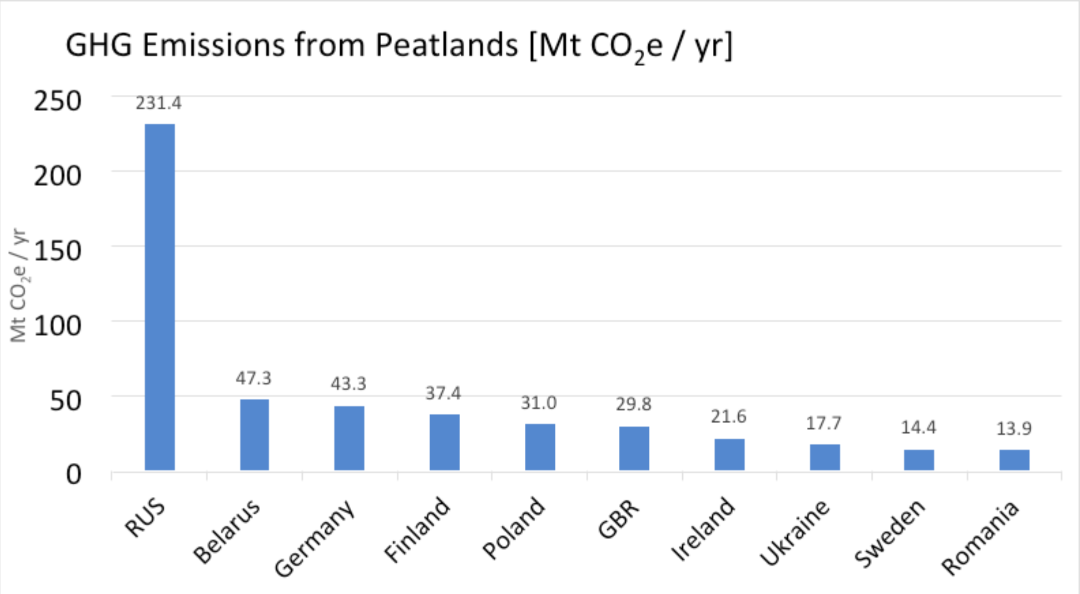


Figure 5.10. Top 10 countries emitting GHG from peatlands in Europe, representing 84% of total peatlands emissions in the region. Calculations are based on the peatland drained area for forestry, agriculture and peat extraction and IPCC (2014) emission factors including CO_2, CH_4, N_2O, DOC, and emissions from ditches. Includes only net, on-site GHG emissions. Wildfire emissions are not included.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

The vast majority of undrained peatlands are termed “not pristine” because the surrounding drainage disturbs their hydrology and has led to partly drained margins (Sallinen *et al*. 2019). Drainage especially alters minerotrophic water discharge to fens, which are dependent upon hydrological connections to their upper catchments. Disturbances in hydrology or a warmer, drier climate, may induce tree encroachment, hummock formation and fen–bog transition. This increases carbon accumulation in the short-term and decreases methane emissions, but the fen-bog transition may threaten fen species, e.g., Lepidoptera species, and habitats (Granlund *et al*. 2021).

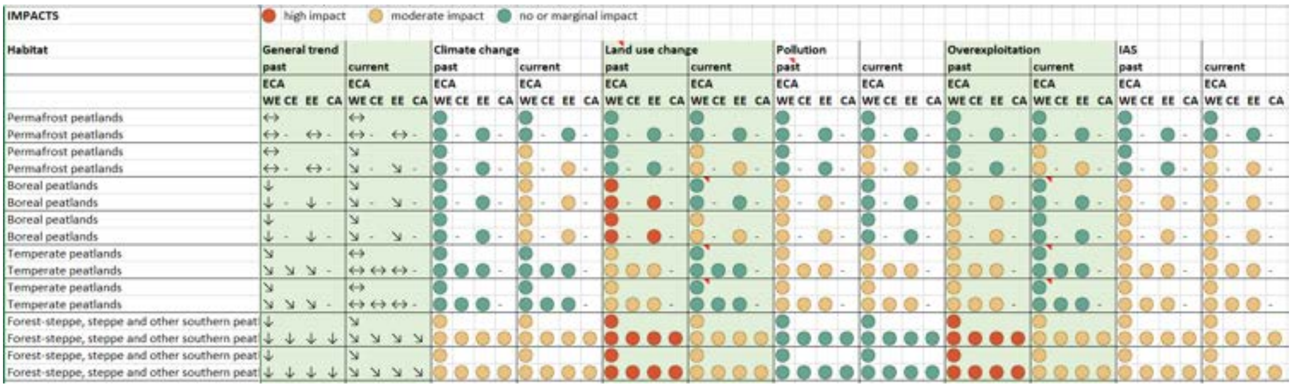
Climate change induces additional peat losses due to drought, especially in the boreal and mid-latitude regions due to permafrost degradation (Huang *et al*. 2021), whereas sea-level rise may result in inundation of coastal peatlands. Permafrost dynamics have caused small carbon gains in the past, but many experts warn about large and rapid losses of old permafrost locked carbon that has only recently begun and will increase in the future (Loisel *et al*. 2021). There has been a greater than 50% reduction in palsa or peat plateau area since the late 1950s (Zuidhoff and Kolstrup 2000; Borge *et al*. 2017). Models make it clear that all of Fennoscandia will become climatically unsuitable for peatland permafrost by 2040 (Fewster *et al*. 2022). When ice-rich permafrost peatlands thaw and collapse, their soils become saturated, which leads to high methane emissions (Christensen *et al*. 2004; Jones *et al*. 2017). Renewed peat accumulation in thermokarst wetlands counteracts this effect to some extent but it may take considerable time before the warming effect changes in a cooling effect. The increased atmospheric deposition of nitrogen and phosphorous may have a nonlinear effect on the peatland carbon sink. Modest nitrogen deposition may result in a net carbon gain but a higher deposition reduces the carbon sink potential owing to the loss of peat-forming *Sphagnum* and enhanced decomposition (Bragazza *et al*. 2006; Olid *et al*. 2014). Nitrogen deposition also reduces biodiversity and water quality (Phoenix *et al*. 2012).

Trends of peatland biodiversity drivers of change in Europe have been analysed in the IPBES regional assessment for Europe (Sirin *et al*. 2018) alongside land use and climate change, pollution and overexploitation (Table 5.2). Current overall trends are mostly negative.

Table 5.2. Past and currently drivers of change with respect to extent (first line) and biodiversity (second line) of major peatland habitat types in Europe and Central Asia.

Abbreviations: WE=Western Europe; CE=Central Europe; EE=Eastern Europe; CA=Central Asia. ↑/↓ denote strong and consistent increase/decrease in the indicator; ↗/↘ denote moderate and consistent increase/decrease in the indicator; ⇆ stable indicator; ⇵ variable trend in the indicator.

Source: Sirin et al. 2018.



IMPACTS 🔴 high impact 🟡 moderate impact 🟢 no or marginal impact

Habitat	General trend								Climate change								Land use change							
	past				current				past				current				past				current			
	ECA				ECA				ECA				ECA				ECA				ECA			
	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA
Permafrost peatlands	↔				↔				🟢				🟢				🟢				🟢			
Permafrost peatlands	↔	-	↔	-	↔	-	↔	-	🟢	-	🟢	-	🟢	-	🟢	-	🟢	-	🟢	-	🟢	-	🟢	-
Permafrost peatlands	↔				↘				🟢				🟡				🟢				🟡			
Permafrost peatlands	↔	-	↔	-	↘	-	↘	-	🟢	-	🟢	-	🟡	-	🟡	-	🟢	-	🟢	-	🟡	-	🟡	-
Boreal peatlands	↓				↘				🟢				🟡				🔴				🟢			
Boreal peatlands	↓	-	↓	-	↘	-	↘	-	🟢	-	🟢	-	🟡	-	🟡	-	🔴	-	🔴	-	🟢	-	🟢	-
Boreal peatlands	↓				↘				🟢				🟡				🔴				🟡			
Boreal peatlands	↓	-	↓	-	↘	-	↘	-	🟢	-	🟢	-	🟡	-	🟡	-	🔴	-	🔴	-	🟡	-	🟡	-
Temperate peatlands	↘				↔				🟢				🟢				🟡				🟢			
Temperate peatlands	↘	↘	↘	-	↔	↔	↔	-	🟢	🟢	🟢	-	🟢	🟢	🟢	-	🟡	🟡	🟡	-	🟢	🟢	🟢	-
Temperate peatlands	↘				↔				🟢				🟢				🟡				🟢			
Temperate peatlands	↘	↘	↘	-	↔	↔	↔	-	🟢	🟢	🟢	-	🟢	🟢	🟢	-	🟡	🟡	🟡	-	🟢	🟢	🟢	-
Forest-steppe, steppe and other southern peat	↓				↘				🟡				🟡				🔴				🟡			
Forest-steppe, steppe and other southern peat	↓	↓	↓	↓	↘	↘	↘	↘	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🔴	🔴	🔴	🔴	🟡	🟡	🟡	🟡
Forest-steppe, steppe and other southern peat	↓				↘				🟡				🟡				🔴				🟡			
Forest-steppe, steppe and other southern peat	↓	↓	↓	↓	↘	↘	↘	↘	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🔴	🔴	🔴	🔴	🟡	🟡	🟡	🟡

Habitat	Pollution								Overexploitation								IAS							
	past				current				past				current				past				current			
	ECA				ECA				ECA				ECA				ECA				ECA			
	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA
Permafrost peatlands	🟢				🟢				🟢				🟢				🟢				🟢			
Permafrost peatlands	🟢	-	🟢	-	🟢	-	🟢	-	🟢	-	🟢	-	🟢	-	🟢	-	🟢	-	🟢	-	🟢	-	🟢	-
Permafrost peatlands	🟢				🟡				🟢				🟡				🟢				🟡			
Permafrost peatlands	🟢	-	🟢	-	🟡	-	🟡	-	🟢	-	🟢	-	🟡	-	🟡	-	🟢	-	🟢	-	🟡	-	🟡	-
Boreal peatlands	🟡				🟢				🟡				🟢				🟡				🟡			
Boreal peatlands	🟡	-	🟡	-	🟢	-	🟢	-	🟡	-	🟡	-	🟢	-	🟢	-	🟡	-	🟡	-	🟡	-	🟡	-
Boreal peatlands	🟡				🟢				🟡				🟢				🟡				🟡			
Boreal peatlands	🟡	-	🟡	-	🟢	-	🟢	-	🟡	-	🟡	-	🟢	-	🟢	-	🟡	-	🟡	-	🟡	-	🟡	-
Temperate peatlands	🟡				🟡				🟡				🟢				🟡				🟡			
Temperate peatlands	🟡	🟡	🟡	-	🟡	🟡	🟡	-	🟡	🟡	🟡	-	🟢	🟢	🟢	-	🟡	🟡	🟡	-	🟡	🟡	🟡	-
Temperate peatlands	🟡				🟡				🟡				🟢				🟡				🟡			
Temperate peatlands	🟡	🟡	🟡	-	🟡	🟡	🟡	-	🟡	🟡	🟡	-	🟢	🟢	🟢	-	🟡	🟡	🟡	-	🟡	🟡	🟡	-
Forest-steppe, steppe and other southern peat	🟢				🟢				🔴				🟡				🟡				🟡			
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Forest-steppe, steppe and other southern peat	🟢				🟢				🔴				🟡				🟡				🟡			
Forest-steppe, steppe and other southern peat	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🔴	🔴	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡

5.4.2. Drivers of Change

The economic interest in peatlands in Europe has a history of over a thousand years and the range of economic uses of peatlands is extremely wide (Joosten and Clarke 2002; Parish *et al*. 2008; Joosten and Tanneberger 2017). Low level impact use ranges from the collection of berries and hunting to the cutting of hay and eco-tourism (Joosten and Tanneberger 2017). Because peatlands are naturally wet, drainage and changes in their water regime have impacted peatlands extensively and profoundly. Earliest evidence for mire drainage in Europe dates back some 3,500 years (Joosten and Tanneberger 2017). As early as 1100 Common Era (C.E.) the Dutch technique of ‘peatland reclamation’ by building dikes and draining the encircled land had achieved such a success that the Dutch expertise was exported across Europe (Borger 1992). Along with the desired land reclamation and production effects, long-term drainage caused many unwanted effects. The most prominent effect was land subsidence with a loss in land surface height of several millimeters to several centimeters per year and a cumulative loss of c. 8 m (Ruyssenaars *et al*. 2020). More recently, in highly developed regions mires only persist as isolated remnants and become a focus of interest for the construction of industrial and transport infrastructure (airports, roads, factories, etc.), often with state support.

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Agriculture is the most widespread use of peatlands in Europe. It has increased in both area and intensity in many countries during the last two centuries. Nearly 15% of European peatlands are used for agriculture, mainly as meadows and pastures (Oleszchruk *et al*. 2008; Joosten and Tanneberger 2017). In countries such as Hungary (98%), Greece (90%), The Netherlands (85%), Germany (85%) and Poland (70%), almost all organic soils were cultivated (Joosten *et al*. 2017). Up to half of all peatlands were used for agriculture in Belarus, Lithuania, and Ukraine, and up to 35% in Ireland (Connolly 2018). Only small areas of peatlands are currently under agricultural use in Finland (2%), the UK (4%) and Sweden (5%) (Oleszchruk *et al*. 2008). In total, over 10 million hectares have likely been drained for agriculture in Europe, but it is not known exactly how much of this area would have been peatlands and how much would have been more shallow organic soils. This is because peat mineralizes and may disappear as a result of long-term use and only circumstantial evidence may suggests that they may once have been peatlands. In the European part of Russia, more than 5 million hectares of land have been drained for agriculture, but the share of peatlands is undefined. In some central provinces, more than half of all peatlands were lost to agriculture (Sirin *et al*. 2017). Drainage, tillage and fertilization led to decreasing peat soil moisture, peat shrinkage, decomposition, mineralization and loss of organic matter.

Drainage for **forestry** has the second largest impact on peatlands in Europe, but this has been confined mainly to Nordic countries (Finland 4.7 Mha, Sweden 1.4 Mha, Norway 0.4 Mha), Baltic States (Lithuania 0.6 Mha, Latvia 0.5 Mha, Estonia 0.46 Mha), Russia (>3 Mha), Belarus (0.3 Mha), Poland (0.1 Mha) and Germany (0.1 Mha), where excessive moisture (especially in the boreal zone) limits the productivity of tree stands (Turunen and Valpola 2020). In some countries, drainage for forestry includes not only peatlands, but also mineral lands that have accumulated large quantities of organic matter, therefore, the above estimates of the area of peatlands drained for forestry are uncertain. This is particularly true for the UK (0.6 Mha) and Ireland (0.45 Mha; Renou-Wilson *et al*. 2022) where previously tree-less peatlands were drained and afforested. The very first attempt to afforest a mire in UK was made as early as 1730 (Paavilainen and Päivänen 1995; Päivänen and Hånell 2012). In Norway, Sweden, Russia, Latvia, Estonia and Finland, peatlands were drained for forestry mainly between the 1950s and early 1980s (Paavilainen and Päivänen 1995; Päivänen and Hånell 2012).

Peat extraction covers less peatland area but has the most profound impact as it removes vegetation and peat and associated carbon stocks. Many peatlands used for peat extraction have completely disappeared, especially in areas where peatlands are rare as is the case in Southern Europe (Joosten *et al*. 2017). After peat extraction ceased for technical or economic reasons or exhaustion of the preferred peat type, many peatlands have been reclaimed for agricultural use. The use of peat as a fuel began in Europe during the Neolithic and peat was periodically a key energy resource (Joosten and Tanneberger 2017). The use of peat for energy is declining everywhere in Europe (Holmgren *et al*. 2008), but peat remains the most used component in horticultural growing media in Europe. Alternative materials are actively being developed (the most promising being *Sphagnum* biomass from rewetted bogs, Gaudig *et al*. 2018), but their use is still limited by their availability (Joosten and Tanneberger 2017).

In Europe in 2021, most peat was extracted in Finland, Belarus, Sweden, Germany and Latvia (United States Geological Survey [USGS] 2022). In Finland, peat extraction for energy has decreased by 75 % in only 2 years by 2021, faster than was targeted (50% reduction) by 2030 (Statistics Finland 2020). In Ireland, milled peat was industrially extracted for electricity generation up until but extraction for domestic energy use and horticulture continues.

Current uses of peatlands in Europe differ strongly between countries (see Fig. 5.11 for selected countries). This highlights the different potential for GHG mitigation in land use, land-use change and forestry (LULUCF) and Climate Change Mitigation (CCM), the potential for restoring biodiversity and the applicable incentives/compensations. Within the EU, the proportions of different land uses differ strongly as well (Fig. 5.12).

5.4.3. Hotspots of Change

Peatland rewetting can no longer focus on marginal or abandoned areas. Drained peatlands disproportionately contribute to GHG emissions. Rewetting must target highly fertilized, productive and deeply drained peatlands because these have the highest GHG emissions, nitrate release rates and biodiversity loss. A wide range of land use alternatives for wetlands is needed. These must include options that provide sufficient biomass yield for a fair income to farmers and which contribute to a healthy relationship between urban and rural areas (Tanneberger *et al*. 2021b). These options can broadly be grouped into three main land use categories:

- High-intensity paludiculture: The cultivation of deliberately established, selected wetland crops under intensive management with the goal to produce the highest quantity and/or quality of targeted biomass.
- Low-intensity paludiculture: Regular harvest from spontaneously established vegetation for biomass use. Initial results indicate that this has the highest biodiversity values.
- Wet wilderness: The absence of biomass harvesting and other on-site management with the focus being on the provision of regulating services and wilderness biodiversity values.

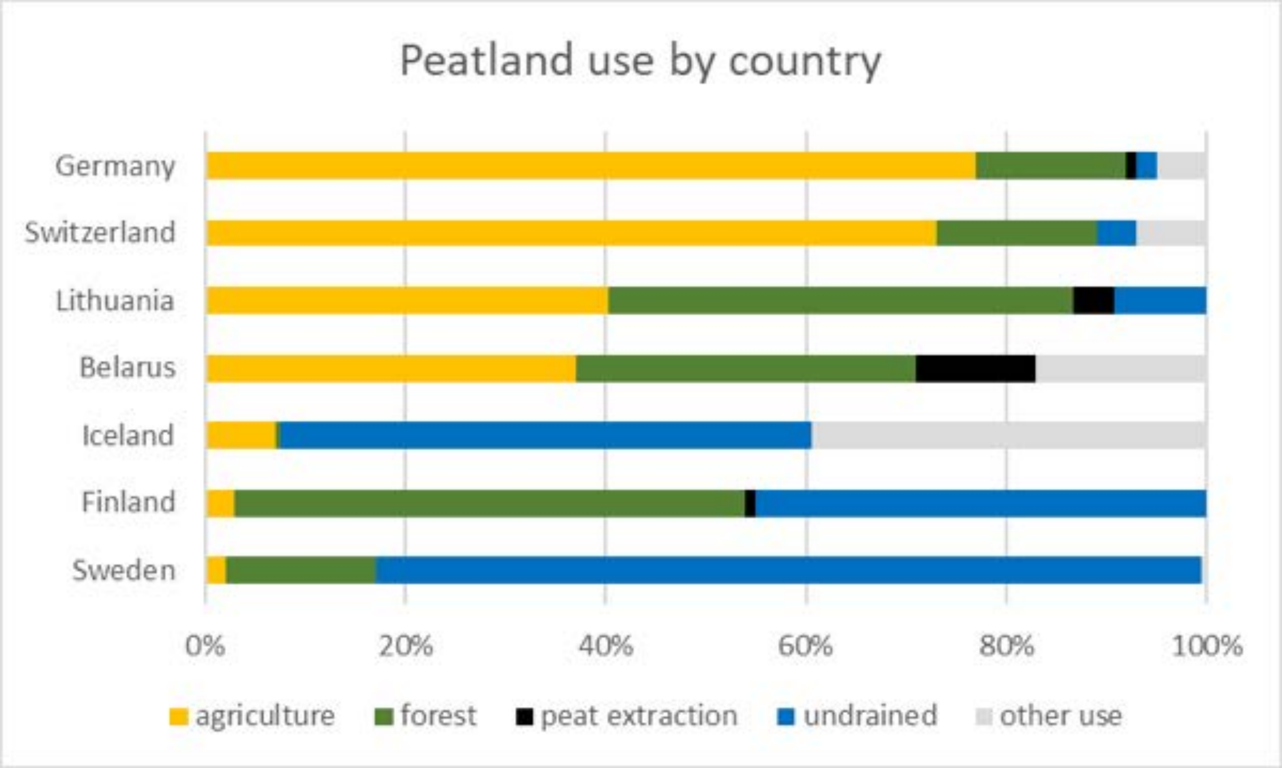

Figure 5.11. Land use on drained organic soils per country in selected countries.
Source: based on UNFCCC National Inventory Reporting.

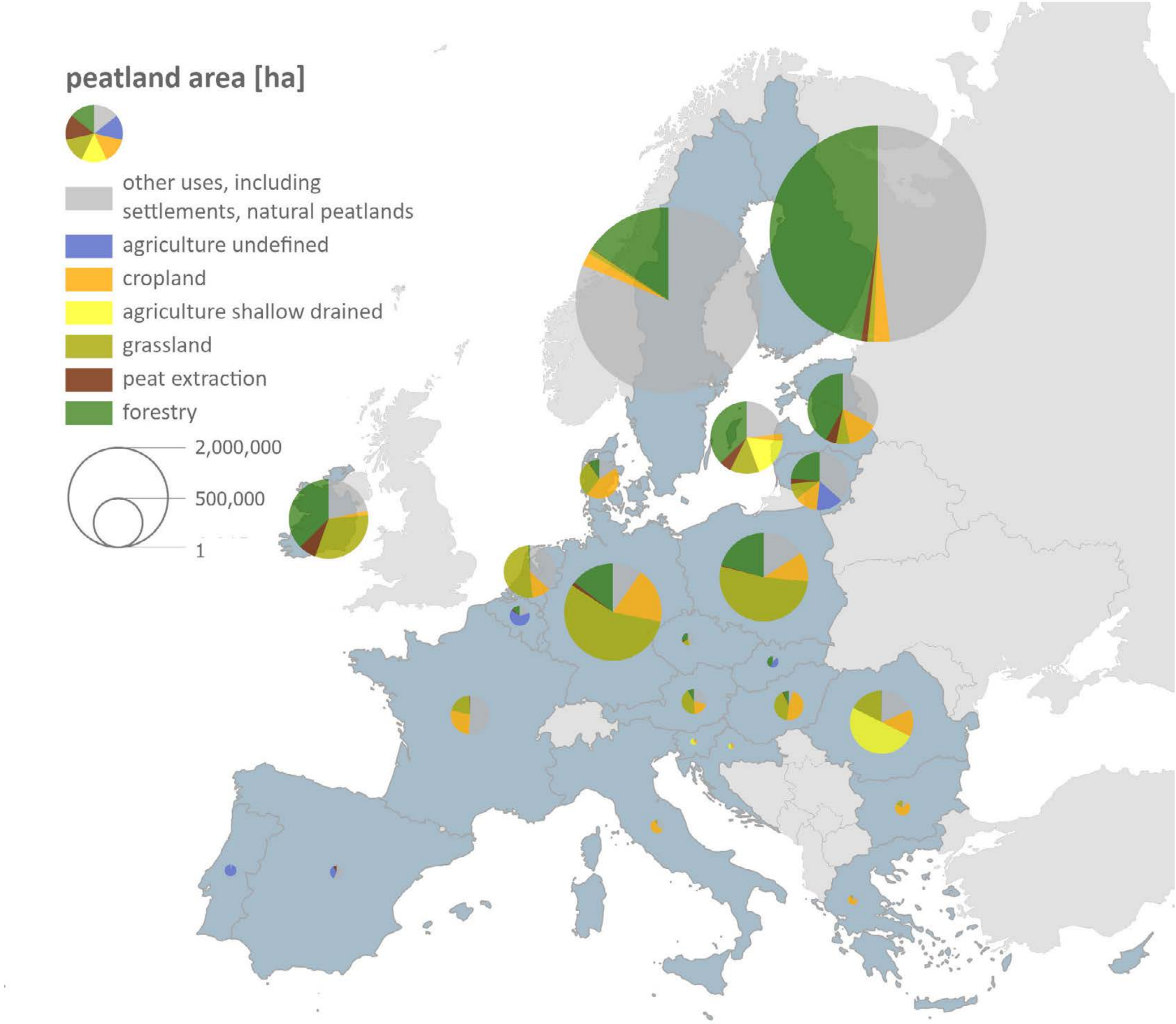

Figure 5.12 Peatland area and proportions of different land use categories per country in the EU.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Paludiculture is the productive land use of wet and rewetted peatlands that preserves the peat soil and thereby minimizes CO_2 emissions and subsidence (Wichtmann and Joosten 2007). Ideally, paludiculture uses aboveground biomass, while belowground biomass remains for peat formation. After establishing high water tables near the soil surface throughout the year, wet grasslands may develop. The diverse options for biomass from paludiculture show great potential for future circular bio-economy applications. The largest variety of paludiculture pilot sites have so far been implemented in Germany through the establishment of a 17 hectares *Sphagnum* cultivation site in NW Germany and a 10 hectares cattail plantation in NE Germany (see also FAO cases of peatland management 2015). Other newly established paludiculture pilot sites can be found in the Netherlands (Geurts *et al*. 2019).

Box 5.1. Country Case Russia

More than half of Europe's peatlands are located in the Russian Federation. The main mire regions of the continent are represented there, with a climate-induced change in features and floristic composition going from west to east. Over the entire Russian Federation only 6% of the peatlands are disturbed and vast areas of mire remain in the north and north-west. However, in some regions of Central Russia (the Volga region, the forest-steppe and steppe zones) more than half of the peatlands were drained and used and many have disappeared as a result (Sirin *et al*. 2017). Floodplain and lowland fen mires in densely populated areas were most affected. The best preserved are the raised bogs further away from settlements and of less economic interest (Minayeva and Sirin 2005). These bogs are traditionally valued for their biodiversity and their location near river headwaters. For these reasons, they are better protected by law. In general, peatlands have been perceived as nuisances or dangerous sites but attitudes are gradually changing (Sirin *et al*. 2017). Peatlands attracted Russian public attention in the late 19th century, when the drainage of more than 1 million hectares of them coincided with a shallowing of major rivers (Sirin *et al*. 2017). This highlighted their importance. There were large-scale peatland drainage and development campaigns later on. In the 1920s, much peat was extracted for use as a strategic resource for fuel and power generation. In the 1950s-1970s, peatlands were converted for use in agriculture and forestry (Minayeva *et al*. 2009; Sirin *et al*. 2017). Now, peatland rewetting and restoration are increasingly being pursued, primarily driven by the need to prevent peat fires. Actions that support peatland fire prevention are important for mitigation and adaption to climate change. There is growing awareness of the need to reduce disturbance to the vegetation cover of peatlands, both in the north for permafrost mires and in the south in the forest-steppe and steppe (Minayeva and Sirin 2012). This helps to protect peatlands from erosion and carbon loss.

5.5. Policy Context, Policy Options and Hotspots of Response

5.5.1. Policy Context

National peatland strategies are critical but difficult to compare as land use, cultural, legal and societal contexts differ between countries. An overview of national mire conservation/peatland restoration policies is provided in the country chapters of Joosten *et al*. 2017; a global overview is in Reed *et al*. (2019). A joint strategy or Pan-European initiative (cf. a European Peatlands Initiative) as add-on to national strategies that covers a wider (bio)geographic region, could do a lot to foster peatland conservation and sustainable use. Additionally, formulating gender-responsive peatland policies is crucial. Promoting the involvement and leadership of women in peatlands conservation not only supports the economic empowerment of women from lower socioeconomic status, but also improves the lives of their families and wider communities whilst simultaneously leading to progress towards environmental sustainability.

Several countries with a high areal proportion of peatlands and/or high GHG emissions from peat soils (Figs. 5.3. and 5.7) have published National Peatland Strategies, for example Finland in 2011, Ireland in 2015, Germany in 2021, the UK in 2021 (Department for Environment, Food and Rural Affairs [DEFRA] 2021), and Austria in 2022. Further, peat soils are included as an explicit part of a National Soil Strategy in Switzerland (peatlands cover <1%) and Denmark (5%) and in the National Climate Agenda of Lithuania (10%) and Norway. Several countries, including Denmark, Sweden, the Netherlands and Finland, have also recognized wetlands as part of the solution to reaching their respective country targets for emission reduction from the LULUCF sector (Lehtonen *et al*. 2021). National Ecosystem Assessments (NEA), such as the one being developed in Bosnia and Herzegovina, can highlight information on peatlands extent, status and values and contribute to decision-making. Here, we present peatland policies of the five most peatland-rich countries in Europe (Russia, Finland, Sweden, Norway, Belarus) as well of five countries with innovative and ambitious approaches to peatland conservation and restoration (Denmark, Germany, Ireland, Lithuania, UK). An overview on examples of countries' targets and implementation actions for protecting, restoring and rewetting peatlands for biodiversity, climate mitigation and hydrological benefits is presented in Annex IV (Table IV.2).

In **the Russian Federation**, state policy on peatlands has a century-long history. The State Decree "On peatlands" (1922) promoted the inventory of peatlands as a peat resource for energy production. Peatlands in Russia are assigned to different land categories (forest, agriculture, industrial, Water Fund or Specially Protected areas, etc.) depending on their use. An Intersectoral Action Plan for Peatland Conservation and Use in Russia (by the Ministry of Natural Resources and Environment of the Russian Federation) served since 2003 to coordinate peatland management. The Water Code (2006) considers peatlands as water bodies and obliges people to protect peatlands against pollution and construction. It also sets rewetting and reclamation of them as a priority. The policy target is to ensure rewetting of all strongly fire-prone drained and unused peatlands in the European part of Russia. From 2010-2013, Europe's largest project for rewetting fire-prone peatlands in the Moscow region was implemented over an area of more than 73,000 hectares (Sirin *et al*. 2020). Peatlands, including peatland restoration, are reported by Russia to UNFCCC within the National Inventories of GHG sources and removals (Sirin *et al*. 2021).

Finland's peatland strategy is currently implemented via restoration and management actions both inside and outside protected areas. The Helmi Habitats Programme by the Ministry of the Environment and the Ministry of Agriculture and Forestry is targeted to halt biodiversity loss in endangered habitats by 2030. Actions include 60,000 hectares mires to be protected on the basis of negotiations and voluntary action by landowners, 59,300 hectares peatlands to be restored, and water from the surrounding area to be returned to 400 protected peatlands.

Additionally, the government has a target of 30,000 hectares of cropland on peat soil to be converted to paludiculture and €30 million Euros were allocated for the implementation of the paludiculture target. Holistic peatland management planning is to be subsidized and current forest subsidies for the re-drainage of the peatlands to be ceased in 2024. A new act on sustainable forest management subsidies will be set in 2023.

Sweden has a program for restoration of wetlands that is mostly used for rewetting. Rewetting is considered as a method of emission reduction to reach net zero emissions until 2045; 100,000 hectares forested peatland and 10,000 hectares agricultural peatlands should be rewetted by 2045 and 50% of it by 2030. The government has allocated kr 775 million Swedish Kronas (~€70 million Euros) to re-wetting peatlands in 2021-2023. One of Sweden’s national environmental quality objectives is 'Thriving Wetlands’, including a favourable conservation status of ‘Healthy Peatlands’. There is no published Peatland or Soil Strategy (Jenny Lonnstad, personal communication).

In **Norway**, restoration works (e.g., blocking of ditches) have been carried out so far in a few Nature Reserves, e.g., the eccentric raised bog Rønnåsmyra where c. 10,000 m of ditches were dammed already in the 1970s. Wetland areas in c. 300 localities, including a number of Mire Nature Reserves, were identified as priorities for restoration in 2011 (Moen *et al*. 2017). Norway’s target is now to restore at least 15% degraded ecosystems by 2025. During 2015-2021, 105 bogs were restored and the state allocated funding towards wetland restoration.

The law of the Republic of **Belarus** "On the Protection and Use of Peatlands" (Belarus Government 2019) has four key principles for implementation: 1. to strictly conserve mires that are still in a natural or near-natural condition; 2. to extract peat mainly from deposits that are already influenced by a network of drainage canals or ineffectively drained for forestry or agriculture, where restoration of the hydrological regime is impossible or inexpedient; 3. to conduct agriculture on peat soils using approaches and methods that ensure minimum loss of organic matter and preserve soil fertility; and 4. to initiate environmental rehabilitation of disturbed peatlands that can no longer be effectively used for (consumptive) commercial purposes.

The **UK** peatland strategy, known as the England Peat Action Plan (DEFRA 2021), sets out a 25-year plan to take action to ensure peatlands are functioning healthily for the needs of wildlife, people and the planet. It is established to ensure that all peatlands are ‘responsibly managed’ or in ‘good hydrological condition’ through restoration as part of the ‘Net Zero’ strategy. A long-term aim is to restore approximately 280,000 hectares of peatland in England by 2050. The initial focus will be on restoration of c. 35,000 hectares of upland peatland (cf. England Peat Map and Peat Restoration Register via the ‘Nature for Climate Fund’ administered by Natural England), with lowland peatlands to be considered through a Lowland Agricultural Peat Task Force (recommendations to be reported by Autumn 2022). Key aspects include the protection of the ‘historic environment’ (the archaeological and palaeoecological record), ‘consultation on phasing out the horticultural use of peat’ and burning of upland peatlands. Supporting guidance for the management of peatland archaeology from Historic England is the first heritage policy guidance in the world for peatlands. The Department for Environment, Food and Rural Affairs (Defra) also intends to develop and drive private investment in peatlands via natural capital markets. Recently the Scottish Government allocated £250m under NatureScot’s Peatland Action Programme to restore 250,000 hectares of peatlands by 2032.

Lithuania's climate agenda targets for restoring peat-forming processes in 8,000 hectares of agriculturally utilized, drained peatlands by 2026 to reduce GHG emissions, restore wetland processes, create favourable conditions for biodiversity habitats, and increase GHG uptake. In 2021, the Ministry of Agriculture earmarked €16 million Euros for restoration of 8,000 hectares from the EU Recovery and Resilience Facility. The biggest peatland complexes have the status of Strict Nature Reserve and Biosphere Reserve.

Denmark's Agreement on the green transition of Danish Agriculture (2021) targets out of the total of 171,000 hectares agricultural soil in Denmark with more than 6% organic carbon, 100,000 hectares (58%) that should be rewetted and extensified by 2030. Rewetting will be given priority for using Common Agricultural Policy (CAP) funds.

Germany's National Peatland Protection Strategy foresees 5 Mt CO_2e emission reduction from drained peatlands by 2030, which is c. 10% of the current total emissions from drained peatlands. Some €4 billion Euros shall be spent on natural climate solutions in 2022-2026, including ~€2 billion Euros for peatland restoration/paludiculture. Since its first presentation in 2019, the 'Peatland GHG transformation pathway' served as a key element to shape the peatland policy discussion in Germany, Fig. 5.13). Similar pathways are in preparation for other European countries.

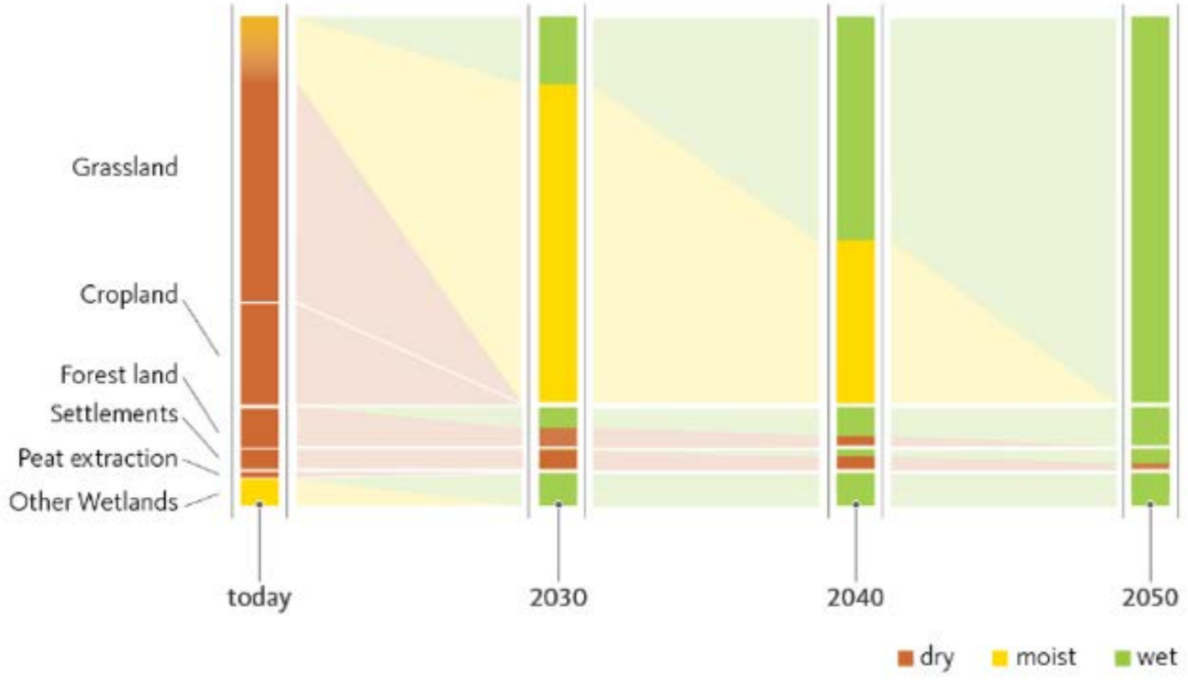

Figure 5.13. Net zero CO_2 emission pathway for organic soils in Germany visualising transformation by land use category (in % of total area of organic soils) over the period 2020–2050 (pathway 1). Dry=deep-drained, moist=shallow-drained (mean annual water table ~ 30 centimetres below soil surface), wet=undrained/rewetted (mean annual water table at the soil surface).

5.5.1.1. The EU Policy Framework

The European Green Deal, the new proposal for a Nature Restoration Law and the EU Soil Strategy 2030 (European Commission 2021) provides the policy framework for addressing sustainable peatland management in the EU. They provide the coordination among the various sectorial EU policies previously addressing peat management in an uncoordinated manner. The new proposal for a Nature Restoration Law (European Commission 2022) contains peatland restoration targets for habitats already covered by EU nature protection legislation, as well as for drained agricultural peatlands. For organic soils in agricultural use constituting drained peatlands, Member States shall put in place restoration measures. Those measures shall be in place on at least:

(a) 30% of such areas by 2030, of which at least a quarter shall be rewetted,

(b) 50% of such areas by 2040, of which at least half shall be rewetted,

(c) 70% of such areas by 2050, of which at least half shall be rewetted.

Member States can choose from a wide range of restoration measures for drained peatlands in agricultural use. These include converting cropland to permanent grassland, extensification measures accompanied by reduced drainage, full rewetting with the opportunity of paludicultural use or the establishment of peat-forming vegetation. Funding for measures to restore and rewet drained peatlands and to compensate possible losses of income can come from a wide range of sources, including expenditure under the European Union budget and European Union financing rogrammes.

The CAP is the EU's largest public funding mechanism for cultivated lands, listing crops and land uses/cultivation methods eligible for payments. The new CAP (2023-2027) will include a better funding framework for rewetted peatlands and paludiculture, but still continues to fund agriculture on drained peatlands. A new 'Good Agricultural and Environmental Condition' will explicitly state that each Member State must ensure appropriate protection of wetland and peatland areas for their important role as stores of carbon. Some good practices, such as grassland maintenance, bans on drainage and bans on burning could be considered as a minimum and appropriate protection. Furthermore, rewetting techniques to remediate past degradation of drained peatlands, paludiculture or other agricultural practices resulting in carbon sequestration in these areas could be financially supported with additional CAP payments via Eco-scheme and/or rural development interventions. In addition, the EU carbon farming initiative and legislative proposal for carbon removal certification will establish an economic incentive for farmers and land managers to reduce emissions and increase the carbon sink.

5.5.2. Options for Action

Peatland protection and restoration towards natural functioning is essential for cost-efficient climate change mitigation and for maintaining biodiversity and water related services. Scientific evidence showing that peatlands restoration re-establishes ecological processes, protects biodiversity and improves carbon storages is accumulating but further evidence is still needed.

Both raising the water level in managed peatlands for more sustainable use in forestry and agriculture, and restoration for protection, should be considered across the region. In many cases, return to natural peatland may not be possible due to severe degradation, but partial restoration of peatland ecosystem functions such as reduced carbon emissions, regulation of water flow/sedimentation retention may.

Rewetting of managed peatlands for paludiculture of agricultural crops or native trees has the potential for a more sustainable use of degraded peatland ecosystems as it provides relatively rapid greenhouse gas mitigation while maintaining income for farmers and landowners. Therefore, it may provide an immediately available socially acceptable pathway to achieve the goal of carbon neutrality on large land areas.

Management with the aim to rise the water level in peatland forests and agricultural peatlands that decreases but does not halt peat loss, i.e., by reducing drainage intensity in situations where full rewetting is not possible, provides some climate benefit. Engagement of, and support to, local communities in making use of new policies and initiatives for sustainable peatland use are relevant for enabling transition to a climate-neutral and resilient society. In countries with small-scale landownership settings, e.g., Ireland, Poland and Ukraine, dedicated local peatland management is particularly vital.

5.5.3. Hotspots of Response

5.5.3.1. Collaboration in Ireland

Ireland is a global hotspot for peatlands, with over 20% of the national territory covered by peatland or peat soils (Connolly and Holden 2009). Drainage of peatlands for agricultural use and peat extraction has been ongoing for centuries. From the 1970s, land conversion became more intensive with additional drainage and planting for commercial afforestation use, alongside a trend towards more intensive peat extraction for domestic use (in addition to the already well-established industrial peat extraction for electricity and horticultural use), intensification of grazing in the uplands by sheep and in more recent years, development of peatlands for renewable energy infrastructure. Together these land uses, driven by EU and national policies across agriculture, energy and forestry sectors, have resulted in the degradation of more than 80% of Irish peatlands (Connolly 2018) with emergent recreational pressures in amenity focused upland areas (Farrell *et al*. 2021). All peatland habitat types, listed under Annex I of the EU Habitats Directive, are considered to be in an unfavourable-bad conservation status since the start of reporting (National Parks and Wildlife Service [NPWS] 2019) with those areas outside of the EU Natura 2000 conservation network largely classified as degraded peatland types (such as eroding bog and/or cutover bog) (Farrell *et al*. 2021).

Changes in land use and the degraded nature of Irish peatlands are well documented (Clarke 2010; Connolly 2018; NPWS 2019). However, there has been a growing awareness since the 1980s of the need to conserve the best remaining examples of peatlands in Ireland. This was one of the main drivers of the extensive Irish peatland areas designated within the EU Natura 2000 network. A National Peatland Strategy developed in 2015 outlines a number of steps to reverse degradation and promote peatland conservation and restoration. It highlights the role of state forestry and peat extraction companies in leading the restoration of commercial afforested peatlands and industrial extraction sites. Despite this, there is much work to do to bring Irish peatlands back to good health. A number of collaborative efforts have emerged in recent years supported by state's Department of Agriculture, Food and the Marine (2020). These collaborations involve direct engagement between peatland ecologists, land managers, farm advisors, catchment scientists and local farming communities. A leading example is the Pearl Mussel European Innovation Partnership project (Pearl Mussel Project 2018). This project developed a results based agri-environment payment scheme (Result-Based Agri-environment Payment Schemes [RBAPS] n.d.) to reward farmers for managing their lands for good peatland habitat quality. As a result of the improved peatland condition, related peatland ecosystem services such as water quality and flow regulation were also improved helping to support EU Annex IV species such as *Margaritifera margaritifera*, the freshwater pearl mussel.

The RBAPs approach is now being extended to wider blanket bog peatland catchments through leading edge research collaborations such as the EU LIFE IP Wild Atlantic Nature (2022), which is working to raise awareness on the values of peatlands to society. Other projects are developing policy solutions for peat soils drained for agricultural use (such as the FarmPEAT EIP project) (FarmPEAT n.d.) with others working to increase awareness on the social and cultural values of Ireland's industrially cutaway bogs (Peatlands and People n.d.). Communities are also increasingly getting involved and the Community Wetlands Forum (Community Wetlands Forum n.d.) established in 2013, is supporting local groups to conserve, restore and appreciate their local peatlands. The state is also supporting rewetting of former state owned Bord na Móna (the Irish Turf Board) peatlands (Department of the Environment, Climate and Communications 2020) from the perspective of reducing carbon losses. Each of these initiatives highlights the role of peatland restoration from a number of perspectives, including the reduction of carbon losses from drained peatlands (Renou-Wilson *et al*. 2019; Wilson *et al*. 2022), the improvement of water quality and regulation of water flows and benefits for biodiversity while also providing cultural ecosystem services to local and broader level communities (Farrell *et al*. 2021). Restoration and/or broader management programmes and peatland strategies clearly require careful planning and consideration of the full array of ecosystem services provided by peatlands from provisioning, regulatory and cultural perspectives.

In 2021, a benchmark event in Ireland highlighted the need and benefits of bringing a wide array of peatland interested people together in a positive and progressive engagement to facilitate necessary and immediate cross sectoral dialogue between government bodies and regulatory agencies (particularly those responsible for farming, water, biodiversity, archaeology, and rural development) in relation to peatlands from the perspective of their restoration and the future security of the benefits derived from peatlands.


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5.5.3.2. Finland: How to Manage Peatland Forests Sustainably?

Finland has one of the highest proportions of peatlands in Europe and in the world, originally 10.2 million hectares, 30% of country's land area. Drainage has been quite recent. In the 1950s, 86% of the country's peatland area was undrained. Now 55% of the peatland area is drained, predominantly for forestry (93% of drained peatland area) (Turunen and Valpola 2020). Peatland forests contribute to one quarter of the growing stock and annual increment and thus have high importance to the forestry industry and contribute to the local and national economy with more than 600,000 private forest owners (Finland's ministry of Agriculture and Forestry 2022). Currently, the drained peatland forests are an overall net carbon sink owing to the increasing carbon stock of trees and owing to the majority of the soils that sequester more carbon than they release to the atmosphere on an annual basis (Statistics Finland 2020). In the most nutrient-rich drained peatland forests, soils are a net carbon source (Ojanen *et al*. 2013). Sustainable management of nutrient rich peatland forests can reduce GHG emissions from peat soil. In Nordic countries, forests are managed conventionally by applying rotational even-aged forestry. There is a 60–100-year-long stand rotation that is followed by clearcutting and ditch network maintenance, which ensures the regeneration of the next tree stand (Päivänen and Hånell 2012). After clear-cutting, sites become emission hot spots (Korkiakoski *et al*. 2019). Continuous cover forestry (CCF) such as harvesting by strip and selection cuttings maintains a forest canopy with a post-harvest carbon sink of trees and attenuates the changes in soil water level. Thus, CCF has the potential to reduce soil CO_2 emissions and prevent CH_4 emissions from peat if the water level remains ~ 30 centimetres deep (Nieminen *et al*. 2018; Leppä *et al*. 2020). Cost–benefit analysis enables to give up maintaining ditch network discarding ditch network maintenance plans in sites where clearing the existing ditches would only produce adverse environmental effects without any economic gain (Juutinen *et al*. 2020; Laurén *et al*. 2021). Currently, long-term effects of wood ash fertilization on peat soil properties and GHG emissions are actively studied (Huotari *et al*. 2015; Lehtonen *et al*. 2021). Lessons learned from sustainable management in Finland are relevant across Northern Europe, where peatland forestry is commonly practiced, including in Nordic and Baltic countries, the UK and Ireland.

5.6. Knowledge Gaps

5.6.1. Peatlands' status in the region

A recent analysis of the area of peatlands under agricultural use in 28 European countries suggested that 15 countries underestimate the area of organic soils in their National Inventory Reports (NIR) compared to data of the European Peatland map (Martin and Couwenberg 2021). At the regional level, the extent of agricultural peat soils was estimated to be 37%, 1.6 million hectares larger than presented in the NIRs. Poor mapping of organic soils may lower the accuracy of GHG emission reporting (Martin and Couwenberg 2021). National GHG inventories should report GHG emissions from organic soils, but most countries are unable to do so and reported estimates are highly uncertain. This challenges monitoring efforts and implementation of international climate agreements.

The assessment of biodiversity of peatlands is limited in Europe to the ecosystems and habitats. There is a knowledge gap at the species level for almost all groups except birds and vascular plants and a major gap for invertebrates, fungi and microbes. There are also considerable data gaps with respect to peatland hydrology and its integration into basin hydrology and the status of the peat deposits.

5.6.2. Peatlands' contributions to people and policies

The contributions to people of highland peatlands through the protection of biodiversity and ecosystem services (like the regulation of natural water sources) are disproportionately high in relation to their area. These peatlands are neither properly recognized in regional mire classification nor appropriately addressed in the peatland conservation and restoration strategies. Examples include Ural Mountains and Arctic and subarctic highlands. Even in EU countries, the relevant policies may not apply to highland peatlands as they are overlooked in the inventories.

Peatland policies and conservation efforts should be gender-responsive ensuring that both women and men benefit from their services and contribute to their development. Peatland wise use policies at local, national, regional, and global levels could be based on the natural capital concept. No European country has completed national inventories of peatlands ecosystem services as part of natural capital accounting, but significant steps have been made in Ireland by the National Statistics Office and research communities (Farrell *et al*. 2021), the UK and Finland. Peatlands (or wetlands) are referred to in almost all national inventories of ecosystem services that EU countries have been requested to provide within the EU Biodiversity Strategy to 2020 (2011-2020). The second step, valuation of the ecosystem services, has been rarely applied to peatlands. The third step, the development of mechanisms for payment of ecosystem services in Europe is in its infancy (cf. a UK pilot project, see Reed *et al*. 2013). Integration of ecosystem services in the economies requires developing financial, fiscal, certification, eco-compensation and other mechanisms.

CHAPTER 6

Regional Assessment for Latin America and the Caribbean

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CHAPTER 6

Regional Assessment for Latin America and the Caribbean

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Regional Highlights

Key Facts

KEY REGIONAL DATA PRODUCED FOR THE GLOBAL PEATLANDS ASSESSMENT 2022[1]	
Total peatland area (hectares)	63,373,122 ha
Peatland cover over total region surface area (%)	3.2%
Degraded peatlands (%)	3.1%
Annual GHG emissions from peatlands (Megatons of carbon dioxide equivalent emissions per year)	91.1 Mt CO_2e / yr
Undegraded peatlands (%)	96.9%
Peatlands within protected areas (%)	25.7%
Top 5 Countries with largest peatland area (hectares)	1. Brazil (26,019,489 ha) 2. Peru (7,651,400 ha) 3. Colombia (5,407,898 ha) 4. Venezuela (5,307,400 ha) 5. Argentina (3,031,659 ha)
ADDITIONAL DATA	
Total peatland carbon stock[2,3] (Megatons of carbon)	20,846 Mt C
Threatened peatland species[4] (VU = vulnerable; EN = endangered; CR = critically endangered)	Flora: 3 VU, 7 EN, 2 CR Fauna: 68 VU, 49 EN, 32 CR
Ramsar Wetlands of International Importance with peat[5]	45 sites (21.2% of total Ramsar sites in Latin America and the Caribbean)

[1] Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

[2] Joosten, H. (2009). The Global Peatland CO_2 Picture. Peatland status and drainage associated emissions in all countries of the World. Wetlands International, Ede, 10 p. + tables.

[3] Hastie, A. *et al.* (2022). Risks to carbon storage from land-use change revealed by peat thickness maps of Peru. Nature Geoscience. 15. 1-6.

[4] Data extracted from the IUCN Red List of Threatened Species.

[5] Data extracted from the Ramsar Sites Information Service.

The intensity of human impacts on peatlands in the Latin America and the Caribbean region (LAC) varies greatly, from relatively intact peatlands that require protection, to highly degraded peatlands that require restoration, with a total peatland area of more than 63 million hectares, representing 12.9% of global peatlands. Wet peatlands are intrinsically valuable for all communities, cultures, and traditional lifeways in LAC and support the livelihoods of many people.

Peatlands provide habitats for several species and numerous ecosystem services including carbon storage, hydrological regulation, and climate change adaptation and mitigation, and should be a priority for conservation and restoration. LAC peatlands are poorly protected and increasingly under threat from degradation via resource extraction, mining (incl. peat), changing climate, infrastructure, overgrazing, drainage, fire, invasive species, conversion to agriculture and urbanization. Timely protection and management can avert the impacts of these threats if action is taken now.

LAC peatlands are poorly characterised in many regions and research is critically needed to assess their biophysical and socioeconomic traits to help inform decision making, conservation, restoration, and sustainable management. There is an urgent need to improve education about LAC peatlands as they are not well recognised in the region. Sustainable management of peatlands, using traditional and scientific knowledge, needs to be further developed to increase the safety and well-being of the human population. Additionally, specific efforts need to be made to ensure peatland management is gender-responsive and that peatland benefits are derived by the whole of society. Furthermore, peatlands need to be integrated into policy to ensure they are adequately managed and protected.

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6.1. Biomes and Ecological Zones

Peatlands are found across Latin America and the Caribbean (LAC region) in three main ecological zones: (sub)tropical lowlands, (sub)tropical mountains, and temperate systems in Patagonia (see Table 6.1 and Global Ecological Zones maps in Annex IV – Figs. IV.1, IV.13, IV.15, IV.19, IV.20, IV.21). Fig. 6.1 shows the distribution of peatlands in the region in aggregated FAO Global Ecological Zones.

6.1.1. (Sub)tropical Lowlands

6.1.1.1. South America

In the lowlands, peat forming ecosystems exist either inland as palm swamps, open herbaceous swamps or pole forests, and in coastal areas as mangrove forests (Fig. 6.9). Peatland ecosystems are dominated by a few key species, including the palm *Mauritia flexuosa* in palm swamps and open herbaceous swamps and the trees *Pachira nitida* (Malvaceae) and *Platycarpum loretense* (Rubiaceae) in pole forests (Draper *et al*. 2014; Honorio Coronado *et al*. 2021). *M. flexuosa* palm swamps occur in all countries of the Amazon basin and within savannahs in riverine areas and waterlogged depressions in Venezuela, Guyana, Suriname and Brazil (Alencar-Silva and Maillard 2011; Table 6.1). Peat also occasionally forms in seasonally flooded forest (Hastie *et al*. 2022). Large belts of mangrove forests are located along the Caribbean coast from Colombia to Northern Brazil, dominated by *Rhizophora mangle* (Franchi *et al*. 2006; Vegas-Vilarrúbia *et al*. 2010; Ezcurra *et al*. 2016; Ward *et al*. 2016) and along the northern Pacific coast of South America from Peru to Colombia. However, further research is needed to determine the extent of peatlands within this mangrove forest belt. Coastal vegetation often transitions from mangrove forests into *M. flexuosa* palm swamps when moving inland (Aslan *et al*. 2003; Cubizolle *et al*. 2013).

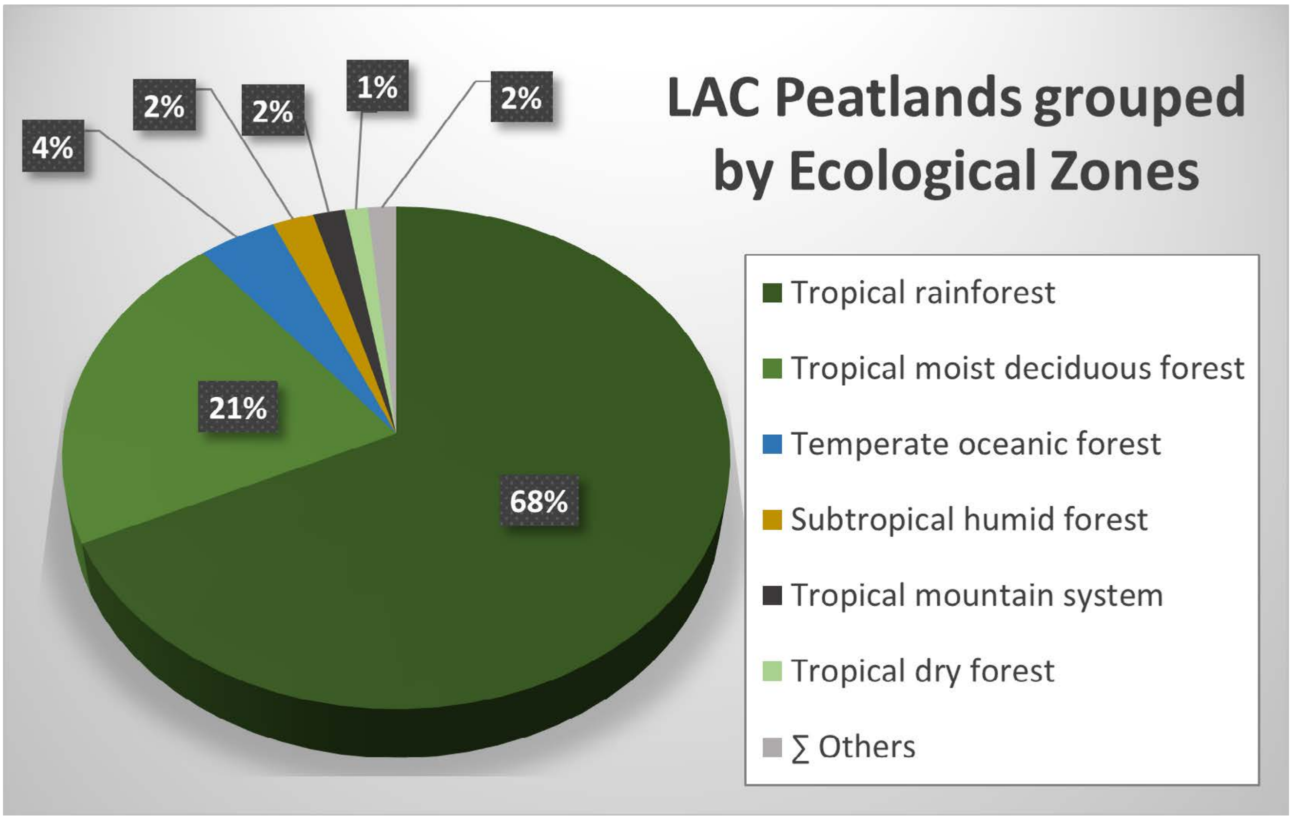

Figure 6.1. The distribution of peatlands in Latin America and the Caribbean (LAC) in aggregated FAO Global Ecological Zones. Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

6.1.1.2. Central America & Caribbean

In Central America and the Caribbean, peatlands are predominantly located along the Caribbean coast from the Yucatan peninsula, Mexico to Panama as well as in the Antilles islands like Cuba. They have a highly diverse vegetation including mangroves (*Rhizophora mangle, Laguncularia racemosa, Avicennia germinans*; Table 6.1), *Raphia taedigera* dominated palm swamps, stands of mixed woody species (including *Campnosperma panamensis* and *Symphonia globulifera*), forested swamps dominated by *Pachira aquatica, Annona glabra, Ficus* spp., *Attalea liebmannii* and *Roystonea dunlapiana* (Infante Mata *et al*. 2011; Moreno-Casasola *et al*. 2012; Rincón-Pérez *et al*. 2020) and open herbaceous swamps (with *Typha domingensis, Thalia geniculata, Pontederia sagittata, Cyperus giganteus, Cladium jamaicensis,* and *Eleocharis* spp.) (Cohen *et al.* 1995; Phillips *et al.* 1997; Moreno-Casasola *et al.* 2010; Campos *et al.* 2011; Peters and Tegetmeyer 2019).

6.1.2. (Sub)tropical Mountains

6.1.2.1. Andes

Geographic, topographic, and climatic factors, as well as water and soil characteristics, determine the peat-forming vegetation types (Table 6.1) and their functional ecosystem processes in the Andes (Chimner *et al*. 2019). Cushion peatlands are found at high elevations from nutrient poor-acidic environments to mesotrophic and alkaline sites. Some species need high rainfall and limited periods of drought (e.g., *Distichia muscoides)* while others better withstand the water deficit and could be resistant to salinity (e.g., *Oxychloe andina*). Sedge and *Sphagnum* dominated peatlands are found at lower elevations. In the dry Puna[1], sedge communities could be more stable productively than cushions and have a higher water table (*Eleocharis* spp; *Phylloscirpus acaulis*) or higher salinity and lower humidity (*Amphiscirpus nevadensis*) (Izquierdo *et al*. 2022). *Sphagnum* dominated peatlands are restricted to the Jalca and Paramo ecosystems, in acidic low nutrient environments and resemble boreal bogs and poor fens. Sedge and grass-dominated peatlands are found in wet, nutrient-rich sites and are similar to rich fens (Cooper *et al*. 2010; Ruthsatz 2012; Benavides and Vitt 2014; Izquierdo *et al*. 2020).

6.1.2.2. Guayana, Central American and Central East Brazilian Highlands

In the Guayana Shield, peatlands originate directly atop the rocky surface (1600-2900 m.a.s.l.; Zinck and Huber 2011), as well as in depressions, small valleys, narrow tectonic crevices and fissures, and narrow floodplains, and on slopes. Peat is usually found in tepuian meadows and shrublands, where rain and runoff waters concentrate (Zinck and Huber 2011). The tepui shrubland, dominated by endemic *Chimantaea* spp., is physiognomically and floristically comparable to the Andean Paramo (Huber 1989), with carnivorous plants and endemic *Sphagnum* spp. (Desamore *et al*. 2010).

Peatlands in Central American highlands are found along the continental divide of the Cordillera de Talamanca and restricted to small and poorly drained depressions subject to seasonal flooding (Jimenez 2016). Species are typically distributed in a zonal pattern that relates to the water depth (Jimenez 2016), with herbaceous flowering plants, *Sphagnum* spp., tree ferns, tussock grasses, and shrubs (Kappelle and Horn 2016).

The Southern Espinhaço Mountain Range (SdEM) is a large plateau (1200-2000 m. a.s.l.), forming a biogeographic barrier between the Atlantic Forest and Cerrado biomes in Brazil (Davis *et al*. 1994; Almeida-Abreu *et al*. 2005; Silveira *et al*. 2016). Vegetation is dominated by wet grasslands, with endemic species (Mendonça 2005) such as *Actinocephalus coutoensis* and *Paepalanthus diamantinensis*, alongside islands of seasonal semi-deciduous high-montane forests, called 'capões de mata', with peat forming in waterlogged depressions. These are old peatlands with >6m deep peat that began forming around 43,000 years B.P. (Horák-Terra *et al*. 2014; Horák-Terra *et al*. 2020; Silva *et al*. 2020).

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[1] Paramo is characterised by cool and wet conditions with no distinct dry season, whereas the Puna has progressively stronger seasonality moving south from Peru to Bolivia. The Jalca is transitional between the Paramo and Puna (Cooper *et al*. 2010; Chimner *et al*. 2019).

6.1.3. Patagonia

Patagonia encompasses a vast territory in southern South America (Argentina and Chile), between 36oS and 56oS, where peatlands are found on plains and mountains, from the hyper-humid Pacific islands to the semiarid steppe, resulting in significant differences in peatland types, scale, and distribution. Patagonian peatlands are influenced by the rainfall gradient generated by the Andes Mountains, with precipitation ranging from more than 3000 mm per year on the Chilean coast to less than 300 mm per year behind the extra-Andean steppe border (Smith and Evans 2007). In the humid Temperate Mountain region, peatlands are cushion bogs dominated by vascular plants in wind exposed coastal areas with sea spray inputs, or ombrotrophic *Sphagnum magellanicum* bogs, generally found in valley bottoms. Both peatland types can reach 12 m depth in southernmost Patagonia; however, cushion bogs in the western continental area and Pacific Archipelago rarely exceed 1.5 m (Pisano 1977; Domínguez *et al*. 2015). In addition, minerotrophic fens are found in areas with groundwater outcrop. In Chiloe Island, Chile, anthropogenic peat bogs (pomponales) exist in areas of high rainfall where *Sphagnum* communities have replaced the former forest ecosystem altered by human activities. The wide temperate steppe extends east of the Andes and in northern Tierra del Fuego (TDF). Minerotrophic fens, dominated by sedges and grasses, are the common peatland type in this region, found in land depressions fed by groundwater. Fens are known as “vegas” or “mallines”, however, these terms also apply to wet meadows that do not accumulate peat. Peatlands spread also on the islands of the South Atlantic Ocean under very oceanic and windy conditions. Tussock vegetation dominated by *Poa flabellata* colonizes the coastal areas and forms peat deposits with a maximum depth of 13 m (Smith and Clymo 1984; Smith and Karlsson 2017).

6.2. Peatland Distribution and Extent

Knowledge on peatland distribution has improved thanks to landscape level efforts to map the distribution of peat forming ecosystems and peat thickness in the lowlands (Draper *et al*. 2014; Honorio Coronado *et al*. 2021; Ribeiro *et al*. 2021; Hastie *et al*. 2022), mountains (Izquierdo *et al*. 2015; Izquierdo *et al*. 2016; Chimner *et al*. 2019; Ministerio del Ambiente [MINAM] 2019), and Patagonia (Iturraspe *et al*. 2012). In the region, peat forming ecosystems do not systematically overlay peat therefore a distinction between peatlands and peat forming ecosystems is important. Peatlands are rarely mapped or identified in the LAC region at the national level whereas peat-forming ecosystems are usually included in surveys, guidelines, inventories. Thus, these peat-forming ecosystems are essential as a source of information, policy, conservation and restoration efforts for peatlands. Recently, efforts to map peatland degradation (Hergoualc’h *et al*. 2017) and the effect of land-use change on carbon stocks (Hastie *et al*. 2022) have also taken place, however these are scarce.

To date, global peatland mapping efforts (Gumbricht *et al*. 2017; Xu *et al*. 2018) do not include (sub) tropical mountain or Patagonian peatlands in the LAC region, hindering a good understanding of peatland distribution. Figs. 6.6 and 6.7 show the peatland distribution in both the Caribbean and South America sub-regions, partly including organic soils, as per the Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Fig. 6.8 shows that Brazil (26,019,489 ha), followed by Peru (7,651,400 ha), Colombia (5,407,898 ha), Venezuela (5,307,400 ha) and Argentina (3,031,659 ha) are the top 5 countries with the largest peatland area, according to the the Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Table 6.1 Peat forming vegetation and ecosystem types, their local names and location according to current and FAO ecological zone classification.

GPA Ecological Zone	FAO Ecological Zone	Vegetation/Ecosystem Type	Local Name	Location
(Sub)Tropical Lowlands (< 800 m.a.s.l.)	Tropical rainforest	*Mauritia flexuosa* palm swamps	Aguajales (Peru), Cananguchales (Colombia), Morichales (Colombia, Venezuela), Buritzales (Brazil), Ité palm marshes (Guyana), marais de palmier bâche (French Guiana), maurisie zwampbos (Suriname)	Amazonia (Colombia, Ecuador, Peru, Brazil, Venezuela, Bolivia, Guyana, French Guiana, Suriname)
	Tropical rainforest	Pole forest	Varillales (Colombia), Varillales hidromórficos (Peru)	Amazonia (Colombia, Peru)
	Tropical rainforest	Herbaceous swamp Freshwater marshes (*Typha domingensis, Sagittaria lancifolia, Pontederia sagittata, Thalia geniculata, Cyperus* spp.)	Pantano Abierto or Pantano herbáceo arbustivo (Peru, Colombia), Cortadera (Panama) Popal-Tular (México)	Amazonia, Central America (Panama), México, Guatemala
	Tropical rainforest	Seasonally flooded forest	Varzea (Colombia), Tahuampa (Peru)	Amazonia
	Tropical shrubland	*Mauritia flexuosa* palm swamps within savanna grassland	Veredas, Varzea (Brazil) Cananguchales (Colombia), Morichales (Colombia, Venezuela)	Colombia, Venezuela & Brazil
	Tropical rainforest	Mangrove *(Rhizophora mangle, Laguncularia racemosa, Avicennia germinans, Conocarpus erectus)*	Manglares	Coastal regions (Peru, Colombia, Venezuela, Brazil, Guatemala, México, El Salvador. Belize)
	Tropical rainforest	Freshwater swamp *(Pachira aquatica, Annona glabra, Roystonea dunlapiana, Ficus* spp., *Dalbergia* spp, *Attalea liebmannii, Pterocarpus officinalis, Raphia taedigera, Haematoxylum campechianum)*	Selvas inundables, selvas de corcho, apompales, zapotonales, tintales	México, Guatemala, Belize, Honduras, Nicaragua, Costa Rica, Panama
(Sub)Tropical Mountains (1000 – 4800 m.a.s.l.)	Tropical mountain systems	Cushion peatlands (*Oxychloe, Distichia, Oreobolus, Plantago*, etc.) *Sphagnum* peatlands Sedge and Rush dominated (*Juncus, Eleocharis, Carex, Phylloscirpus*, etc.) Tussock grass dominated (*Calamagrostis, Cortaderia*, etc.) Lake ecosystems (*Schoenoplectus*) *Chusquea* (Poaceae) dominated	Turbera (Colombia, Ecuador, Venezuela), bofedal, oconal, juku (Peru, Ecuador, Bolivia), totoral (Peru, Bolivia), vegas y mallines (Chile, Argentina) Chuscales (Colombia), paramillos, turberas de altura (Costa Rica)	Andes (Colombia, Ecuador, Peru, Bolivia, Chile, Argentina), Venezuela, Costa Rica, Panama
	Tropical mountain systems	table-mountains, sandstone–quartzite mesetas, Inselbergs, tepuian meadows, tepuyan shrublands, tepuian grasslands	Turberas tepuyanas	Venezuela, Brazil, Guyana and Colombia
	Tropical mountain systems	Wet grasslands Seasonal semideciduous forest ("capões de mata")	Brejo, terra preta	Brazil
Patagonia	Temperate Mountain	Raised bogs (*Sphagnum* spp.)	Turberas de *Sphagnum* Esfagnosas	Argentina, Chile
	Temperate Mountain	Cushion bogs or pulvinated peatlands (*Astelia* spp., *Donatia* spp.)	Turberas compactas Pulvinadas	Chile
	Temperate Mountain	Secondary or anthropogenic peatlands	Pomponales	Chile
	Temperate steppe	Graminoids - cyperaceae fens (*Carex* spp. *Marsippospermun* spp.)	Vegas & mallines	Argentina, Chile

Figure 6.2 Peatlands in the (sub)tropical lowlands.

1: Mauritia flexuosa palm swamp in Loreto, Peru 2: Herbaceous swamp with occasional M. flexuosa in Loreto, Peru 3: Pole forest dominated by Pachira nitida and Platycarpum loretense in Loreto, Peru 4: Mangrove dominated by Rhizophora mangle in Colombia 5: Freshwater swamp and freshwater marsh in Veracruz, Mexico 6: Freshwater swamp with Pachira aquatica in Veracruz, Mexico. Photos: Charlotte Wheeler (1 and 2), Euridice Honorio (3), Kristell Hergoualc'h (4), Dulce Infante (5 and 6)

Figure 6.3 Cladium jamaicense dominated grassland on peat in Ciénaga de Zapata, Cuba with Typha domingensis and Sabal parviflora

Source: Peters and Tegetmeyer 2019.

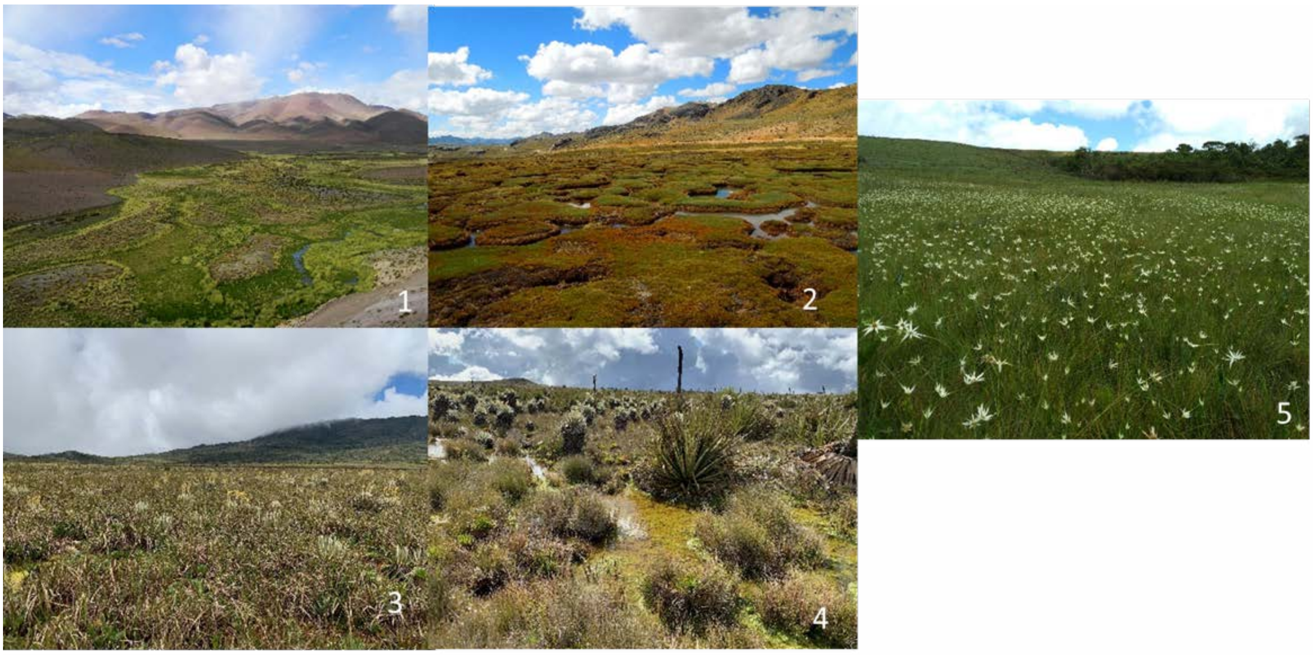

Figure 6.4 Peatlands in the (sub)tropical mountains.

1: Cushion peatland of Oxychloe andina (vega) in Incachule, Salta, Argentina;2: Cushion peatland of Distichia muscoides (bofedal) in Ayacucho, Peru; 3: Sedge peatland in Guatavita region, Colombia; 4: Sedge and Sphagnum peatland in Rabanal área, Colombia; 5: peatland of grasslands and "capões" (Forest) in Central East Brazil.

Photos: Andrea Izquierdo (1), Monica Maldonado (2), Juan Benavides (3 and 4), Alexandre Christofaro (5)

Top-left: *Astelia* cushion bog, TDF-Arg (TM); Top-center: Peninsula Mitre, TDF-Arg (TM); Top-right: Carabajal Valley, TDF-Arg (TM)
2nd line: cipres de las Guaytecas on*Sphagnum* bog, Magallanes-Chile; Gramineous fen, (TS)
Down-Left: Pools on Sphagnum bog, TDF-Arg (TM); Down-Center: Beaver dam beside a peatland (Andorra Valley, TDF- Arg (TM)
Down-Right: Mallin on Santa Cruz River-bank
TM: Temperate Mountain
TS: Temperate steppe

Figure 6.5 Peatlands in Patagonia.

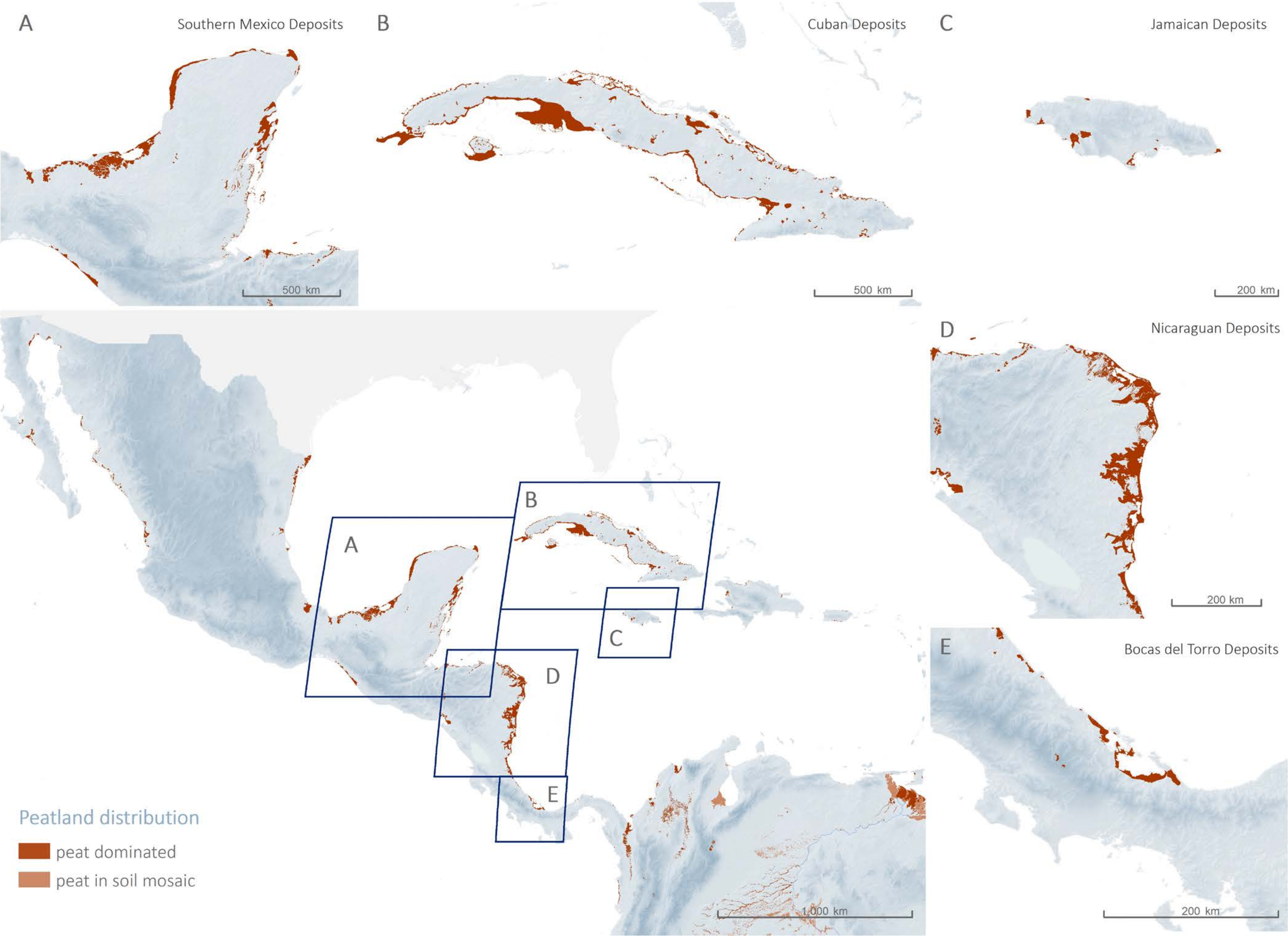

Figure 6.6 Peatland distribution in the Caribbean sub-region (partly incl. organic soils).

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III. Production of the Global Peatland Map 2.0.

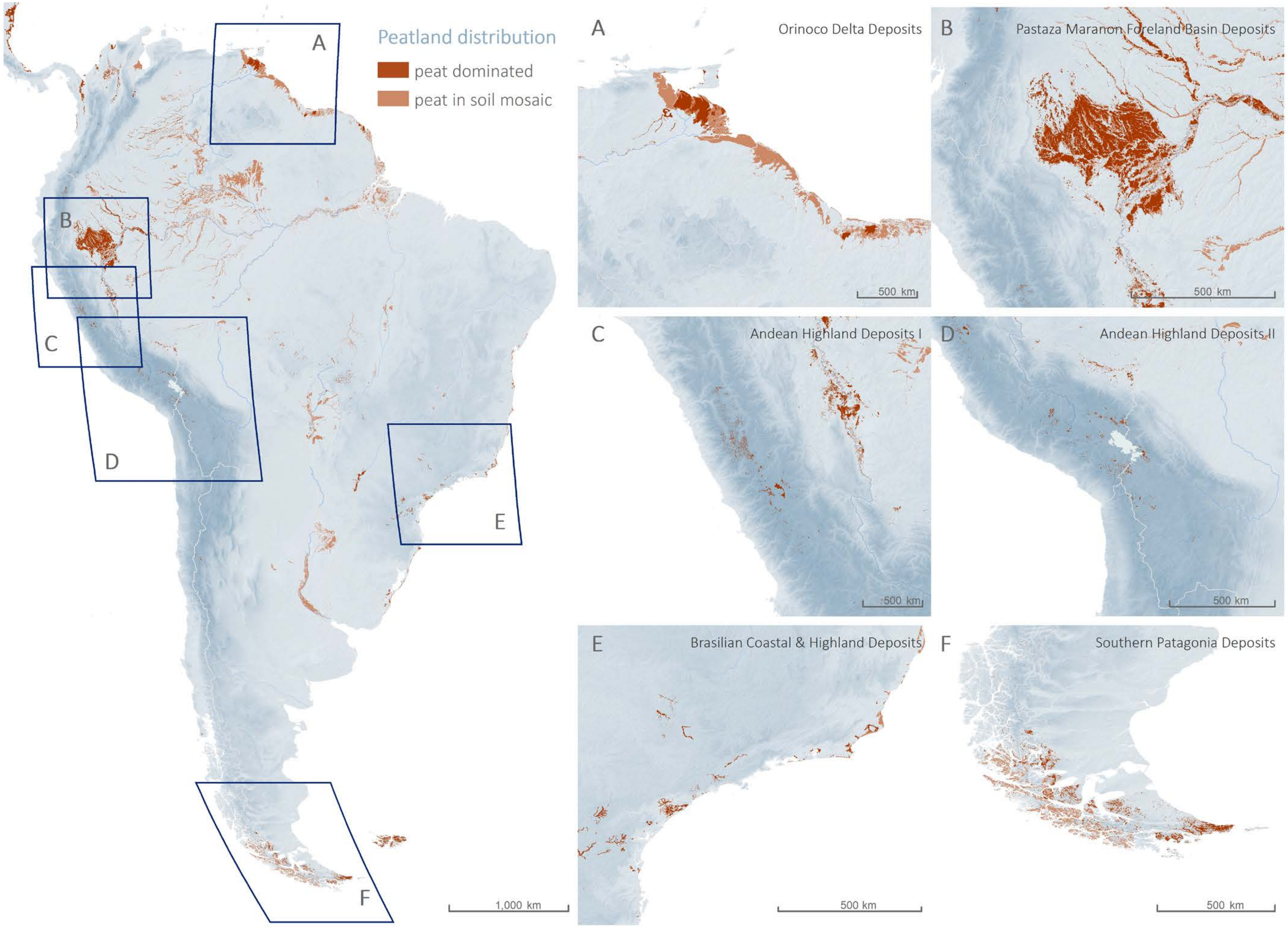

Figure 6.7 Peatland distribution in South America (partly incl. organic soils).

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III. Production of the Global Peatland Map 2.0.

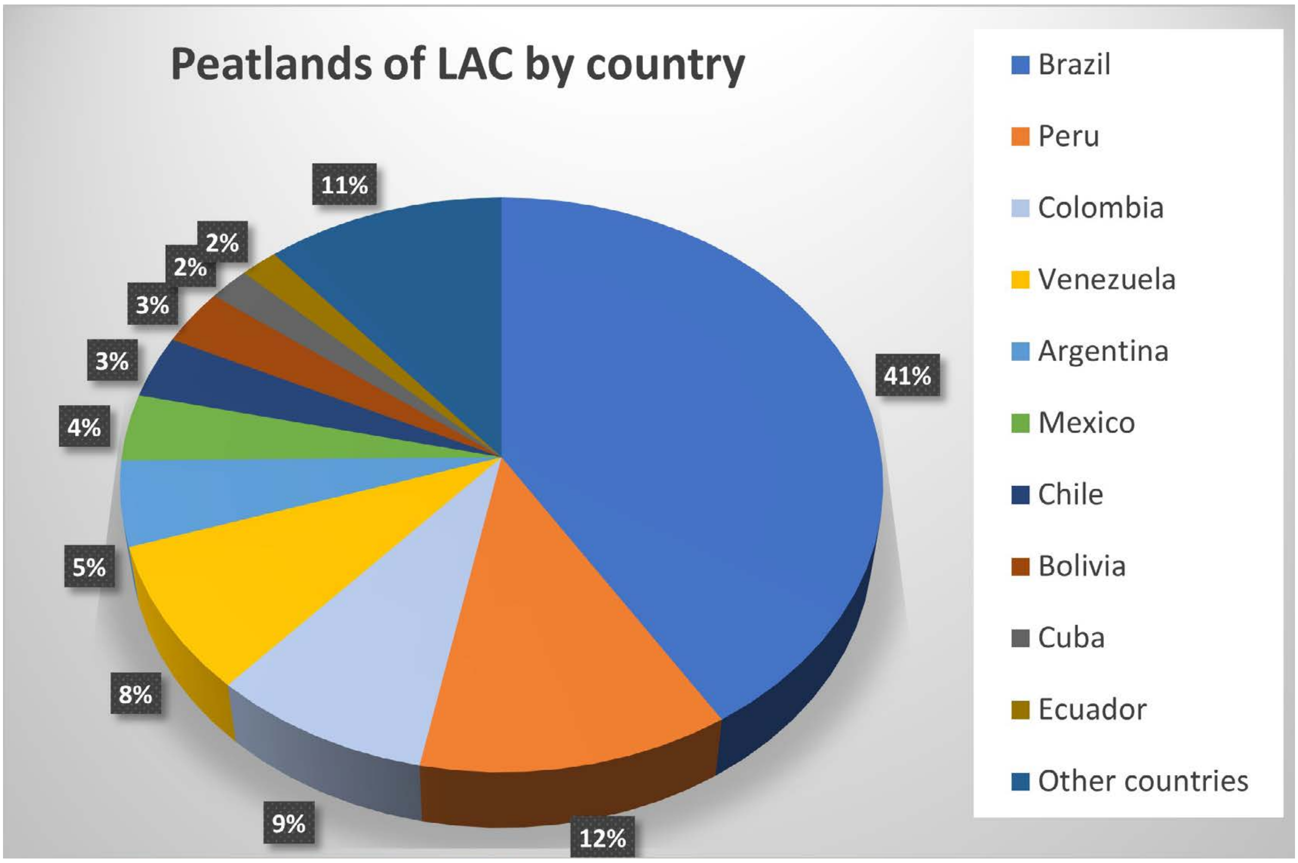

Figure 6.8 Proportion of the total peatland area of Latin America and the Caribbean (LAC) by country.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

6.2.1. (Sub)tropical Lowlands

6.2.1.1. South America

Global mapping efforts (Gumbricht *et al*. 2017) (Fig. 6.9) predict substantial peat deposits across the South American lowlands, with the greatest extent in Brazil, followed by Peru and Colombia (Fig. 6.8). However, these maps have not yet been validated by field data, due to lack of resources, capacities and the remote location of the peatlands. The exception is Peru, where research efforts over the past two decades have greatly improved knowledge of peatland distribution, particularly in the Pastaza-Marañon Foreland Basin (PMFB), the Madre de Dios basin and the Ucayali basin where peat deposits of up to 9 m have been reported (Lähteenoja *et al*. 2009; Lähteenoja and Page 2011; Householder *et al*. 2012; Lähteenoja *et al*. 2012; Draper *et al*. 2014; Bhomia *et al*. 2019; Diaz Cardenas 2019; Honorio Coronado *et al*. 2021). A recent study predicted 6,271,400 hectares of peatlands in lowland Peru (Hastie *et al*. 2022), increasing previous estimates by 42% (Householder *et al*. 2012; Draper *et al*. 2014), with palm swamps accounting for 78% of peatland ecosystems and the predicted extent of pole forests, the most carbon dense peatland ecosystem in Amazonia, increasing by 61% within PMFB (Honorio Coronado *et al*. 2021).

The largest peat deposits in Brazil are predicted in the interfluvial plains of the Rio Negro and Rio Branco and scattered along rivers across the Amazon basin (Figure 6.8; Gumbricht *et al*. 2017). However, the presence of peat in the Rio Negro has only been confirmed by a single study (Lähteenoja *et al*. 2013). *M. flexuosa* palm swamps (‘*Veredas*’) are also found in the drier Cerrado biome, forming in isolated patches along rivers and waterlogged depressions (Fagundes and Ferreira 2016; Chiminazzo *et al*. 2021). However, maps of Veredas are limited to specific sites (e.g., Alencar-Silva and Maillard 2011), with limited knowledge of their distribution and extent across the entire cerrado biome. In the Brazilian coastal plains, peat deposits of both fluvial (abandoned meanders, floodplains) and marine origin (lagoons, mangroves) are found alongside some major rivers including the Paraíba do Sul river, which has particularly deep deposits of up to 6 m (Berquó *et al*. 2004; Franchi *et al*. 2006), and coincides with the most developed and densely populated areas of Brazil, making them susceptible to degradation (Ribeiro *et al*. 2021).

In Venezuela, peatlands are concentrated in the upper Rio Negro near the border with Brazil and Colombia, and in the Orinoco delta (Vegas-Vilarrubia *et al*. 2007). The vegetation across the delta includes mangroves along the coast and river channels, and *M. flexuosa* swamps and herbaceous swamps in the interfluvial plains. The largest peat deposits, some with continuous areas up to 20,000 hectares and peat up to 10 m thick are in the northwest of the delta. Along the coastline of Guyana, Suriname and French Guiana, large peat deposits (Figure 6.4) of up to 9 m have been observed (Warne *et al*. 2002; Aslan *et al*. 2003; SWRIS 2018) which are principally *M. flexuosa* palm swamps.

Lowland peatlands in Ecuador and Colombia are found in the Amazon basin with similar vegetation and geomorphological setting as in Peru (Ruokolainen *et al*. 2001). Peat is found in abandoned meanders or on first order rivers (following Strahler classification, Strahler 1964) with a stable water table but low energy or in subsiding basins (Gumbricht *et al*. 2017).

6.2.1.2. Central America & Caribbean

Assessments of the distribution of Central American and Caribbean peatlands are limited. Studies have predominantly focussed on the Caribbean coasts of Panama, Costa Rica, Nicaragua, and Mexico, although small deposits have been reported more widely across the Caribbean (Page *et al*. 2011; Sjögersten *et al*. 2021). In a regional peatland scoping effort covering areas in Costa Rica, Cuba, Honduras, Nicaragua and Panama, Peters and Tegetmeyer carried out an "Inventory of peatlands in the Caribbean and first description of priority areas" (Peters and Tegetmeyer 2019). Peat forming vegetation is found along the Caribbean coastline, the largest areas have been reported in Panama, the best studied example being the 8,000 hectares ombrotrophic, domed, Changuinola deposit in Bocas del Toro on the Caribbean coast (Phillips *et al*. 1997), Damani-Guariviara (Hoyos-Santillan *et al*. 2016), and along the Atlantic coast in Costa Rica, with peat deposits ranging between 0.5 - 15 m (Obando *et al*. 1995). Peat up to 7 m thick has been reported in Jamaica in a wetland area covering around 220 hectares, as well as on other Caribbean islands (Harty *et al*. 1991). In Mexico, peatlands have been identified in the southern coastal plains, mainly in Veracruz, Tabasco, Campeche and Chiapas states (Rincón-Pérez *et al*. 2020; Sjögersten *et al*. 2021; Cejudo *et al*. 2022).

In Cuba, peatland research dates back to the 1960s, when Soviet peatland scientists performed extensive research on peat deposits (Perejrest 1964). Peatlands can be found mostly along the coastline in river deltas and coastal plains (Voronov *et al*. 1970). The peatlands of Ciénaga de Zapata are the largest areas of peatlands in Cuba and even in the Caribbean region with a potential peatland area of 345,300 hectares (Peters and Tegetmeyer 2019). Pajón *et al.* (2004) indicate a peat depth of up to 7 m and Perejrest (1964) even a peat depth of up to 10 m in the area around Laguna del Tesero, one of the core sites of Ciénaga de Zapata.

6.2.2. (Sub)tropical Mountains

6.2.2.1. Andes

Mountain peatlands are difficult to detect because of the small size of individual peatlands in the area (Lähteenoja and Page 2011; Gumbricht *et al*. 2017). In Figure 6.9, the regional map of mountain peatlands shows the distribution of high-elevation peatlands along the Andes mountain range. Efforts of mapping peatlands in the Andes are ongoing in several countries. In Argentina, peatlands are mapped within the wider framework of mapping ecosystem types, such as the high Andean vegas. The extension of green vegas is between 61,100 to 94,400 hectares (Izquierdo *et al*. 2015; Izquierdo *et al*. 2016). However, these maps do not distinguish which wetland types have peat. Likewise in Peru, the estimated area of bofedales could be as much as ~1,380,000 hectares (López Gonzales *et al*. 2020), about three times the area reported by the government (548,200 hectares, MINAM 2019). The ongoing inventory of bofedales (by the National Institute for Research on Glaciers and Mountain Ecosystems - INAIGEM) will update this number. Ecuadorian peatlands are common throughout the Paramo. They represented 18% of a mapped region in the north-central part (Hribljan *et al*. 2017). In Colombia, peatlands are broadly distributed across the Paramo in the Western, Central and Eastern Cordilleras, preliminary analysis from the central cordillera shows that peatlands cover 5-16% of the landscape (Lilleskov pers. com.). In the Titicaca-Desaguadero-Poopo-Salar de Coipasa System where almost all bofedales of the Bolivian Andes are, their extension is 102,300 hectares (Alzérreca *et al*. 2001).

6.2.2.2. Guyana, Central American and Central East Brazil Highlands

Estimates for Venezuela suggest ~ 150,000 hectares of peatlands in the highlands. The total area of Paramo in Costa Rica and Panama is very small. In Costa Rica peatlands just cover 240 hectares, with the largest patches in the Dúrika sabanas and Cerro Utyum (Jimenez 2016). An estimated 14,300 hectares of peatlands is predicted in the Southern Espinhaço Mountain Range, with individual peatlands ranging from 5 to 840 hectares (Silva *et al*. 2013).

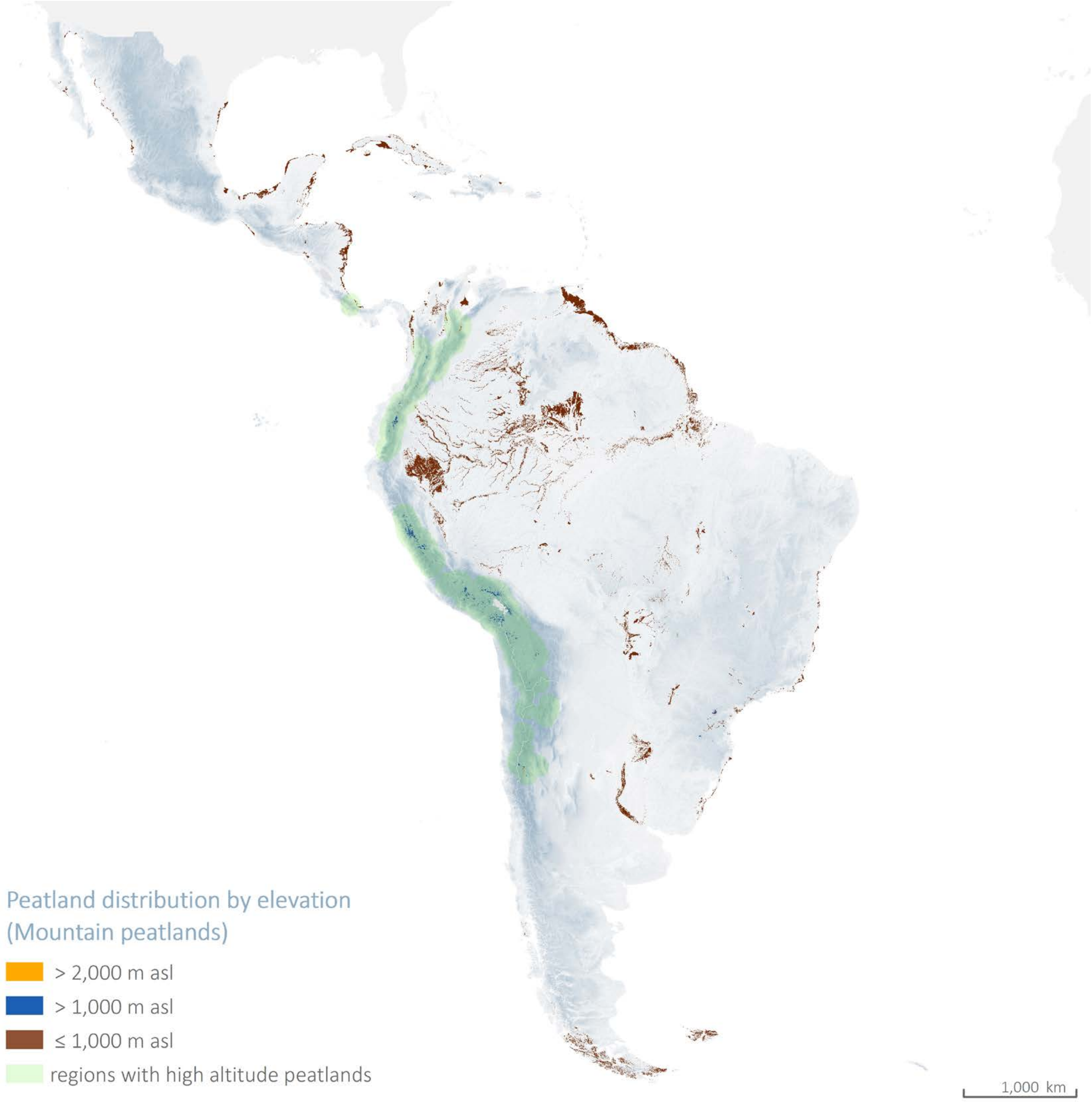

Figure 6.9. Distribution of Latin America and the Caribbean Mountain peatlands by elevation (in meters above sea level).

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III.3 Production of Thematic Maps.

6.2.3. Patagonia

In Chile, peatlands are found from the Araucanía Region to the Magallanes Region (Pisano 1977; Schlatter and Schlatter 2004). Joosten (2009) estimated an area of 1,099,600 hectares of peatlands for Chile. The National Forest Corporation (CONAF) native forest Inventory indicates an area of 3,229,600 hectares of peatlands (Corporación Nacional Forestal [CONAF] 2014), while Xu *et al*. (2018) report 227,600 hectares. It is evident that there is great uncertainty in information and estimates about this type of habitat in the region. The National Institute of Agricultural Research (INIA) of Chile has updated *Sphagnum* bog maps in the Magallanes and Aysén regions, predicting 269,500 hectares in the Magallanes and Antartica Chilena Region (Vega-Valdés and Domínguez 2015) and 15,200 hectares in the Aysén Region (Villarroel *et al*. 2021), with additional unsurveyed areas of cushion bogs, gramineous fens and other peatland types, including *Sphagnum*-dominated areas in the Los Lagos Region.

In Argentina, most peatlands are located in the Isla Grande of Tierra del Fuego (TDF), where they cover an extension of 270,000 hectares (Iturraspe *et al*. 2012). Most of them extend on the eastern sector of this Island, where mire complexes dominate the landscape, in many cases only disrupted by forest islands on mineral soil hillslopes. In the Luz River basin, for example, peatlands cover 82% of the basin area (Iturraspe *et al*. 2012; Lindholm *et al*. 2012). Peatland types and dominant vegetation are very variable in Eastern TDF, forming heterogeneous fen-bogs mosaics, as well as blanket bogs. In the more oceanic environments *Astelia pumila-Donatia fascicularis*-communities have colonised primary *Sphagnum* bogs forming cushion bogs. Deep raised bogs prevail in mountain valleys located south of Lake Fagnano, while cyperaceous-gramineous fens are more frequent north of the lake. The limit for *Sphagnum* bogs distribution roughly matches the 500 mm annual precipitation isoline, while some northern fens occur where yearly precipitation reaches just 300 mm. The only available peatland inventory for TDF concerns a bog-fen-grassland-forest mosaic that extends 35,500 hectares to the east of Lake Fagnano, with a mean depth of 2.6 m, and 20% peatland cover (Roig *et al*. 2001).

In the Argentinean Continental Patagonia, small peatlands spread with low coverage on valley floors of the Andean forest ecoregion, south of 36°S (Carretero 2004; Perotti *et al*. 2005; Chimner *et al*. 2011; Iturraspe and Urciuolo 2021). Minerogeneous fens occur mainly in land depressions of the western sector of the extra-Andean steppe. Decreasing precipitation across the Andes results in a W-E bog-fen-wet meadow succession. No peatland maps are available for this region, for which Iturraspe and Urciuolo (2021) estimate a peatland area between 25,000 – 30,000 hectares. Thus, the full extension of peatlands in the Argentinean Patagonia could be around 300,000 hectares.

6.3. Biodiversity, Nature's Contributions to People and Hotspots of Value

6.3.1. Biodiversity

Peatlands in the LAC region support unique floral biodiversity that is tolerant to waterlogged conditions. Lowland Amazonia peatlands typically have lower tree species diversity than surrounding *terra firme* forest, however as they host a unique flora, these peatlands contribute to high levels of regional diversity (Draper *et al*. 2018; Honorio Coronado *et al*. 2021). High Andean peatlands have characteristic cushion plants, which modify the physical structure of the environment, altering the availability of resources for other organisms (Jones *et al*. 1997; Badano and Cavieres 2006; Badano *et al*. 2007). Patagonian peatlands host an assemblage of plant species typical of acidic conditions and provide unique environments for flora and fauna, including microorganisms.

These unique floral communities provide important habitats for wildlife, with many species found in peatlands under threat (Table 6.2). In lowland palm swamps, *M. flexuosa* provides an important food source for many species (Gilmore *et al*. 2013), such as the Lowland Tapir (*Tapirus terrestris*), which is also an important seed disperser (Tobler *et al*. 2010) and provide nesting sites for species such as the Blue and Yellow Macaw (*Ara ararauna*) (Brightsmith and Bravo 2006). Mangroves, freshwater swamps and marshes also provide nesting sites for migratory birds, habitat for crocodiles, turtles (Moreno-Casasola *et al*. 2012) and mammals such as jaguars, monkeys and raccoons (Diario Oficial de la Federación [DOF] 2000; Hernández Hernández *et al*. 2018; Pozo-Montuy *et al*. 2021), as well as various species of fish such as the Alligator Gar, 'Pejelagarto' (*Atractosteus tropicus*) (Gómez González *et al*. 2012). Caribbean peatlands, specifically the one in Cuba like Ciénaga de Zapata host habitats of a variety of rare and endemic animal species like Zapata Wren (*Ferminia cerverai*) (Garrido 1985). The Zapata Peninsula, which includes the Zapata Swamp (*Ciénaga de Zapata*) (Matanzas, Cuba), supports 23 of the 26 endemic bird species found in the whole country, with nine of those species considered globally threatened. This Peninsula is also the only location in the country where all eight endemic genera occur (Kirkconnell *et al*. 2005; Kirkconnell and Wiley 2015; Goulart *et al*. 2018). Bee Hummingbird (*Mellisuga helenae*) (Vázquez 2009), world's smallest bird, Cuban Crocodile (*Crocodylus rhombifer*) (Ramos Targarona 2013), and American Manatee (*Trichechus manatus*) (Alvarez-Alemán *et al*. 2017) also occur in this area.

Andean peatlands are particularly important in the dry season for herbivores, such as endemic Vicuñas, and carnivores like the Puma (*Puma concolor*) (Borgnia *et al*. 2010; Maldonado Fonken 2014; Cuyckens *et al*. 2015) and are key for the breeding and survival of high-elevation amphibians (Seimon *et al*. 2017). The Costa Rican highlands are essential in supporting highly diverse endemic bird populations (Gastezzi Arias *et al*. 2021).

Table 6.2 Some threatened, endemic and iconic animal species associated with LAC peatlands. IUCN Red list status shown in bold.

Region		**Mammals**	**Birds**	**Reptiles & Amphibians**
(Sub) Tropical Lowlands	South America	-Lowland Tapir (*Tapirus terrestris*) **VN** -Jaguar (*Panthera onca*) **NT** -Agouti (*Dasyprocta fuliginosa*) -Carachupa (*Dasypus* sp.)	-Blue and Yellow Macaw (*Ara ararauna*)	-Anaconda (*Eunectes murinus*)
	Central America & Caribbean	-Nine-Banded Armadillo (*Dasypus novemcinctus*) -American Manatee *(Trichechus manatus)* **VU** -Baird's Tapir (*Tapirus bairdii*) **EN** -Geoffroy's Spider Monkey (*Ateles geoffroyi*) **EN** -Mantled Howler Monkey (*Alouatta palliata)* **EN** -Yucatán Black Howler Monkey (*Alouatta pigra*) **EN** -Jaguar (*Panthera onca*) **NT**	-Black-bellied Whistling Duck (*Dendrocygna autumnalis*) -Great White Egret (*Ardea alba*) -Snowy Egret (*Egretta thula*) -Roseate Spoonbill (*Platalea ajaja*) -Wood Stork (*Mycteria americana*) - Scarlet Macaw (*Ara macao*) - Zapata Wren (*Ferminia cerverai*) **EN** - Zapata Sparrow (*Torreornis inexpectata*) **NT** - Bee Hummingbird (*Mellisuga helenae*) **NT**	-Yellow Eyelash Viper *(Bothriechis schlegelii)* -Morelet`s Crocodile *(Crocodylus moreletii)* **LC** -American Crocodile (*Crocodylus acutus)* **VN** - Cuban Crocodile (*Crocodylus rhombifer)* **CR** -American Snapping Turtle (*Chelydra rossignoni)* **VN** -Narrow-bridged Musk Turtle (*Claudius angustatus*) **NT** - Northern Giant Musk Turtle (*Staurotypus triporcatus*) **NT** -Meso-American Slider (*Trachemys venusta)*
(Sub)Tropical Mountains	Andes	-Vicuña *(Vicugna vicugna)* -Spectacled bear (*Tremarctos ornatus*) **VN** -Puma (*Puma concolor)* -Andean mountain cat *(Leopardus jacobita)* **EN** -Andean tapir *(Tapirus pinchaque)* **EN** -Taruca *(Hippocamelus antisensis)* **VN**	-Rhea *(Rhea pennata)* -White-Bellied Cinclodes *(Cinclodes palliatus)* **CR** -Andean Ibis *(Theristicus Branickii)* **NT** -Andean Condor *(Vultur gryphus)* **VN**	- Marbled Water Frog (*Telmatobius marmoratus)* **EN** -Andean Toad *(Rhinella spinulosa)* -Marbled Four-eyed Frog *(Pleurodema marmoratum)* **VN**
	Central East Brazil Highlands	-Giant Anteater (*Myrmecophaga tridactyla)* **VN** -Maned Wolf (*Chrysocyon brachyurus*) **NT**		-Pajamas Treefrog (*Boana cipoensis*) **NT**
Patagonia		-Pudu (*Pudu puda*) **NT**	-Ruddy-headed Goose (*Chloephaga rubidiceps)*	

IUCN Red list status; NT = Near threatened, VN = Vulnerable, EN = Endangered, CR = Critically endangered. Where no status is shown species is classed as least concern.

Source: IUCN 2022.

6.3.2. Nature's Contributions to People

6.3.2.1. Regulating Contributions (Including Regulating Services)

Hydrology (freshwater quantity, location, and timing)

Peatlands act as water reservoirs, helping to regulate water flow into rivers and provide water for many communities. For example, in Veracruz, Mexico the soil water holding capacity ranged from 556 to 834 litres per square metre for swamp areas and from 687 to 880 litres per square metre for marshes; the thickness of soil organic layers in the wetland studied had a major impact on soil water storage (Campos *et al*. 2011). In areas that have a water deficit for a few months of the year, such as the Brazilian Cerrado (Alencar-Silva and Maillard 2011), peatlands, known as *Veredas*, may be the only source of water for rural communities and wildlife during dry periods (Resende *et al*. 2013; Fagundes and Ferreira 2016). Peatlands release water gradually over time, making rivers perennial, rather than seasonal (Bispo *et al*. 2015; Fagundes and Ferreira 2016). Similar processes occur during dry periods in the Patagonian steppe, with fens supplying water for native fauna, agricultural activities, and contributing to water supply for urban and rural populations in the towns of Punta Arenas, Ushuaia, and Chiloé (Iturraspe and Urciuolo 2021). Conversely, during winter in Southern Patagonia, delayed bog surface freezing contributes water flow into rivers, while other water sources are frozen and inactive (Iturraspe and Urciuolo 2021). The water regulation service of peatlands is also evident in the Andes where the proportion of peatland coverage is correlated with water discharge in several river micro-catchments (Mosquera *et al*. 2015). Quito, Ecuador, is home to nearly 2 million people, and is dependent on the Paramo ecosystem and its peatlands for more than 90% of its domestic water (Buytaert *et al*. 2017).

Hazards and Extreme Events

The presence of wide mangrove and coastal peatland belts along the Caribbean coast can mitigate the risks of hurricanes on economic activities in Central America (Peters and Tegetmeyer 2019). Along the Pacific coast of Mexico, wetland connectivity is decreasing because of fires and human activities, with hurricanes Paulina (1997) and Mitch (1998) exacerbating degradation (Reyes-Arroyo *et al*. 2021). However, areas with mangrove belts > 1 km are virtually unaffected by hurricane activity (del Valle *et al*. 2020; Miranda *et al*. 2020).

Carbon

Peatlands in LAC store large carbon stocks below ground, with varying estimates depending on their extent, peat thickness, peat bulk density and carbon concentration (Table 6.3). Research into peatland carbon stocks is limited but recent studies estimate that peatlands in the Peruvian Amazon store 5,400 Mt of carbon (Table 6.3, Hastie *et al.* 2022) and started to accumulate up to 8,900 years ago (Lähteenoja *et al*. 2012). Peatlands of Patagonia are the principal carbon sink and stock in the extratropical Southern Hemisphere, contributing to climate change mitigation (Iturraspe 2016; Holl *et al*. 2019). Estimates of carbon stored in peatlands of Patagonia (Table 6.3) differ due to the uncertainty of the estimated peatland area (Loisel *et al*. 2015) and mean thickness (Iturraspe and Urciuolo 2021), however they are thought to be substantial. There are no data available regarding fluvial outputs of dissolved organic carbon from peatlands of Patagonia.

Box 6.1. Peat and Peat Accumulation in the Andes

Andean peatlands are one of the most carbon-dense ecosystems in the world (Donato *et al.* 2011; Hribljan *et al.*, n.d. in review, 2016). The mixture of mineral sediments with the accumulating organic matter of geologically active basins in the Andes increases the bulk density of these organic soils, leading to high soil C content despite the relatively low C concentration in the peat (Hribljan *et al*. 2016). Long term accumulation rates of peat are relatively slow with linear increments of 0.5 to 2 mm per year during the last 6,000 years (Kuhry 1988; Hribljan *et al*. 2017). Recent rates of peat accumulation are much higher and are particularly high in cushion dominated peatlands with rates of accumulation of 3-4 cm per year (Benavides *et al*. 2013; Cooper *et al*. 2015). Tropical mountain peatland long-term apparent rates of carbon accumulation averaged about 28.5 grams per square metre per year, which is toward the higher end of rates of accumulation (Hribljan *et al*. n.d.). These rates increased with elevation and decreased with mean annual temperature, with the highest rates of accumulation (>100 grams per square metre per year) in cushion-plant dominated cooler sites above 4000 m elevation. In other mountain peatlands of the LAC, like the *Central East Brazil Highlands*, the carbon accumulation rates are between 0.3 and 70.1 grams per square metre per year (Silva *et al*. In press.).

Table 6.3. Peat carbon density, peat depth, carbon stocks, for different peat forming ecosystems in the LAC region.

Ecological Zone	Ecosystem type	Peat Carbon Density (Mg C ha-^{1})	Aboveground Carbon Density (Mg C ha-^{1})	Peat Depth (cm)	Area (ha)	Total Carbon Stock (Mt C)	Location
(sub) tropical Lowlands	*Mauritia flexuosa* palm swamp	648 (80)[1]	76 (8)[1]	161 (17)[1]	4,642,300[2]	3,830[2]	Lowland Peru
	Pole Forest	1034 (92)[1]	78 (13)[1]	274 (22)[1]	699,700[2]	720[2]	Lowland Peru
	Herbaceous swamp	628 (132)[1]	41 (23)[1]	282 (46)[1]	688,200[2]	690[2]	Lowland Peru
	Mangroves	892[3]	177 (60)[3]	197 (18)[3]	37,900[3]	40[3]	Southern Mexico
	Mangroves	1771[4]		618[4]			Panama
	Mixed forest	1884[4]		509[4]			Panama
	Broadleaved evergreen forest	1695[4]		529[4]			Panama
	Sawgrass	1488[4]		529[4]			Panama
(sub) tropical Mountains	Andean peatlands (Paramo)	1282[5]		380[5]			Eastern Ecuadorian Andes
	Central East Brazil Highlands	428[6]		119[6]	14,300[6]	10[6]	SdEM, Brazil
Patagonia	Anthropogenic peatland	117[7]	5[7]	70[7,8]	10[8]		Chiloé island, Chile
	Natural peatland - Bog			159[8]	140[8]		Chiloé island, Chile
	Sphagnum/Astelia bog			678[9*]			Argentina
	Astelia cushion bog			996[10*]			Argentina

[1] (Honorio Coronado *et al.* 2021) [2] (Hastie *et al.* 2022), [3] (Sjögersten *et al.* 2021), [4] (Upton *et al.* 2018), [5] (Hribljan *et al.* 2016), [6] (Silva *et al.* 2013), [7] (Cabezas *et al.* 2015),[8] (León *et al.* 2018), [9] (Borromei *et al.* 2016), [10] (Borromei *et al.* 2014). Numbers presented in the table represent data currently available for a given ecosystem type. When available, mean values are presented (e.g., when a large number of field-based sample points have been collected and presented in a paper), otherwise the range of available values is presented. In most cases data are limited to specific study sites and are unlikely to represent the full range of values for a given ecosystem type.

6.3.2.2. Material Contributions (Including Provisioning Services)

Food, Feed & Materials

Peatlands in LAC produce many widely consumed food products and materials. In lowland Amazonian palm swamps, the fruits of the *Mauritia flexuosa* palm, locally known as 'Aguaje', are widely harvested from wild populations either for direct consumption or sold for processing into beverages, ice cream and oil (Figure 6.7; Virapongse *et al*. 2017). The palm fronds and fibres of the *M. flexuosa* palm also provide materials used in construction, such as thatching, used by the Pemón indigenous group in Southern Venezuela (Rull and Montoya 2014), and fibres made from the young leaf buds are also used for the production of mats, nets and handicrafts, particularly in the states of Mato Grosso, Goiás and Maranhão, Brazil and by the Urarinas indigenous communities in the region of Loreto, Peru (Cattani and Baruque-Ramos 2016; Brañas *et al*. 2019). Selling of *M. flexuosa* fruits and products is an important source of income for women in rural communities. In (sub)tropical mountain regions and further south into Patagonia, peatlands are used extensively for livestock pasture and water source, and are especially important in arid and seasonal regions such as the Puna (Maldonado Fonken 2014; Salvador *et al*. 2014; Domic *et al*. 2018; Quiroga and Cladera 2018; Yager *et al*. 2019; Navarro *et al*. 2020; Suarez *et al*. 2022). In mangroves (Mexico), palms (*Attalea liebmannii, Roystonea dunlapiana* and *Acrocomia aculeate*) are used as food and construction materials (Gonzalez *et al*. 2012), whereas mangroves are also used for the production of honey. The extraction of peat and *Sphagnum* moss fibres for use in the horticulture industry is practised in Patagonia, Bolivia and Peru, and provides an informal income source for rural families in Chile. However, all these practices can be destructive when done for commercial purposes, causing peatland degradation. In 2021 Peru banned peat extraction with peat allowed to be used for domestic and traditional purposes, with enforcement and control challenging (Decree 006-2021-MINAM) (Diario Oficial El Peruano 2021). Currently, Chile is working on a Peatlands Protection Law, now being discussed in the Senate, that prohibits extraction of *Sphagnum* moss.

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Box 6.2. Managing Tropical Peatland Forests in the Peruvian Amazonia

Peatland forests cover 3.5 million hectares (Draper *et al*. 2014) in northern Peru, where *Mauritia flexuosa*, locally known as "aguaje", dominates the palm swamp forests. The sustainable management of natural resources in Amazonia started with Indigenous Communities since ancestral times (Brañas *et al*. 2019), e.g., in Loreto, the Maijunas sustainably harvested aguaje by collecting ripe fruit from the ground, which was influenced by (1) the strong spiritual relationship between communities and the forest, and (2) the low level of extraction that was used mainly for self-consumption in Urarinas communities (Gilmore *et al*. 2013; Brañas *et al*. 2019).

In contrast, during the last decade and at a regional scale, an increasing demand for aguaje fruit was reported (22 tons daily) (Horn *et al*. 2013), with its sale contributing up to 22% of the rural family income, whilst in urban areas (Iquitos) this is the main or only economic source (for approx. 5,000 families) (Del Castillo *et al*. 2021). Consequently, fruit extraction, typically by cutting female trees across most communities, has a high impact on peatland health.

Fortunately, a growing number of communities have changed to sustainable harvesting of aguaje since the 1980s. This process is commonly led by public institutions or NGOs such as the Instituto de Investigaciones de la Amazonía Peruana (IIAP), which had a key role in this transition for the communities Veinte de Enero and Parinari. It was also gratifying that some communities changed to sustainable harvesting by themselves, such as Puerto Alegría (close to Iquitos) (Hidalgo Pizango *et al*. 2022). From 93 evaluated forest stands, 20% are extracted sustainably using a tree climbing technique, highlighting that it takes similar time compared to when the entire tree is cut down (25–30 minutes) for collecting the aguaje fruit (Hidalgo Pizango *et al*. 2022). Thus, sustainable harvesting of aguaje fruit could increase the fruit production and the economy for Amazonian families by 50 %.

Overall, from these experiences in the Peruvian Amazonia, managing key resources is probably the best way to preserve tropical peatlands in the Amazonia.


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6.3.2.3. Non-Material Contributions (Including Cultural Services)

Supporting Identities

Peatlands and their resources are closely linked with the cultural identities of some Indigenous Peoples. For example, the weaving of *M. flexuosa* fibres for the production of traditional mats called '*Ela*' is an important part of the cultural identity of the Urarina communities from the Chambira basin in Loreto, Peru (Figure 6.10; Brañas *et al.* 2019; Schulz *et al.* 2019). These traditions are particularly important for the identity of women, who exclusively harvest young palm leaf shoots, make and dye fibres, and weave, with these skills being passed down through female generations (Brañas *et al*. 2019).

The ecosystems of the Espinhaço mountains, Minas Gerais, Brazil, which include mountain peatlands, are essential for the life of traditional communities. In 2019, the harvesting of wild sempre-vivas flowers (*Paepalanthus* spp.), a centuries-old activity carried out by traditional populations, gained recognition from the FAO as one of the 'Globally Important Agricultural Heritage Systems' (GIAHS), revealing the importance of these ecosystems for sustainable regional development (Silva *et al*. In press.).

The use of peatland flora was part of the cultural heritage of the original peoples of southern Patagonia, including the Kawesqars and Yámanas people, canoe nomads who inhabited the southern fjords. They gathered the fruits of various shrubs associated with peatlands (e.g., *Empetrum rubrum* and *Gaultheria* spp.), used *Oreobolus obtusangulus* grasses for caulking and sealant material in their canoes, as well as *Marsippospermum grandiflorum* to produce ropes and baskets. Medicinal plants were also gathered such as *Senecio acanthifolius* for disinfectant and anaesthetic. These traditions have been passed through generations and these traditional techniques are now used to produce handicrafts for tourists. Peatlands have been the inspiration for the contemporary art in the Chilean pavilion at Venice Biennale 2022 called "Turba Tol", which features indigenous culture of Selk'nam people from Patagonia beside peatland ecology and a living *Sphagnum* installation (Macchiavello and Marambio 2022), as shown in Box 6.3.

Figure 6.10. Fibres made from Mauritia flexuosa palm buds, and an Urarina woman weaving an 'Ela' using dyed fibres. Photos: Charlotte Wheeler

Box 6.3. Indigenous, Scientific and Artistic Hearts of Patagonian Peatlands

Turba Tol Hol-Hol Tol, the "heart of the peatlands" in the language of the Selk'nam people, one of the original inhabitants of Tierra del Fuego, in Patagonia, is the official exhibition of the Chilean Pavilion at the 59th International Art Exhibition of La Biennale di Venezia. Led by curator Camila Marambio, this collective project seeks an experimental path toward raising awareness of and preserving Patagonian peatlands. It stems from the long-term research of Ensayos, eco-cultural conservation work in Tierra del Fuego and other archipelagos through collaborative art, science, and community projects in partnership with existing ecological and cultural conservation initiatives, like the Wildlife Conservation Society Chile, in Karukinka Park in Tierra del Fuego, and the Selk'nam Cultural Foundation Hach Saye. The exhibition allows viewers to immerse themselves in the material and ancestral experience of the peatlands with a multisensory installation, which highlights an aesthetics of care and art motivated by real commitments to make progress on conservation action.

The Selk'nam freely inhabited Tierra del Fuego and lived with the peat bogs of their ancestral land for 8,000 years, until the colonizers responsible for their genocide arrived. Official history insists that the Selk'nam people were wiped out, but today the Selk'nam community rejects that myth, in a movement to be recognized as a living culture with its own language, and Hach Saye demonstrates this by being an integral part of the creative process for Turba Tol. It teaches us that their rights and the rights of the peatlands are interdependent, and that these ecosystems must be recognized as a living body. Beyond Chile, cultural history proves that peatlands all over the world play a fundamental role in indigenous cultures and other ancestral traditions, and therefore they urgently need to be valued as a reservoir of memories. On an increasingly hot and dry planet, these wetlands are in danger. Their preservation is intrinsically linked to the future wellbeing of humanity, planetary balance, and, in Patagonia, to the empowerment of the Selk'nam people. This curatorial project aims to bring visibility to these important ecosystems in the context of climate change, with a repair process based on the intersection of science, fiction, and traditional knowledge.

Tourism

The unique biodiversity and scenic attributes of peatlands are a big draw for tourism. In lowland Amazonia, herbaceous swamps attract tourists for bird watching such as the Área de Conservación Ambiental El Garzal, in Loreto, Peru. In mountain valleys of TDF, Argentina, *Sphagnum* bogs attract tourists for recreational winter activities (cross-country skiing, snowshoeing, dog sledding, and ice skating). Protected areas with peatlands also attract wildlife tourism, such as the Karukinka reserve (TDF, Chile), the Andorra Valley (TDF, Argentina), and Pacaya-Samiria National Reserve (Loreto, Peru) and the Zapata Swamp (*Ciénaga de Zapata* National Park) (Matanzas, Cuba). The Zapata Swamp, considered to be the largest the largest, best-preserved wetlands in the Caribbean islands, is a UNESCO Biosphere Reserve (Kirkconnell *et al*. 2005; Goulart *et al*. 2018; Ramsar Sites Information Service n.d.) and a Wetland of International Importance. Besides wildlife observation activities, it also supports other touristic activities such as boat rides, sport fishing and hiking (Ramsar Sites Information Service n.d.).

6.3.3. Hotspots of Value

6.3.3.1. Pastaza-Maranon Foreland Basin, Loreto, Peru

Aguaje fruits from the *Mauritia flexuosa* palm are widely consumed in this region. The city of Iquitos is the largest regional market (Delgado *et al*. 2007), with approximately 230,000 sacks of Aguaje fruits (8200 tons) entering Iquitos annually (Horn *et al*. 2018). This widespread harvesting is an important source of income for many rural communities, contributing about 15% of annual household income (Manzi and Coomes 2009). After harvesting the felled *M. flexuosa* stems are an important substrate for growing the edible beetle larvae '*suri*' (*Rhynchophorus palmarum*), which is widely eaten by indigenous and rural communities (Manzi and Coomes 2009). Climbing instead of cutting *Mauritia* palms to sell fruits is proposed as a sustainable method to conserve resources, carbon storage and maintain livelihoods in this region (Baker *et al*. 2019; Hidalgo Pizango *et al*. 2022).

6.3.3.2. Central East Brazil Highlands, Minas Gerais, Brazil

The peatlands of the Espinhaço mountains, Minas Gerais, form the headwaters of several important rivers and their tributaries in Eastern Brazil, including the São Francisco, Doce and Jequitinhonha Rivers (Campos *et al*. 2012; Silva *et al*. 2020), which support large numbers of people, providing water supply to communities and irrigation for agriculture. For example, the Araçuaí River, a principal tributary of the Jequitinhonha River, supplies water to the homes of 310,000 people living in the catchment, highlighting the importance of peatlands for the support of water resources in this region (Bispo *et al*. 2015).

6.3.3.3. Water Conservation for Quito, Ecuador

The efforts of source water conservation for Quito, through its 22-year-old Environmental Fund for Water Protection (FONAG), focus on conserving Paramo and other mountain wetlands. New water conservation reserves have been achieved by restoring overgrazed degraded paramos and rewetting drained peatlands previously used for livestock farming (e.g., De Bievre *et al*. 2019). Short term benefits in water yield and regulation are anticipated, while water quality benefits, especially those related to dissolved organic carbon that causes colour problems, seem to be more long term.

6.3.3.4. Mitre Peninsula, Tierra del Fuego, Argentina

The Mitre peninsula has an importance for climate change regulation due to the presence of >200,000 hectares of peatlands with peat thickness of 3 - 3.5 m especially valued for forming a huge reservoir of carbon in the extreme south of South America. These are the southern-most peatlands in the world and their wild condition and the exceptional beauty of this area offer a unique opportunity for recreation and nature tourism. Therefore, the local community has been pushing local governments to make the Mitre peninsula a provincial protected area.

6.4. Status of Peatlands, Drivers of Change and Hotspots of Change

6.4.1. Status of Peatlands

Large areas of peatlands are still hydrologically intact in the LAC region, principally due to their remote location and difficult access (Hastie *et al*. 2022). However, peatlands are increasingly facing threats, including overgrazing, resource extraction, mining, oil exploration and exploitation, hydroelectric dams and climate change (Householder *et al*. 2012; Roucoux *et al*. 2017; Lilleskov *et al*. 2019). Fig. 6.11 shows the proportion of drained and undrained peatlands in the LAC region per country (partly including organic soils), with a total of just over 3% degraded peatlands. Belize is the country in the region presenting the highest proportion of their peatlands drained for forest, agriculture or peat extraction (more than 20%). Fig. 6.12 shows the annual GHG emissions from peatlands drained for forestry, agriculture and peat extraction in key LAC countries. The resulting annual GHG emissions are just over 90 Mt CO_2e per year, with Brazil, Mexico, Suriname, and Argentina being responsible for half of those emissions.

The threats to peatlands in the region are described in the following sections.

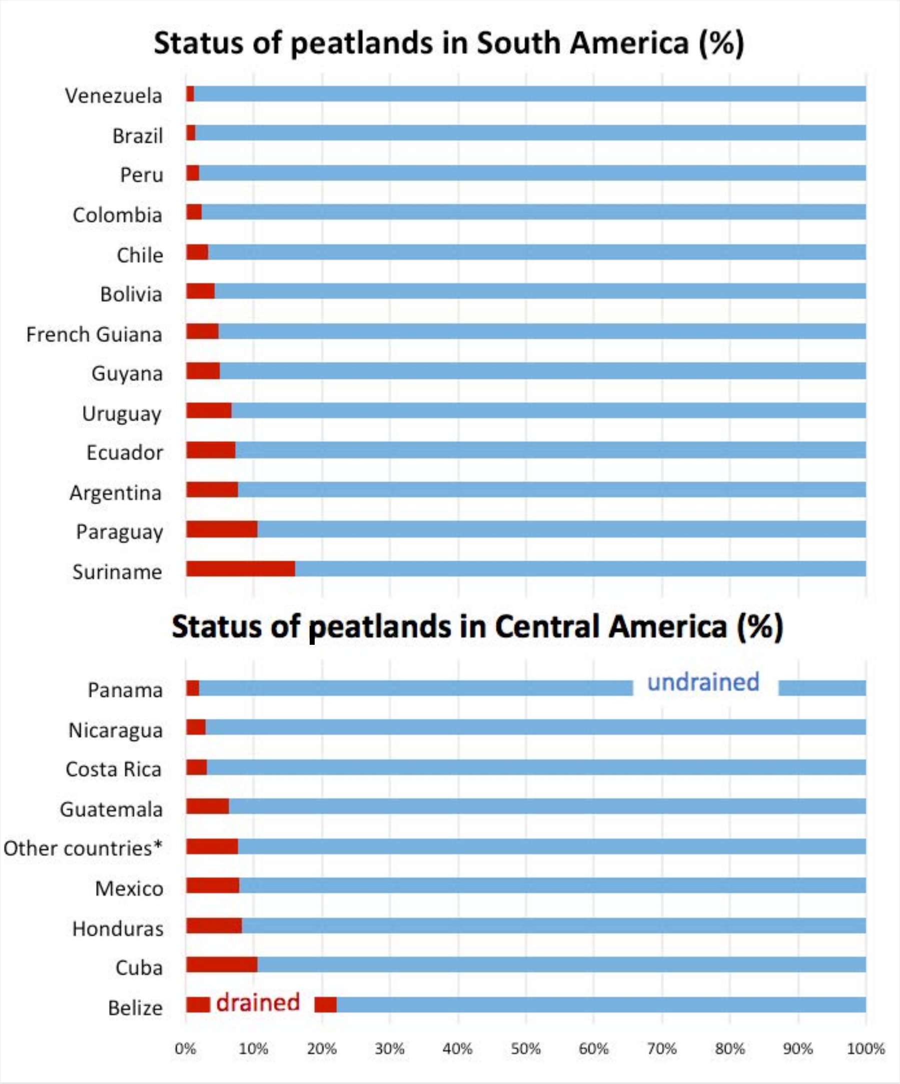

*Figure 6.11. Proportion of drained (red) and undrained (blue) peatlands in LAC per country (partly including organic soils). Calculations are based on the drained area for forestry, agriculture and peat extraction. *Sum of LAC countries with less than 100,000 hectares of peatland area.*

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

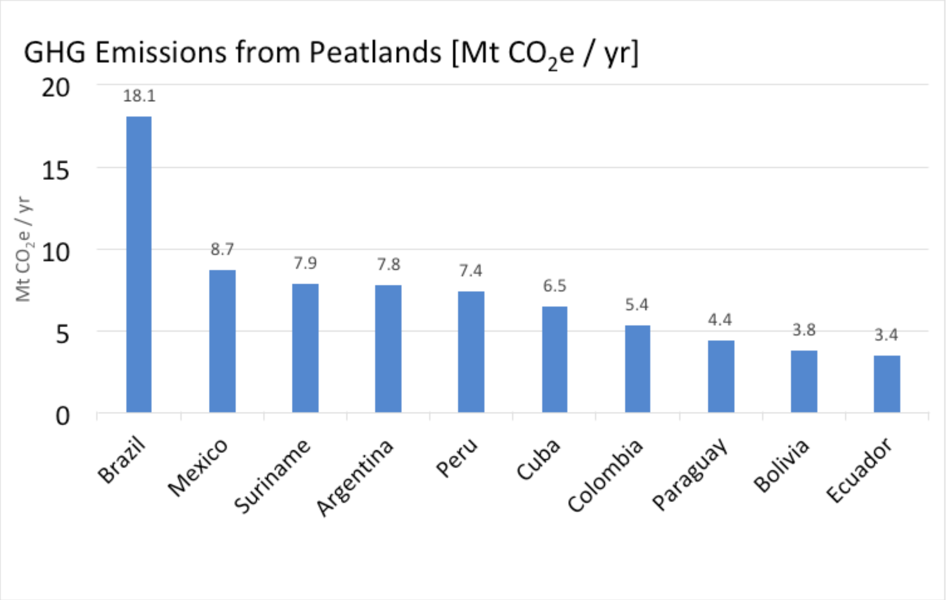

Figure 6.12. Top 10 countries emitting GHG from peatlands in LAC, representing 81% of total peatlands emissions in the region. Calculations are based on the peatland drained area for forestry, agriculture and peat extraction and IPCC (2014) emission factors including CO_2, CH_4, N_2O, DOC, and emissions from ditches. Includes only net, on-site GHG emissions. Wildfire emissions are not included. Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

6.4.1.1. Overgrazing

Grazing has a long history in the LAC region, particularly in the mountain peatlands in the Andean Puna where camelid pastoralism has been practised in the altiplano of southern Peru and Bolivia (Yager *et al*. 2019) and Argentina (Quiroga and Cladera 2018) for thousands of years. Ruminants introduced by Europeans have also become widespread in the Andes, Eastern Brazilian highlands and Patagonia, with the impacts of grazing increasing in the 19th and 20th centuries. Peatlands are often drained as part of introduced grazing management (Maldonado Fonken 2014; Chimner *et al*. 2019; López Gonzales *et al*. 2020). Overgrazing by livestock also causes trampling of vegetation, which results in soil compaction, reducing infiltration and increasing surface water runoff, inducing and accelerating erosion. Overgrazing can also result in the loss of mires, exposing them to significant rates of water and wind-driven erosion (Rincón-Pérez *et al*. 2020). However, there is large spatial variety of overgrazing impacts that are still poorly understood (Izquierdo *et al*. 2018; Navarro *et al*. 2020). In Central America and Mexico, swamp forests have been extensively logged for cattle ranching, and broadleaf swamps are burned and drained annually to encourage regrowth of introduced invasive African grass species for cattle (Moreno-Casasola *et al*. 2012).

6.4.1.2. Resource Extraction

Peatlands provide numerous resources of economic value (See § 6.3.1.3), however the commercial harvesting of such resources often leads to degradation of peatlands, altering carbon dynamics and greenhouse gas fluxes. In Amazonia, fruits of the *M. flexuosa* palm are widely harvested via felling adult female stems, altering the structure and litter inputs of palm swamps (Hergoualc'h *et al*. 2017; Horn *et al*. 2018). In mountain peatlands (Ecuador) charcoal, "mortiños" (berries), herbs (Ecuador) or flowers (Brazil) are extracted. Since the 1970s, peat extraction for horticulture has expanded rapidly in Tierra del Fuego and the high-altitude Andes (Valenzuela and Schlatter 2004; López Gonzales *et al*. 2020; Iturraspe and Urciuolo 2021); additionally, in Patagonia, *Sphagnum* moss is harvested for horticulture. In Argentina and Chile, peat extraction takes place within formal mining concessions, meaning that extraction is contained within specific areas, whereas in the Andes, peat extraction is done without permits or regulations to restore damaged peatlands.

6.4.1.3. Peatland Drainage for Agriculture

Many peatlands in Central America and the Caribbean have been drained for agricultural production, although the extent of peatland conversion for agriculture is unknown. For example, the expansion of banana plantations along the Caribbean coast since the early 20th century, has led to creation of drainage ditches across peatlands to transport crops and harvest wood, such as those seen in the Changuinola, Panama (Aronson *et al*. 2014). Other areas of peatland in the region have also been drained for cattle grazing and smallholder crop production (Peters and Tegetmeyer 2019). In Mexico, mainly freshwater wetlands have been drained for the establishment of sugar cane, banana and oil palm plantations. In Zapata, Cuba, peat soils got salinated by the capillary rise of salt water from in sites formerly drained e.g., for rice and sugar cane cultivation. Also due to intensive agriculture in adjacent inland areas, nutrient inputs into the peatland increased and large-scale irrigation of e.g., citrus and sugar cane plantations reduced freshwater discharge into the peatland sites (Peters and Tegetmeyer 2019). In Amazonia, peatlands are drained for palm oil and rice cultivation. Such activities have been observed in the Ucayali and San Martin regions in Peru, but the extent of forested peatlands converted to agriculture is still predicted to be relatively low, in Peru at least (Hastie *et al*. 2022).

6.4.1.4. Dam Construction, Oil & Gas Exploration and Roads

Across Amazonia, dam construction for hydroelectric power (HEP) generation is a major threat to wetland hydrology, with dam reservoirs reducing river discharge, increasing evaporation and preventing downstream flow of materials, which can alter the hydrological dynamic of peatlands. Power generation is set to double from ~18,000 megawatts (MW) from 154 large dams up to ~34,000 MW, once a further 21 dams, currently under construction, are operational. 277 additional dams are also in the planning stages (Castello and Macedo 2016), meaning there is potential for further expansion of HEP with associated impact on peatland hydrology.

Similarly, in western Amazonia hydrocarbon (oil and gas) exploration and extraction is expanding, with oil blocks covering 73,341,400 hectares in 2015, increasing by 4,500,000 hectares since 2008 (Finer *et al*. 2015), with many of these blocks and oil pipelines found in peatland areas and indigenous lands. The construction of oil pipelines results in the clearance of forest, furthermore several cases of oil spills within forested areas that include peatlands have taken place in recent years (Vasquez Jara 2019), leading to contamination of the affected forest areas. Additionally, oil projects that are accessed by road, open up the region to agriculture, increasing deforestation, wildlife poaching and trafficking thanks to ease of access and reduced transportation costs.

6.4.1.5. Urbanization

Intense urban occupation along the Brazilian coast has resulted in extensive drainage of floodplains, particularly in the 5,700,000 hectares Paraíba do Sul River basin (Acselrad *et al*. 2007). The construction of reservoirs, dams and weirs has been used to control water flow and minimise flooding (Marengo and Alves 2005), resulting in a discontinuous floodplain that is intensively drained by historical anthropic processes (Instituto Brasileiro de Geografia e Estatistica [IBGE] 2007). The alteration of natural flood dynamics alongside land-use change has led to heavily drained peatlands along the Brazilian coast. In Mexico, there are cities established in the floodplains of large rivers, for example, Veracruz and Tabasco, reducing wetlands, thus aggravating the problems of flooding and subsidence (Landgrave and Moreno Casasola 2012).

6.4.1.6. Mining

Mining of various minerals takes place across LAC, either directly destroying peatlands or indirectly affecting them due to contamination and alteration of the water provision (Maldonado Fonken 2014). In Amazonia, illegal gold mining along rivers has expanded, leading to peatland disturbance, for example in Madre de Dios, Peru (Asner *et al*. 2013). Approximately 40% of the peatlands show signs of mining activities, leading to the loss of peatlands alongside acute problems of contamination of water sources (Householder *et al*. 2012). Meanwhile in the Andes, lithium mining is a growing cause for concern, due to the associated high freshwater consumption, which comes from the wetlands of the region, and the production of contaminated waste (Izquierdo *et al*. 2015; Flexer *et al*. 2018).

6.4.1.7. Climate Change

The effect of climate change is already being felt in parts of the LAC region, with changes in waterflow (Morales *et al*. 2015), and these impacts are likely to become more pronounced moving forward, particularly in high altitude regions. The high Andes is likely to be very sensitive to climate change, with models predicting temperature increase of + 4.5°C for altitudes >3,500 m.a.s.l., and changes in the precipitation patterns (Vuille *et al*. 2003; Urrutia and Vuille 2009). In the Guayana Highlands, whilst still being mostly pristine, peatland biota are threatened by habitat loss by upward displacement due to the projected global warming (Rull and Vegas-Vilarrúbia 2006). Possible alterations in temperature and rainfall driven by climate change will affect peat formation and water storage capacity (Zinck and Huber 2011). In the lowlands of Amazonia, the increased variability of the hydrological cycle leading to more locally severe drought and flooding events (Gloor *et al*. 2013) could alter species composition of peatlands and peat accumulation (Flores Llampazo *et al.* 2022). In addition, climate change could shift these peatlands from sink to source of CO_2 (Wang *et al*. 2018).

6.4.1.8. Invasive Species and Pests

In Tierra del Fuego (TDF), exotic Beavers (*Castor canadensis*), introduced in 1948, have colonised the entire archipelago, including peatlands. Beaver activity alters peatland hydrology by dam flooding and channel excavation. Inundation of bogs kills vegetation, inhibits carbon accumulation, and causes organic matter decomposition (Iturraspe 2021). In the Andes, phytophagous red spider-mites (*Tetranychidae* spp.) feed on cushion-forming rushes (*Patosia, Distichia* and *Oxychloe* spp.) when the plants are stressed by drought. Spider-mite colonies can reach several meters in diameter, causing the death of cushions. Damage to the cushion can recover in years with abundant rainfall (Ruthsatz 2012; Ruthsatz *et al*. 2020), and whilst reports of these mites are rare, they thrive in drier conditions, meaning their presence could increase with climate change. The establishment of the African palm (*Elaeis guineensis*) has been observed naturally in the mangroves and freshwater swamps of Chiapas (Mexico), for which it has been identified as an invasive species and eradication plans have been implemented within the La Encrucijada Biosphere Reserve. In Zapata, Cuba, invasive species like *Casuarina equisetifolia* and *Melaleuca quinquinervia* can easily spread along the channels, increase evapotranspiration and suppress native species (Peters and Tegetmeyer 2019).

6.4.1.9. Overuse by Tourism

The popularity of tourism in the high Andes, TDF and tepui summits in the Guyana highlands (Zinck and Huber 2011) has grown in recent decades. Impacts on vegetation cover, structure and community composition have been observed due to increased trampling by hikers and pack animals (Barros and Pickering 2014), as well as increased tolerance of wildlife of visitor use (Barros *et al*. 2015). More serious damage is also seen from unauthorised use of quadbikes through peatlands, however, its ecological impacts are poorly understood and rarely considered (Barros *et al*. 2015).

6.4.2. Drivers of Change

The main drivers of change, level of importance and trends identified for the region are presented in Table 6.4. The level of importance and trend for each driver is assessed by expert opinion of the authors of this assessment due to limited data availability.

Table 6.4. Drivers of change in peatlands in the LAC region, showing the level of importance and trend for each driver.

Driver of Change	(Sub)Tropical Lowlands		(Sub)Tropical Mountains			Patagonia	
	South America	Central America & Caribbean	Andes	Guyana and Central American Highlands	Central East Brazil Highlands	Temperate Mountains	Temperate Steppe
Degradation via Resource Extraction	🟥 ↗	🟧 ↗	🟧 →	🟩 ↘	🟧 →	🟥 ↗	🟩 →
Livestock Overgrazing	🟩 →	🟧 →	🟥 →	🟩 ↘	🟥 ↗	🟧 →	🟥 →
Peat Extraction – Horticulture	🟩 →	🟩 →	🟧 →	🟩 ↘	🟩 ↘	🟥 ↗	🟩 →
Peat Extraction – Fuel	🟩 →	🟩 →	🟩 →	🟩 ↘	🟩 ↘	🟩 →	🟩 →
Peatland Drainage – Agriculture	🟩 →	🟥 ↗	🟧 →	🟩 ↘	🟩 ↘	🟩 →	🟧 →
Peatland Drainage – Livestock	🟩 →	🟥 →	🟧 →	🟩 ↘	🟩 ↘	🟧 →	🟧 →
Infrastructure - Road expansion	🟧 ↗	🟧 →	🟧 ↗	🟧 →	🟩 ↘	🟧 →	🟧 →
Oil/gas (Infrastructure and spills)	🟧 →	🟧 →	🟧 ↗	🟩 →	🟩 ↘	🟧 →	🟧 →
Infrastructure - Hydroelectric Dams	🟧 ↗	🟧 →	🟧 ↗	🟧 ↘	🟩 ↘	🟩 →	🟧 ↗
Infrastructure - High voltage towers	🟩 →	🟩 →	🟩 →	🟩	🟩 ↘	🟩 →	🟧 →
Infrastructure - Water use (deviations channels, extraction, etc.)	🟩 →	🟧 →	🟧 ↗	🟧 →	🟩 ↘	🟧 →	🟧 →
Mining – Gold	🟧 ↗	🟩 →	🟧 ↗	🟥 ↗	🟩 ↘	🟧 ↗	🟧 ↗
Mining - Other minerals	🟩 →	🟩 →	🟧 ↗	🟥 ↗	🟧 ↗	🟧 →	🟧 ↗
Urbanization	🟧 ↗	🟧 →	🟧 →	🟩 →	🟧 ↗	🟧 →	🟧 →
Invasive Species	🟩 →	🟩 →	🟩 →	🟩 ↘	🟧 ↗	🟧 ↗	🟧 ↗
Phytophagous pests (like mites)	🟩 →	🟩 →	🟩 →	🟩 ↘	🟩 ↘	🟩 →	🟩 →
Climate Change	🟧 ↗	🟧 ↗	🟥 ↗	🟧 ↗	🟧 ↗	🟧 ↗	🟧 ↗
Fire	🟧 ↗	🟧 →	🟧 →	🟧 →	🟥 ↗	🟥 ↗	🟧 ↗
Overuse by Tourism	🟩 →	🟧 ↗	🟧 ↗	🟧 ↗	🟩 →	🟧 →	🟩 →

Importance of Driver	🟩 Not Important	🟧 Moderately Important	🟥 Very Important
Trend	↘ = Decreasing	→ = Stable	↗ = Increasing

6.4.3. Hotspots of Change

6.4.3.1. Patagonia, Argentina and Chile

Peat extraction for horticulture and floriculture including for export, is increasing in Tierra del Fuego and southern Magallanes regions. Cutting the upper layer of peat removes the ecosystem's living plants, which inhibits the CO_2 sink function of peatlands, leading to increased organic matter decomposition and CO_2 emissions, as well as drainage of peatlands. *Sphagnum* moss is also harvested for horticulture, typically by local communities. In some regions such as the Chiloe islands (Valenzuela and Schlatter 2004), *Sphagnum* resources were depleted by the early 2000s. However, this practice is still expanding; in Chile, dry *Sphagnum* fibre exportation has increased four-fold since 2000, to 4,615 tons worth $21 million US Dollars by 2019 (Salinas *et al*. 2021).

6.4.3.2. Loreto, Peru

The harvest of Aguaje fruits from the *M. flexuosa* palm typically involves felling female stems (Gockel and Gray 2009), leading to a higher proportion of male adult palms and low regeneration in highly degraded palm swamps (Hidalgo Pizango *et al*. 2022). The rapid increase in the demand for fruits from the 1980s (1,825 tons per year) to 2010s (8,206 tons per year) in Iquitos market in Peru (Padoch 1988; Horn *et al*. 2018) has already halved the economic value of palm swamps and caused degradation near to the market (Hidalgo Pizango *et al*. 2022). In San Martin and Ucayali, Peru, heavily harvested palm swamps have been converted into rice and oil palm plantations (López Gonzales *et al*. 2020). Such land use change due to deforestation and degradation reduces peat carbon stocks due to biomass loss and peat decomposition (Hastie *et al*. 2022) and alters GHG emissions (van Lent *et al*. 2019; Hergoualc'h *et al*. 2020).

6.4.3.3. Coastal plain of Chiapas, Mexico.

In the state of Chiapas, more than 20 rivers drain into a short flood plain, causing the establishment of peatlands with a high capacity to store carbon (Rincón-Pérez *et al*. 2020; Sjögersten *et al*. 2021). Following floods caused by hurricanes Paulina (1997) and Mitch (1998), embankments were built changing river courses (Carranza-Ortiz *et al*. 2018; Reyes-Arroyo *et al*. 2021). Embankments reduced residence time of water and increased sediment flow through the wetlands, causing siltation of lagoons (Tovilla 2005; Hernández 2014). This area has become very degraded in the 25 years since embankments were established, alongside additional agricultural and livestock activities and the fires (Barrios-Calderón *et al*. 2018; Barrios-Calderón *et al*. 2020). Collectively these activities continue to degrade the area at a very fast rate, with coastal areas at risk of losing resilience.

6.5. Policy Context, Options for Action and Hotspots of Response

6.5.1. Policy Context

In the region most countries have policies on wetlands or on specific ecosystems that can have peat such as Bofedales in Bolivia (Dominc A. com. pers., 2022), Veredas in Brazil, or Morichales in Venezuela. However, these policies do not mention peatlands and their unique importance and vulnerability. Only a few countries have policies that explicitly refer to peat or peatlands (Table 6.5). The oldest national policy relates to peat extraction (e.g., Argentina), while the newer ones focus on the protection of peatland ecosystems (e.g., Chile, Uruguay and Peru).

Table 6.5. National policies and proposals that explicitly refer to peat or peatlands in the LAC region.

Country	Policy	Details
Argentina	Mining Code (Law 1919, and its updates) and Mining Environmental Law (N° 24585)	Regulate the extractive use of peat. Mining can only be done when the peat is deeper than 1 m
	General Environmental Law (N° 25675)	States environmental policies, principles and instruments for sustainable and adequate environmental management and the preservation of biological diversity
	Proposal of Wetlands Law	Minimum budget for the conservation, protection and regulation for a sustainable use of wetlands, including peatlands
Chile	Measures for the protection of *Sphagnum magellanicum* moss (Supreme Decree 25, Ministry of Agriculture, 2018-19)	Regulate the extraction of surface vegetation, especially live moss, to mitigate environmental impacts in the areas where it is harvested. Its 2019 update eliminated several requirements, and introduced changes that could compromise the recovery of moss growth (Álvarez Piñones and Domínguez 2021)
	Proposal of law for the environmental protection of peatlands (2022)	Prohibits the exploitation of and intervention in peatlands (in revision, approved only by the Chamber of Deputies)
	Protection of urban wetlands (Law 21202)	Activities that involve the extraction of plant cover from peatlands must be submitted to the environmental impact assessment system
Peru	General provisions for the multisectoral and decentralized management of wetlands (Supreme Decree N°006-2021-MINAM)	Provide the first official concepts of peat and peatland. Recognition of the necessity for peatland conservation and sustainable management. Commercial use of peat is forbidden; only traditional and domestic peat use is allowed
	Proposal of criteria for prioritizing wetlands (RM Nº 019-2022-MINAM)	Suggests prioritising strategic actions in peatlands especially those affected by peat extraction (in revision)
Uruguay	National climate change policy and the first Nationally Determined Contribution (Decree N° 310/017, 2017)	Protection of peatlands

Box 6.4. Complementary local regulations in TDF (Argentina)

The Environmental Protection Law (N° 55, 1992) prohibits actions that degrade ecosystems.

The Peatland Management Resolution (Res. SDSyA N°401/11) defines areas for the preservation of peatlands and areas for exploitation with regulated authorization for extractive use. Peatland management is carried out in a coordinated manner between environmental and mining technical areas, following the guidelines of the Peatland Management Resolution.

The Municipality of Ushuaia, by Ordinance 3123/2006, declared the urban **peatlands located between 200 and 300 m altitude as Environmental Reserve** for their conservation and protection as Historical and Cultural Heritage.

Agencies in charge of managing peatlands and their services include those regulating agriculture, water, mining and environmental areas. Multiple sectors are involved, depending on the use of peatlands (e.g., forage for livestock, agriculture, forestry, extraction for growing media or fuel). In addition, the nature of the policy system (federal or unitary) influences the generation and implementation of policies and the type of actors involved (local or central government). For example, in Argentina, where there is a federal system, the most relevant policies related to peatland conservation and management were developed at the local level (Box 6.4).

Multi-sectoral regulation can generate conflicts of interest. For example, Veredas in Brazil must be surrounded by > 50 m wide buffers (New Forest Code, Federal Law number 12,651 / 12). However, drainage and agricultural use of floodplains is promoted through the Provárzeas national program for the use of irrigable lowlands (Decree 86,146), which leads to wetland destruction across Brazil including drainage of Veredas in Minas Gerais. In Chile, recent policies to protect peatlands, are undermined by existing laws and amendments, which allow the extraction of peat resources (Table 5).

Policies are based on research information developed by national institutes, universities, NGOs and international organisations (e.g., § 6.6. Peru study case). Since 2012, interested parties in Argentina and Chile have been researching peatland conservation alternatives, and both countries have made progress toward a new peatland vision. Over time, this collaboration resulted in the Patagonian Peatlands Initiative (PPI) led by Wildlife Conservation Society (WCS) and the Chilean Ministry of Environment with links to the Global Peatlands Initiative. The first PPI meeting was held in April 2022 with participants from both countries. The first trans-boundary agreement reported in the LAC region focuses on the protection of the environment from negative effects of energy, mining and industrial activities in the Andean region, and peatlands are highlighted as key and vulnerable ecosystems. The Centro Regional Ramsar para el Hemisferio Occidental (CREHO), based in Panama, acts as an institution to share knowledge and build capacities on peatlands in the region, especially in regard to management plans and their implementation in Ramsar sites.

So far, only three countries (Chile, Costa Rica and Uruguay) have included peatlands in their NDCs submitted to the UNFCCC[2] (Table 6). But other countries are updating their NDCs with new mitigation measures targeting peatlands (e.g., Peru, Panama).

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[2] NDC Registry https://unfccc.int/NDCREG

Table 6.6. Nationally Determined Contributions (NDC) specifically addressing peatlands in the LAC region.

Country	Commitments
Chile	- To identify wetland and peatland areas by 2025.
	- To evaluate the capacity of wetlands (especially peatlands) for climate change adaptation and mitigation, implementing actions to favour co-benefits in five pilot protected areas by 2030.
Costa Rica	- To maintain or increase the uptake of GHG and/or to reduce emissions from ecosystems including peatlands.
Uruguay	- To survey the area of peatlands by 2025.
	- To protect at least 50% of the peatland area by 2025 (41,800 hectares) to avoid CO_2 emissions. Protection could target 100% of peatland area if specific additional means of implementation are available.

6.5.2. Options for Action

Key areas of action for most LAC countries include laying the groundwork for NDCs by 1) improving national maps of peatland extent and anthropogenic land use, 2) developing GHG emissions factors for the dominant peatland uses, 3) training in the development of NDCs using national maps and emissions factors, and 4) implementing gender-responsive national policies aligned with NDCs. Intentional development of a regional community of practice linked to the Global Peatlands Initiative in peatland science, management, and policy would further support the development of effective policies.

Peatland conservation and restoration can be included in existing consolidated funding mechanisms such as the Peruvian MERESE (Mecanismos de Retribución por Servicios Ecosistémicos – Compensation mechanisms for ecosystem services), and Water Funds. Based on recently advanced knowledge on the extent and hydrological role of peatlands within the Ecuadorian paramo, the oldest and largest Water Fund in the region, FONAG, has recently integrated in its portfolio of natural infrastructure interventions, conservation and rewetting of high-altitude peatlands, which provide more than 90% of Quito's domestic water demand. Implementation of gender-responsive initiatives is recommended as these take into account the specific needs and contributions of both women and men in society; and especially those from lower socioeconomic status who are often left behind.

6.5.3. Hotspots of Response

Several promising and successful peatland conservation and management case studies are presented below.

In the Peruvian Amazonia, in response to the recurrent degradation of palm swamps, their sustainable management has been promoted since the 2010s, especially in protected areas. Within the Pacaya Samiria national reserve, climbing techniques for fruit harvesting were developed by local people to replace the practice of cutting the palms (e.g., Flores family in Parinari). In 2020 the Protected Areas National Service (SERNANP) has defined a monitoring system based on indicators for assessing the ecological, economic and social impacts of fruit harvesting on palm swamps.

In the Andes, traditional pre-Hispanic water management practices to expand the grazing area of Bofedales (like Carhuancho in Peru) have been common for centuries and are still used by some communities. Verzijl and Quispe (2013) described the use of different types of channels to maintain and extend the area of Bofedales by up to 40% with a 36 km system of channels. The existence of similar water management systems has been reported elsewhere in Peru, Bolivia and Chile (Alzérreca *et al*. 2001; Maldonado Fonken 2014; Villarroel *et al*. 2014; Baiker *et al*. 2022; Lane *et al*. 2022; Uribe-Álvarez *et al*. 2022) and highlights the importance of communal organization. The implementation of these practices is of great interest to other communities where Bofedales are drying out.

Even though their effect on peat accumulation and GHG emissions is unknown, the practices contribute to the conservation and management of peatlands in harmony with people's livelihoods. Scientific investigation on GHG fluxes and other environmental impacts of these practices is needed for effective national policies, international agreements and initiatives to expand them.

In Argentina, Fuegian (meaning 'of Tierra del Fuego') peatlands have been mined for more than 20 years, without regulation. The growing demand for peat and the lack of policies for their management as wetlands led to the degradation of valuable *Sphagnum* mires, generating the need for environmental regulation. The problem was mainly caused by the partial application of the Mining Code without considering the integration of other environmental norms. To achieve local planning for the use of fuegian peatlands, a participatory process has been carried out over the last 20 years that involves: national and provincial technical areas of environment, mining, and tourism; scientists and academics, local and international non-governmental organizations (NGOs), mining entrepreneurs and other interested parties. Through that participative process, the "Strategy and Action Plan for the wise use of the mires of Tierra del Fuego" was formulated in 2008 (Biancalani and Avagyan 2014). Finally, the TDF Peatland Use Plan was approved by the province (Resolution S.D.S. y A. No 401-2011, In Spanish: Ordenamiento y zonificación de turberas) through local consensus. The plan regulates the spatial arrangement of peat mining, concentrating extractive use in a delimited zone while protecting those peatlands that had been identified as important for conservation.

Box 6.5. Peru Country Case

The recognition of the relevance of Peruvian peatlands is the result of a transparent and long-term participative process and collaboration between scientists, policy makers and civil society. In 2019, as the leading entity of the national wetland committee, the Biodiversity General Directorate of the Ministry of Environment (MINAM) initiated workshops and exchanges on the conceptual framework of peatlands, a process that helped develop general definitions for the country (see § 6.5.1). Several national and international research institutions and universities have been pivotal in the process, sharing with the government their rapidly increasing knowledge on peatlands from both the Amazon basin and the Andes. Science-policy meetings and dialogues further led to the publication of a synthesis on current knowledge on Peruvian peatlands (López Gonzales *et al*. 2020). Peatland experts are also part of the technical team working on updating the forest reference emission level (FREL). Although the FREL submitted to the UNFCCC in 2021 (MINAM, a national decree for a sustainable management of wetlands (Supreme Decree N°006-2021-MINAM), which specifically addresses peatlands. The government is currently developing criteria for prioritising the conservation, restoration, and sustainable management of wetlands including peatlands and developing strategic actions. In addition, the Ministry of Environment of Peru is developing a sectorial proposal to include Amazonian peatlands in its NDC (Alvarez-Alemán *et al*. 2017).

6.6. Knowledge Gaps

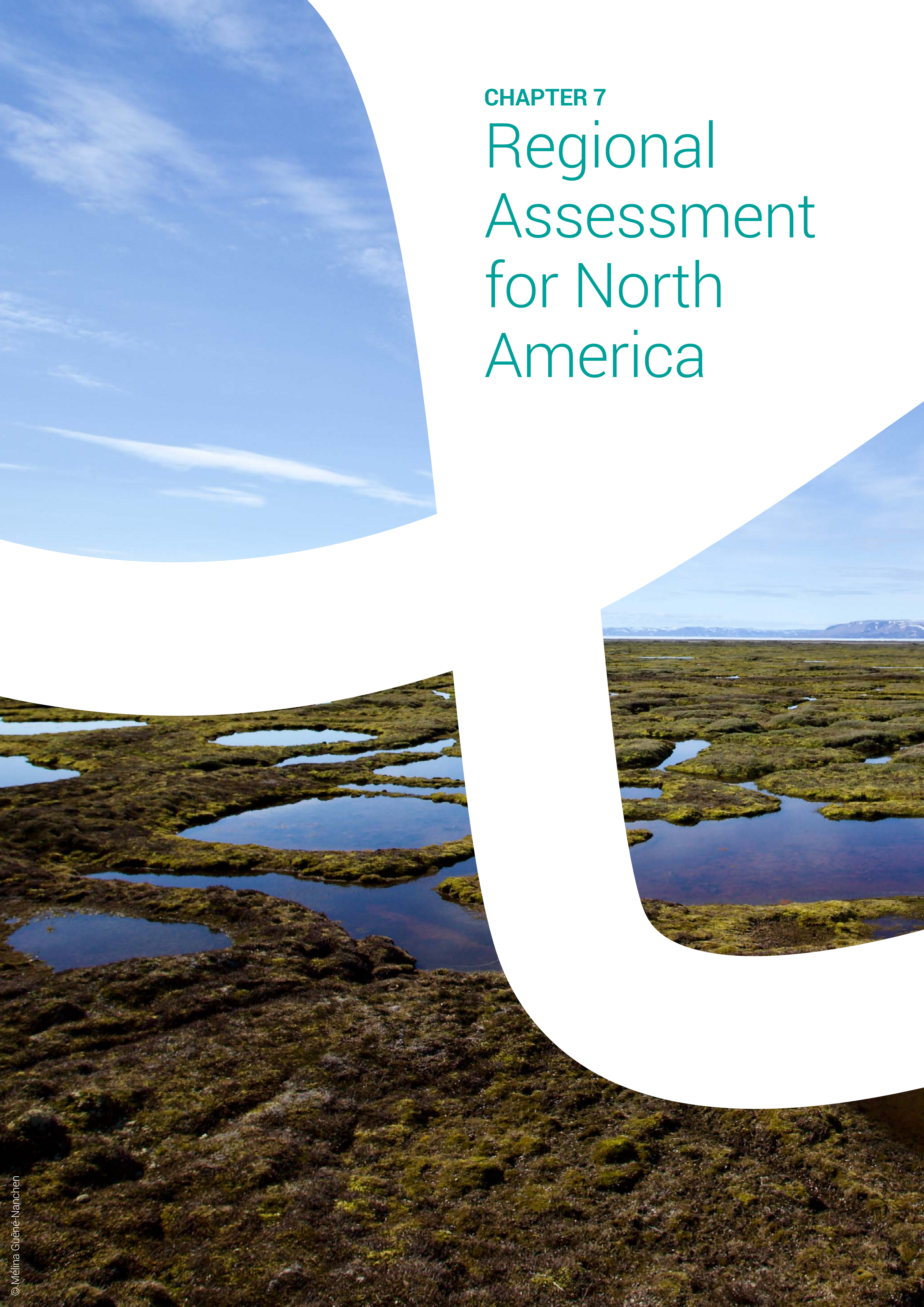
Peatland research is much less developed in LAC than in the northern hemisphere or in Southeast Asia, with significant research efforts only beginning in the last decade. The contributions of women in peatland research should be encouraged and acknowledged, as they face unique barriers and challenges. Large uncertainties about peatland distribution, status and the anthropogenic impact of disturbance and climate change on carbon storage and GHG fluxes persist in the region. Throughout LAC, national inventories of peatlands are incomplete or not developed, and the inclusion of peatlands into conservation, land use, and climate policy is very limited.

There are still knowledge gaps regarding peatlands distribution and extent (Table 6.7), particularly in mountainous regions where peatlands form in small, isolated patches (e.g., bofedales, vegas) or in remote locations where fieldwork is difficult (e.g., central Amazonia). Mapping peatlands in LAC is challenging as some ecosystems, considered 'peat-forming', do not always accumulate peat, such as Bofedales and Vegas in the Andes (Izquierdo *et al*. 2022), *M. flexuosa* swamps in Amazonia (Hastie *et al*., 2022) or Mallines in Patagonia. Therefore, maps of peatlands only indicate potential peatlands. The presence of peat can only be validated by ground-truthing, which requires substantial funding and major efforts to access remote and inaccessible locations.

Research related to GHG fluxes as influenced by ecosystem type or as impacted by anthropogenic degradation has been limited to just a couple of sites in Peru (Hergoualc'h *et al*. 2020) and Panama (Girkin *et al*. 2018; Sjögersten *et al*. 2018). Much more efforts are needed to understand to what extent peatlands have been altered and how disturbance alters GHG fluxes. This knowledge is critical to understand how LAC peatlands contribute to global peatland emissions and to climate change.

Table 6.7. Knowledge gaps of peatlands distribution and extent in LAC.

Region	Current understanding	Knowledge Gap
Amazonia (Brazil)	Estimated area of peatlands of 31.23 million hectares (Gumbricht *et al*. 2017)	Lack of extensive field validation of presence of peat.
Andes (Peru)	Estimated area of bofedales > 3500 m a.s.l. (Chimner *et al*. 2019; MINAM 2019; López Gonzales *et al*. 2020)	Actual peatland extent related to bofedales and totorales (lacustrine sedge ecosystems, e.g., Lake Titicaca) Peatlands at lower altitudes Other potential peatlands similar to chuscales in Colombia (Orellana *et al*. 2016)
Guayana and Central American Highlands	In Venezuela: estimated area of tepuian peatlands under the assumption that 30% of the tepuis have been covered by peatland (Huber 1995)	Actual peatland extent of tepuis Distribution maps
Central East Brazil Highlands	In the Southern Espinhaço Mountain Range : estimated area of peatlands, with restrictions due to the resolution of the satellite images (Silva *et al*. In press.)	Peatlands < 5 hectares Peatlands buried by erosion/sedimentation and geomorphological processes
Patagonia	In Chile: cushion bogs and fens distribution in the Pacific Archipelago and continental shores. In Argentina - Andean region: Distribution of scattered peatlands present in the continental area. In the extra Andean steppe: Identification of peatland areas in vegas or mallines	Lack of complete peatland inventories both in Chile and Argentina. Uncertainty on peatland area and peat depth. Lack of field surveys in wetlands where peat formation is difficult to analyse by remote sensing.
Central America and Caribbean	Costa Rica, Cuba, Honduras, Nicaragua, and Panama have an ¨Inventory of peatlands in the Caribbean and first description of priority areas¨ (Peters and Tegetmeyer 2019). Mexico is working on the ¨National Wetland Inventory¨, but a second step should be to define which are peatlands. Chiapas, Tabasco and Veracruz in tropical Mexico have coastal wetland ecosystems that contain large carbon stocks.	Lack of systematic field work to define the limits of peatlands, their carbon content and status.



CHAPTER 7

Regional Assessment for North America

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CHAPTER 7

Regional Assessment for North America

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Regional Highlights

Key Facts

KEY REGIONAL DATA PRODUCED FOR THE GLOBAL PEATLANDS ASSESSMENT 2022[1]	
Total peatland area (hectares)	158,200,825 ha
Peatland cover over total region surface area (%)	8.5%
Degraded peatlands (%)	1.8%
Annual GHG emissions from peatlands (Megatons of carbon dioxide equivalent emissions per year)	89.4 Mt CO_2e / yr
Undegraded peatlands (%)	98.2%
Peatlands within protected areas (%)	19.5%
Top 5 Countries with largest peatland area (hectares)	1. Canada (119,377,000 ha) 2. United States (38,813,000 ha) 3. Greenland (8,000 ha) 4. Saint Pierre and Miquelon (2,800 ha) 5. Bermuda (25 ha)
ADDITIONAL DATA	
Total peatland carbon stock[2,3] (Megatons of carbon)	184,151 Mt C[2] 129,500 – 154,000 Mt C[3]
Threatened peatland species[4] (VU = vulnerable; EN = endangered; CR = critically endangered)	Flora: 12 VU, 15 EN, 11 CR Fauna: 30 VU, 21 EN, 5 CR
Ramsar Wetlands of International Importance with peat[5]	36 sites (16.4% of total Ramsar sites in North America)

[1] Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

[2] Joosten, H. (2009). The Global Peatland CO_2 Picture. Peatland status and drainage associated emissions in all countries of the World. Wetlands International, Ede, 10 p. + tables.

[3] Kolka, R., Trettin, C., Tang, W., Krauss, K. W., Bansal, S., Drexler, J. Z., Wickland, K. P., Chimner, R. A., Hogan, D. M. and Pindilli, E. J. (2018). Terrestrial wetlands. US Global Change Research Program, 2018, 507–567; Tarnocai, C. (1997). The amount of organic carbon in various soil orders and ecological provinces in Canada. In R. Lal, J. M. Kimble, R. F. Follett, and B. A. Stewart, Soil processes and the carbon cycle (pp. 81–92). CRC Press.

[4] Data extracted from the IUCN Red List of Threatened Species.

[5] Data extracted from the Ramsar Sites Information Service.

Peatlands cover an estimated 158 million hectares in North America, representing about 32% of global peatlands. There is still uncertainty in that number as some areas of North America have well-developed peatland maps and some areas do not. Better maps are still needed for remote Sub-arctic and Arctic areas, some mountain territories and some peatlands found in forests. In addition, better data on carbon stocks are needed to refine estimates for North America.

Climate change will affect all peatlands in North America, including the vast permafrost peatlands and boreal areas (Heffernan *et al*. 2020; Helbig *et al*. 2020; Hugelius *et al*. 2020) that are threatened by permafrost thaw and increased fire frequency and intensity. Agriculture, involving deliberate draining of peatland, has been by far the most damaging activity damaging peatlands followed closely by exploration and extraction by the oil and gas industry (Table 7.3). While it is well understood how to restore peatlands impacted by forestry operations, roads, networks of narrow forest clearings or seismic lines, and peat extraction activities, the science of restoring peatlands damaged by agriculture is not well developed. The science of restoring North American swamps also needs more attention.

Knowledge on how to conserve, manage and restore peatlands in North America has grown considerably over the past 40 years. Given this increased knowledge, regulators and government officials should update older peatland and wetland policies with newer information so that they better protect intact and untouched peatlands, more effectively repair those lands that have been damaged and help support Indigenous Peoples and Local Communities (IPLCs) who are rights-holders of these areas.


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7.1 Biomes and Ecological Zones

There are five main climatic regions in North America. These define the types, sizes and form of peatlands (Table 7.1). Fig. 7.1 shows the distribution of North American peatlands in aggregated FAO ecozones.

Table 7.1. Peat forming vegetation and ecosystem types, their local names and locations according to general and FAO Global Ecological Zone classification.

GPA Ecological Zone and peatland abundance	FAO Ecological Zone	Vegetation (frequent species)	158,200,825 ha	158,200,825 ha
Arctic (9%)	Polar	**Fens:** brown mosses (e.g., *Scorpidium* spp., *Aulacomnium* spp.), sedges (e.g., *Carex aquatilis, Eriophorum scheuchzeri*) and grasses (e.g., *Arctagrostis latifolia, Dupontia fisheri*) (Ellis and Rochefort 2004) **Permafrost peatlands:** palsas, pingos, polygonal peatlands, peat plateaus (Ecosystem Classification Group 2013)	Tundra wetlands	Alaska, Northwest Territories, Yukon Territory, Nunavut, northern Alberta and Saskatchewan, Greenland
Boreal (82.5%)	Boreal tundra woodland, Boreal coniferous forest	***Sphagnum* moss and black spruce bogs:** *Sphagnum fuscum, S. capillifolium, S. magellanicum (sensu lato), S. rubellum, S. angustifolium, Polytrichum strictum, Eriophorum vaginatum, Rhododendron groenlandicum, Chamaedaphne calyculata, Kalmia spp., Vaccinium oxycoccos, Drosera rotundifolia, Carex limosa, Picea mariana* **Fens:** *Larix laricina, Sphagnum subsecundum, Carex aquatilis, C. lasiocarpa, Trichophorum cespitosum* **Swamps***: Acer rubrum, Abies balsamea, Fraxinus nigra, Viburnum* spp., *Alnus* spp., *Ilex* spp. (National Wetland Working Group 1997)	Muskeg, bog, fen, swamp French: tourbière, plée, savanne, mocauque	From Alaska to Newfoundland and Labrador, north of the prairies (Alberta, Saskatchewan, Manitoba)
Temperate, cool (5%)	Temperate continental forest, Temperate oceanic forest	***Sphagnum* bogs, fens, swamps:** *Picea mariana, Thuja occidentalis, T. plicata, Abies balsamea, Acer rubrum, Fraxinus nigra, Larix laricina* (Pellerin *et al.* 2009)	Kettle-holes, swamps, fens, bogs	Mostly found along the east coast of the United States and Canada, in the Great Lakes region, and in the St. Lawrence Lowlands
Temperate, warm (2%)	Subtropical humid forest, Tropical moist deciduous forest	**Swamps:** *Pinus serotina, Chamaecyparis thyoides, Taxodium distichum, Acer rubrum, Nyssa sylvatica, Persea borbonia, Liriodendron tulipifera* **Fens:** *Cladium mariscus* spp. *jamaicense, Panicum* spp., *Eleocharis* spp., *Nymphaea* spp., *Utricularia* spp. (Lugo and Snedaker 1974) **Coastal mangrove forests:** *Rhizophora mangle, Avicennia germinans, Laguncularia racemosa*	Swamps, pocosins, sloughs	Mostly found along coastal regions of the US southeast coastal plain, extending from the Great Dismal Swamp in Virginia southward along the Atlantic coast to the Everglades of South Florida and westward along the coastal Gulf of Mexico
Mountains (1.5%)	Boreal mountain system, Temperate mountain system, Subtropical mountain system	**Fens:** ~ 50 species of Cyperaceae including *Carex aquatilis, Calamagrostis canadensis, Amblystegiaceae, Salix* spp., *Kobresia simpliciuscula* **Hypermaritime fens and blanket bogs:** *Sphagnum* spp., *Pinus contorta, Tsuga heterophylla, Carex pauciflora, Trichophorum cespitosum, Vaccinium microcarpum, V. vitis-idaea, Rubus chamaemorus, Andromeda polifolia* (Cooper et al. 2012)	Fens, blanket bogs	Rocky Mountains from New Mexico to northern Canada and the Brooks Range of Alaska, the Sierra Nevada of California, the Coastal Range, and the Appalachian and other eastern North American Mountain ranges

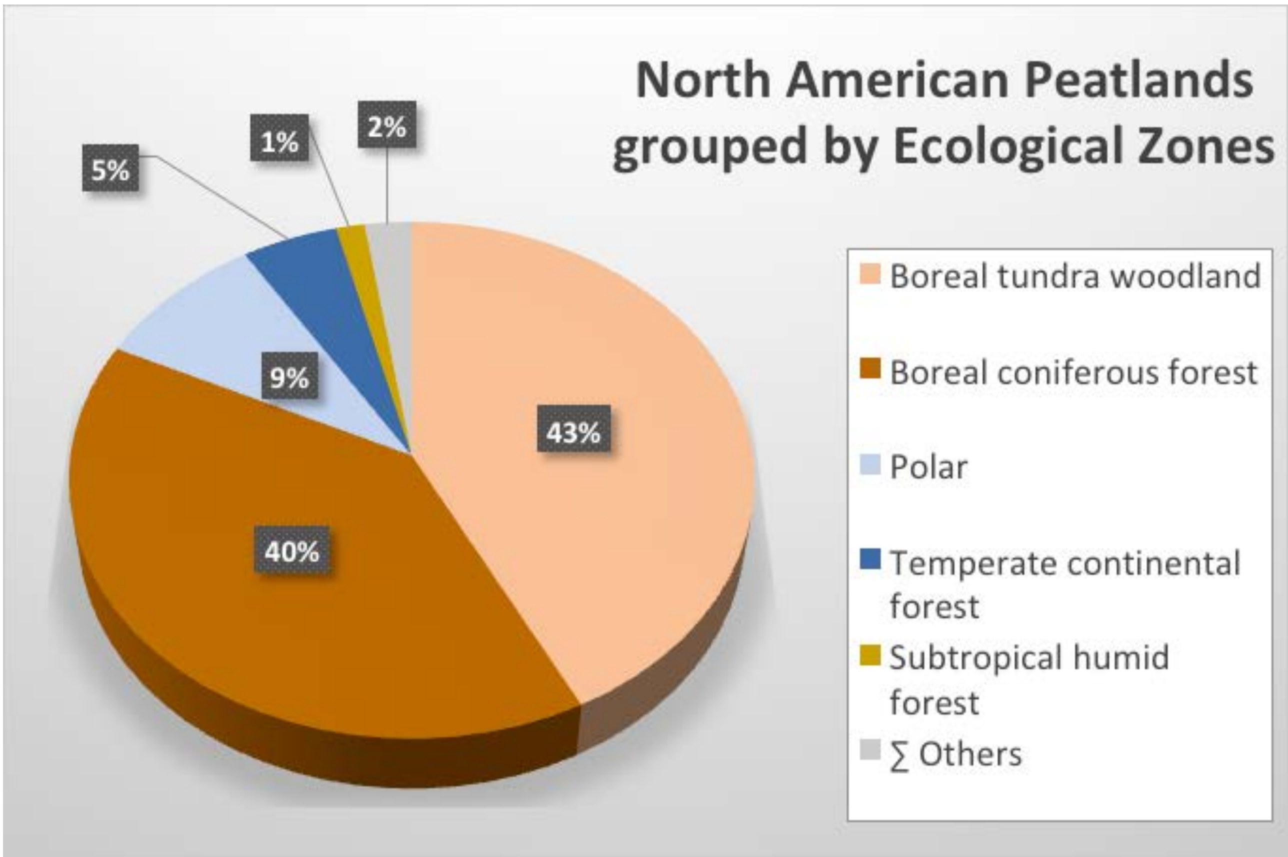

Figure 7.1. The distribution of North American peatlands in aggregated FAO Global Ecological Zones.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

7.1.1. Arctic

Severe climatic constraints in the Arctic, including low precipitation, many months of freezing temperatures, and short growing seasons resulting in low plant primary productivity, control peatland types and distribution (Remmert 1980). Peatlands are common in the southern Arctic (Low Arctic wetland regions) but are less frequent in the mid and high Arctic. Peat thickness is shallow compared to average boreal peatlands although thick peat accumulation was recorded in some areas (LaFarge-England *et al.* 1991; Garneau 1992; Ellis and Rochefort 2004). Shallow peat makes the transition between peatlands and wetland tundra (with < 30 to 40 cm peat) hard to differentiate. Because of dominant lateral hydrological inputs, the peatlands consist mainly of Arctic fens (Woo and Young 2006), which are known as essential habitats for herbivores, especially waterfowl species such as Snow Goose (*Anser caerulescens*) (Gauthier *et al*., 1996). Herbivores in Arctic fens, directly and indirectly, impact vegetation composition, biodiversity, carbon sequestration, nutrient cycle, and permafrost properties (Gauthier *et al*. 2004; Falk *et al*. 2015). The extent, distribution, ecology, and drainage status of peatlands/organic soils in Greenland (Greenlandic: Kalaallit Nunaat) are not well known (but see the work on Arctic C sequestration dynamics from the Zackenberg Valley, e.g., López-Blanco *et al*. 2020). Peat deposits are predominantly shallow (< 30 cm) and occur in coastal environments close to the Arctic and the North Atlantic Oceans (Barthelmes *et al*. 2015).

7.1.2. Boreal

Peatlands cover approximately 25-30% of the boreal forest in North America (Gorham 1991; Wieder *et al*. 2006). Because of their wide distribution, the development and type of boreal peatlands are influenced by latitudinal (primarily temperature) and longitudinal (primarily precipitation) gradients, as well as by the geological formations on which they lie (Gorham *et al*. 2003; Wieder *et al*. 2006). Most boreal peatlands originated 10,000-6,000 years ago, after the last deglaciation (Halsey *et al*. 2000; Kuhry and Turunen 2006). The rate of peatland initiation in the region has reached its highest point between 7,000 and 8,000 years ago (Gorham *et al*. 2007). Peat fire and, to some extent, permafrost, also play a significant role in peatlands' past and current formation (Kuhry 1994; Gibson *et al*. 2018). As a vast diversity of peatland types can be found in the boreal zone, a number of characteristics are used, in combination or alone, to distinguish them. These include the chemical and hydrological conditions (e.g., bog vs fen), the dominant vegetation type (e.g., *Sphagnum*, brown mosses, sedges, ericaceous), the density of the tree cover (0-10% tree cover is classified as open peatland, 10-25% as treed peatland, and > 25% as forested peatland) and the presence of surface structures (e.g., string and flarks vs domed vs flat) (Bona *et al.* 2020).

7.1.3. Temperate: Cool, Warm (Coastal Plains - Sub-Tropical)

A vast diversity of peatland types is found within this climatic region. In the northern part, especially in the Hemi-boreal regions of the Upper Great Lakes and near Southern Ontario and Quebec, many peatlands resemble boreal peatlands with similar vegetation as described above. Further south, temperate and subtropical peatlands are often forested, with a dense tree or high shrub canopy (freshwater peat swamp or coastal mangrove forests) (Mitsch and Gosselink 2015). Emergent herbaceous peatlands are also found in this region, either as isolated depressions, margins of peat swamps, or expansive patterned fens like the sawgrass marshes of the Everglades. Peat swamps are found in the eastern United States, all the way south to the cypress swamps in Florida, and throughout southern Quebec and Ontario, and the Great Lakes region (Davidson *et al*. 2022). They can also be found at the margins of domed bogs (Paradis *et al*. 2015). Peat thickness, fluctuations of the water table, and tree density determine the plant diversity of peat swamps (Zoltai and Vitt 1995; Ott and Chimner 2016). The Everglades of southern peninsular Florida are an expansive peatland landscape that covers 100,000 hectares from Lake Okeechobee south to Florida Bay (Craft and Richardson 2008) with Everglades National Park at its southern end designated a Wetland of International Importance (Ramsar 2005) and a United Nations World Heritage Site. The distribution and structure of Everglades peatlands is largely driven by the monsoonal seasonal patterns of surface water sheet flow in the freshwater Everglades (McVoy *et al*. 2011). It is also driven by the interaction between vertical soil accretion and sea level rise in coastal mangroves (Cahoon and Lynch 1997).

7.1.4. Mountains

Mountains typically have cool temperatures and high annual precipitation compared to the surrounding lowlands. This extra moisture creates conditions favourable for peatland formation (Cooper *et al*. 2012). Although both bogs and fens occur in the mountains of western North America, fens are the dominant peatland type with bogs occurring primarily in hyper maritime regions in coastal mountains (Cooper and Andrus 1994; Warner and Asada 2006; Cooper *et al*. 2015). Mountain peatlands can form in valleys, basins, small depressions, or on slopes (Chimner *et al*. 2010). Mountain peatlands occur in distinct elevation zones and are typically small compared to low elevation peatlands due to valley confinement, steep slopes, and small catchment sizes (see Annex IV – Fig. IV.24. Distribution of Mountain Peatlands in North America by elevation).

However, larger peatlands (> 6,000 hectares) can be found in sizeable valleys or in intermountain basins (Patterson and Cooper 2007; Chimner *et al.* 2010; Lemly and Cooper 2011; Cooper *et al.* 2012; Cooper *et al.* 2015). Sloping fens can occur on steep (up to 30%) mountainsides where perennial groundwater regularly discharges (Chimner *et al*. 2010; Cooper *et al*. 2015) and can create patterns of strings and flarks, terraces, and pools. In maritime regions, blanket bogs are common on slopes (Warner and Asada, 2006). Because many mountain peatlands are groundwater supported, watershed geology strongly influences the chemical content of their source water and vegetation composition (Vitt and Chee 1990; Cooper and Andrus 1994; Chimner *et al.* 2010).

7.2 Peatland Distribution and Extent

North American peatlands cover approximately 158 million hectares (GPD 2022) (Fig. 7.1), with a majority in the boreal biome. The provinces of Manitoba, Ontario and Quebec have the largest areas, including the Hudson Bay Lowlands (Table 7.2). Peatland abundance in the northern territories (Northwest Territories and Nunavut) remains uncertain and better maps of this vast area are needed.

Table 7.2. Total peatland area (hectares) per province or territory in Canada and for overall USA[a].

Canada: Province or territory	Area (ha)	Area from Global Peatland Map 2.0[b] (ha)
Newfoundland (Island)[1]	1,300,000	
Ontario[1]	26,130,000	
Northwest Territories and Nunavut[3]	25,111,000	
Manitoba[1]	21,089,800	
Quebec2	16,100,000	
Alberta (> 40 cm)[1]	10,300,000	
Saskatchewan[3]	9,309,000	
Newfoundland (Labrador)[1]	5,129,000	
British Columbia[1]	3,287,973	
Yukon[3]	1,298,000	
Nova Scotia[1]	175,000	
New Brunswick[1]	140,000	
Prince Edward Island[1]	7,527	
Total Canada	**119,377,300[c]**	**119,377,300**
USA[4]	**19,078,300**	**38,813,000**
Greenland[5]	7,500	8,000
St-Pierre-et-Miquelon[6]	1,700	2,800
Bermuda[7]	100	24
Total North America	**138,464,900**	**158,201,124**

[a] Country totals given in bold, italicized text are the best estimates of peatland area assessed by the author team.

[b] Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

[c] Previous estimates are 105,630,400 (Tarnocai *et al.* 2000) and 113,560,790 hectares (Tarnocai *et al*. 2011).

[1] Data gathered and compiled from Rochefort and Garneau (2011) with an update by

[2] Pellerin and Poulin (2013). If no new available data were available, the estimates of

[3] Tarnocai (1984) were used.

[4] Kolka *et al*. (2018)

[5,6] Conchedda and Tubiello (2020)

[7] Global Peatland Database (2020)

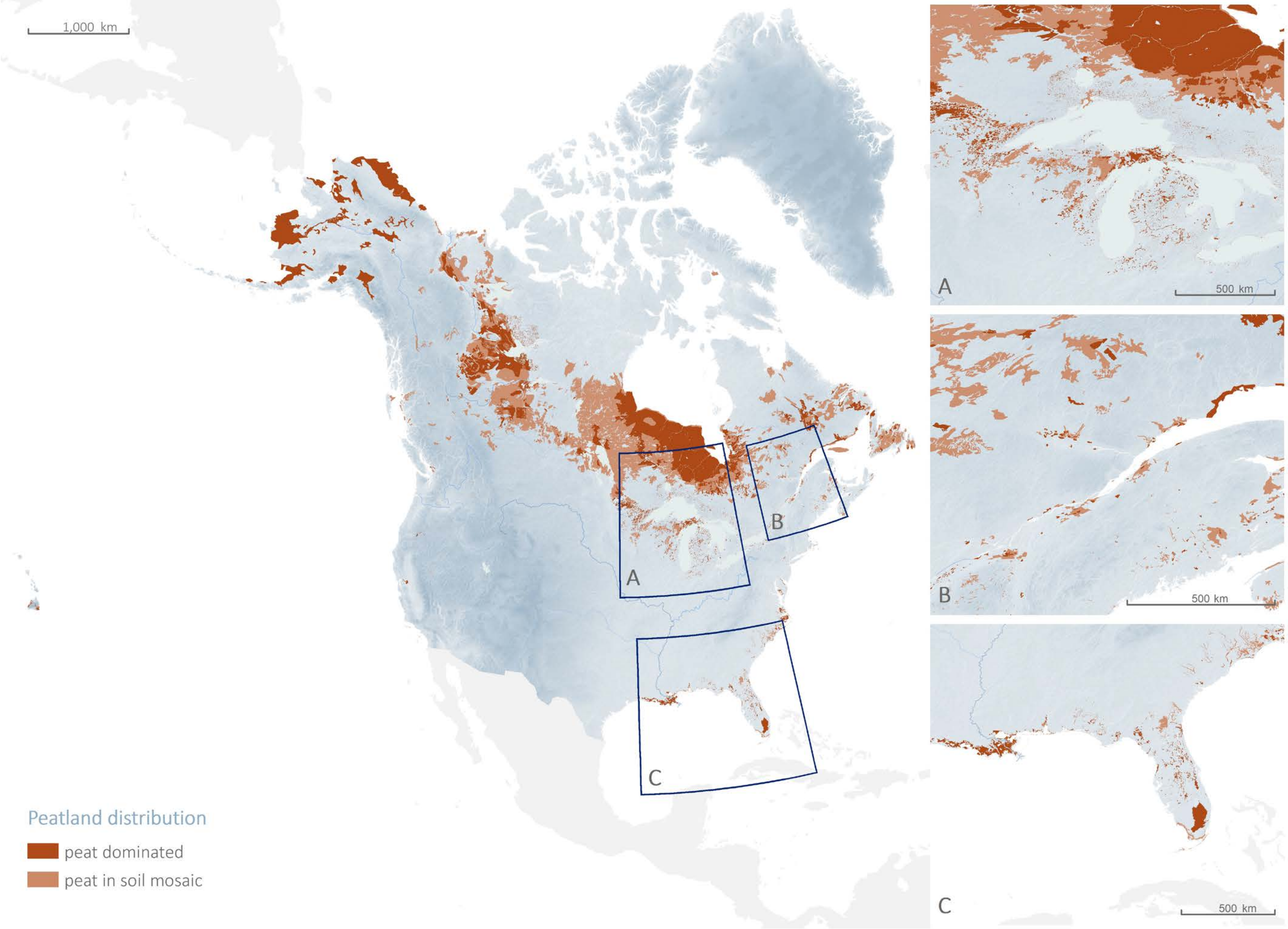

Figure 7.2. Peatland distribution in North America (partly incl. organic soils).

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III. Production of the Global Peatland Map 2.0.

Fig. 7.3 shows the proportion of North America's total peatland area per country, with Canada holding more than two thirds of the total peatland area in the region, i.e., 75%.

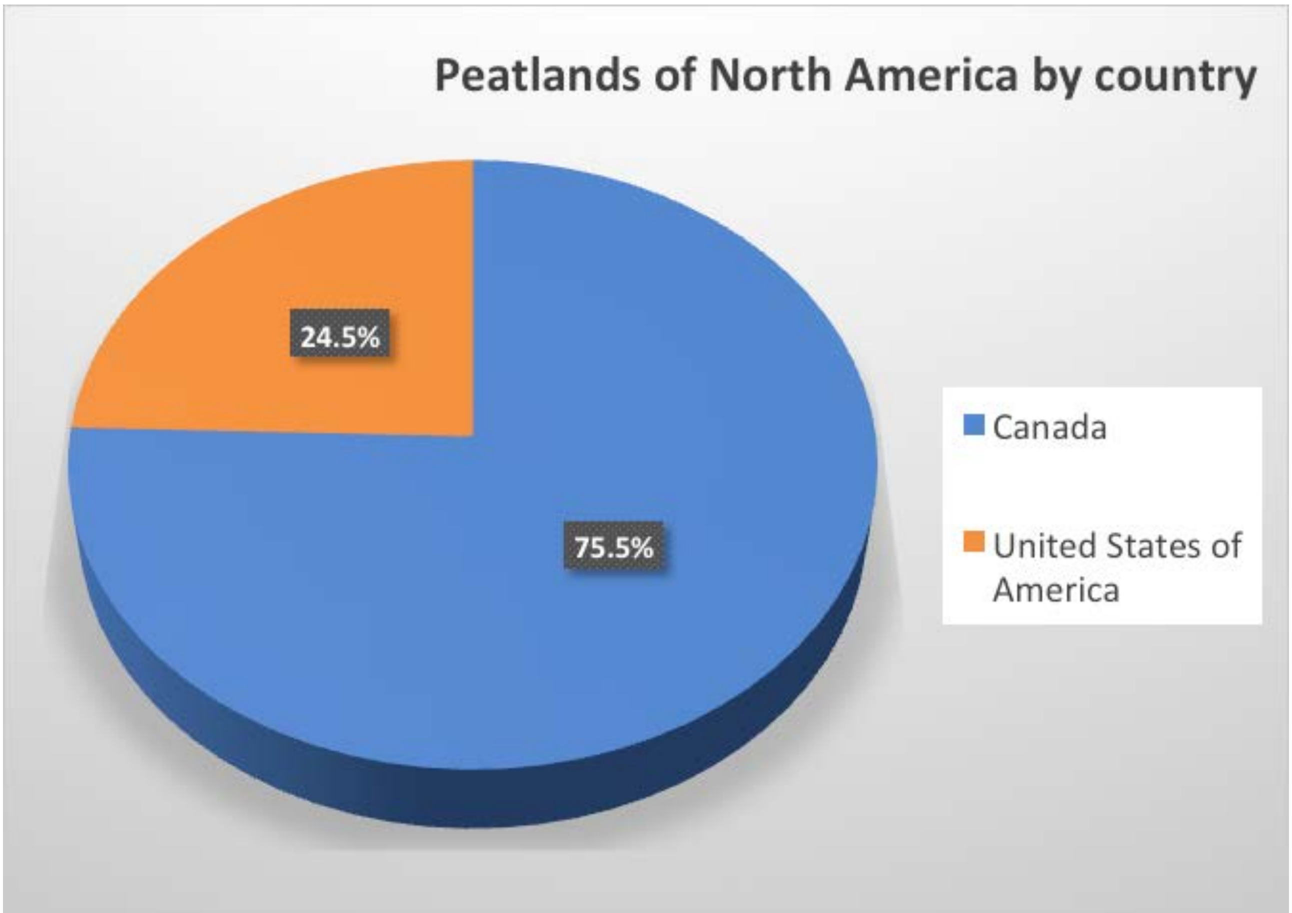

Figure 7.3. Proportion of North America's total peatland area per country.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

7.3 Biodiversity, Nature's Contributions to People and Hotspots of Value

7.3.1. Biodiversity

The biodiversity of North America's vast peatlands is poorly characterized largely because peatlands have not usually been differentiated from other types of habitat, particularly the boreal black spruce forest (Warner and Asada, 2006). Many peatlands consist of a mosaic of peatland types in close proximity, including bogs and fens, which have considerable variety in carbon densities (Packalen *et al*. 2016). Fens are typically characterized by shallower and denser peat layers than bogs, but both peatland types tend to store similar amounts of carbon. The greater number of plant species in fens and specific composition clearly separates them from bogs. Herbs, ferns and bryophyte richness is greater in fens whereas trees, shrubs and lichens are more prevalent in bogs.

Notably, the declining populations of Woodland Caribou (*Rangifer tarandus caribou*) are retaining attention with federal regulation calling for people to restore and maintain the integrity of the caribou northern habitats inclusive of peatlands (Hebblewhite 2017; DeMars and Boutin 2018; Hill *et al*. 2021). Among the 40 bird species regarded as peatland species (Desrochers 2001), the Palm Warbler (*Setophaga palmarum*) is the North American bird most closely associated with bogs. As most of the world population of Palm Warblers breeds in Canada's peatlands, it confers Canada with a high responsibility for the conservation of these habitats. Lincoln's Sparrow (*Melospiza lincolnii*) and White-winged Crossbill (*Loxia leucoptera*) are also species of concern for conservation, found in humid habitats of the boreal forests but restricted to peatlands in the southern part of Canada (Calmé *et al*. 2002). Conversely, Sandhill Crane (*Antigone canadensis*) populations are increasing in eastern Canada (Desrochers and Rochefort 2021). Boreal peatlands are renowned as a bird nursery for billions of migratory birds (Desrochers and Duinen 2006). In southern Ontario, peatlands are important nesting and hibernation sites for species of reptiles and amphibians considered threatened under Canada's Species at Risk Act, including the Eastern Massasauga Rattlesnake (*Sistrurus catenatus*) and Blanding's Turtle (*Emydoidea blandingii*) (Markle *et al*. 2020). Warner and Asada (2006) report the presence of about 106 species of beetles (Coleoptera) in bogs and fens of Canada and 14 species of dragonflies in bogs supporting three specialized genera (*Gomphaeschna, Williamsonia* and *Mannothemis*). There are 45 species of biting flies in bogs and 22 species in fens, none are restricted to peatlands though. The rotifer *Habrotrocha angusticollis* is an important part of the soil microfauna found in wet *Sphagnum* mossy peatlands (Warner and Chengalath 1991). Examples on the richness of protozoa, often referred to as testaceans or thecamoeba, can be found in the work of Lamarre *et al.* (2013), Amesbury *et al.* (2018), Zhang *et al.* (2020), and Mackay *et al.* (2021).

7.3.2. Nature's Contributions to People

Peatlands' contributions to nature and people have often been underestimated and undervalued, despite the numerous benefits peatlands provide (regulating, provisioning, and cultural ecosystem services) and the biodiversity they hold (and associated intrinsic values) (Parish *et al*. 2008). Canada holds the world's largest peatland carbon stock (Harris *et al*. 2022) (see § 7.3.3.2. Hudson Bay Lowlands), with an important regulating role for the global climate. Besides the regulating contributions, peatland ecosystems are included in the territory of several IPLCs across the region who maintain a dependency of these territories due to the social, community, cultural and economic values they provide (see § 7.3.3.1. Indigenous Land Use). Gender-responsive approaches to peatland conservation that take into account the livelihoods and contributions of both women and men are highly recommended.

Although the contributions peatlands provide in the North America are not often explicitly valued, there have been some assessments conducted with information available for decision-making. For example, the province of Manitoba has estimated the monetary value of peatlands in both Eastern and Interlake Manitoba to be $128 million Canadian Dollars (~$93 million US Dollars) per year. This estimate has considered the following goods and services: provisioning (water supply and subsistence), regulating (climate regulation, water regulation, water treatment, erosion control), cultural (spiritual well-being and recreation) alongside with the value those peatlands represent as a habitat/refugia for species (Voora *et al*. 2013).

7.3.3. Hotspots of Value

Three examples of peatlands' contributions to people in North America are provided below.

7.3.3.1. Indigenous Land Use

Covering a vast expanse of North America, peatlands make up large proportions of the traditional territories of many of the region's Indigenous nations. Indigenous peoples associate wetlands with hunting, trapping, berry picking, and medicines (Speller and Forbes 2022).

Berries, such as bog cranberry (*Vaccinium oxycoccos*), cloudberry (*Rubus chamaemorus*) and blueberries (largely *Vaccinium uliginosum* and *V. angustifolium*), are important food sources. Fire was traditionally used to increase berry yields in some regions (Speller and Forbes 2022). Some wetlands are used in winter months to reduce travel time to traplines and can be important features and markers of regional trail networks. It is common for people to have cabins and to camp near wetlands. Indeed, archaeological evidence indicates that communities were sometimes based directly on peatlands (Speller and Forbes 2022). There are also several peatlands that include traditionally harvesting areas that are culturally and spiritually significant, and some that are central to local histories and family traditions.

The specific needs of Indigenous women should also be taken into account as per SDG target 2.3. Indigenous women are one of the most vulnerable groups. With the knowledge that their livelihoods are closely tied to peatland resources, capacity building and economic empowerment, targeting Indigenous women would significantly help improve their adaptive capacities to climate change and depleted natural resources.

7.3.3.2. Hudson Bay Lowlands

The Hudson Bay Lowland (HBL) region of Canada ranks among one of the world's largest continuous peatlands (Fraser and Keddy 2005) at ~ 33.5 million hectares (Riley 2011) with a carbon stock of 30,000 Mt (Packalen *et al*. 2014) that formed over the last 7000 years (Glaser *et al*. 2004). Ensuring that the HBL peatlands remain net carbon sinks in the future is important, as they can help the world achieve net-zero emission targets. The HBL peatlands consist of a mosaic of peatland types in close proximity, including bogs and fens, which have considerable variety in carbon densities (Packalen *et al*. 2016). Fens are typically characterized by shallower and denser peat layers than bogs, but both peatland types tend to store similar amounts of carbon. Climate warming in this region may lead to peatlands increasing their rate of peat accumulation (Charman *et al*. 2013). The HBL is not close to the dry limit of peatland distribution in North America, so it should not be as sensitive to drier summers as western Canada is. With that said, given the increasing pressure from the extractive ore mining industry to exploit some of HBL's peatland-rich areas (see § 7.5 Drivers of change), avoiding the conversion of these natural carbon stores should be prioritized (Drever *et al*. 2021; Harris *et al*. 2022; Loisel and Walenta 2022). In addition, these peatlands support the production of fresh water in the region and help sustain valuable biodiversity (Webster *et al*. 2015; Stralberg *et al*. 2020).

7.3.3.3. Paludiculture: a Concept on the Sustainable Use of Peatlands

Paludiculture supports several sustainable development goals. It offers habitat for biodiversity, it preserves carbon stocks, it restores carbon sinks, it regulates and purifies water, and it provides cultural services (Ziegler *et al*. 2021). In North America, examples of paludiculture are *Sphagnum* farming, cranberry cultivation in former peat-extracted peatlands, and wood harvesting in naturally forested peatlands.

Sphagnum farming

In the region, growing media for the horticulture industry heavily rely on *Sphagnum* peat. This makes peatlands targets for extraction. There is a global effort to develop more sustainable growing media that can replace extracting peat. *Sphagnum* farming allows for: 1) the cultivation of *Sphagnum* mosses without loss of quality (Jobin *et al*. 2014; Aubé *et al*. 2015), 2) the conservation of the C accumulation and stocks of the peatland supporting the farm (Brown *et al*. 2017), 3) the retention of a certain amount of biodiversity within the farm setting (Muster *et al*. 2020), and 4) the contribution to climate change mitigation (Wichmann *et al*. 2015).

Cultivated *Sphagnum* mosses have many potential horticultural and restoration uses. These include the use of mosses in orchid propagation, their use in landscaping and plant pots, their use as a partial or complete replacement of peat in growing substrates (Jobin *et al*. 2014; Aubé *et al*. 2015) and their use as a reintroduction material for peatland restoration (Hugron and Rochefort 2018). Advances have been made in *Sphagnum* farming research over the past two decades in Eastern Canada, as summarized by a recent guide on the topic, but implementation at an industrial scale remains to be demonstrated (Guêné-Nanchen and St-Hilaire 2022).

Paludiculture in US Forestry

It is common in many parts of the world to ditch peatlands for forestry operations. This impacts water quality, carbon sequestration, and biodiversity. However, the drainage of peatlands for forestry in North America is uncommon. In the Great Lakes region of the United States and the eastern United States, lowland conifer swamps (peatlands) containing a combination of species such as Black Spruce (*Picea mariana*), Tamarack (*Larix laricina*), Balsam Fir (*Abies balsamea*) and Northern White Cedar (*Thuja occidentalis*) are commonly harvested in undrained peatlands (Grigal and Brooks 1996). Wood products are typically used for pulp, paper, or specialized wood products. Forest harvesting typically takes place during the winter on frozen soils or using swamp mats to minimize disturbance to the sensitive organic soils (Grigal and Brooks 1996).

Cranberry Bog Farms

Cranberry (*Vaccinium macrocarpon*) is used fresh or made into cranberry juice. Cranberries are grown mostly in peatlands across the northern part of the United States and parts of Canada. The major production areas are Wisconsin, New Jersey, Massachusetts, Oregon, Washington, British Columbia, Ontario, Quebec, New Brunswick and Nova Scotia. Cranberries are harvested in the fall by flooding the peatlands causing the berries to float and allow for harvesting. The sustainability of this farming option in relation to the protection of the carbon in the peat soil remains to be demonstrated.

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7.4 Status of Peatlands, Drivers of Change and Hotspots of Change

7.4.1. Status of Peatlands

In North America, between 3-4 million hectares of peatlands are degraded by anthropogenic activities. Large uncertainties exist in this number because impacts such as roads, fills, railways, ore mining, and power lines have not been calculated yet by all provinces or states. If this value is accurate, it indicates that more than 97% of the peatlands in North America are still in a relatively intact state. Agriculture is definitely the main activity degrading peatlands in North America, followed by the petroleum industry in Canada (Table 7.3). On a smaller scale, the threats to peatlands in Greenland include mining, oil exploitation and the expansion of agriculture due to the warming of the Arctic and Subarctic. Based on the GPA data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre, estimated greenhouse emissions from degraded peatlands in Canada and the United States are 89.4 Mt CO_2e per year. This estimated value is higher than the one calculated previously by Kolka and collaborators, which was 77 Mt CO_2e per year (Kolka *et al.* 2018).

Table 7.3. Estimated peatland area disturbed (hectares) by anthropic activities in North America.

Disturbance type	Estimated area disturbed (ha)			Total for North America
	Canada	US	Greenland	
Agriculture[1]	1,315,373	1,557,278		
Development[2]		100,632		
Pasture[2]		141,386		
Mining (including oil and gas seismic and roads)[3]	370,000			
Treated or planted[4]	(1,344)			
Hydroelectricity reservoirs[5]	245,000			
Power lines[5]*	12,600			
Forestry operations (drained)[5]*	69,700			
Other (roads, dumps, fill, railways)[2,5]*	56,200	87,244		
Horticultural peat extraction[6]	24,964	134		
Restored	(8,182)	(29)		
Reclaimed	(2,168)			
Total area of disturbed peatlands	2,082,143	1,557,278	300[7]	**3,639,721**
Total area of degraded peatland from Global Peatland Map 2.0[8]	1,350,000	1,464,900		**2,814,900**

[1] Canadian estimations vary from 710,000 to 1,315,373 hectares (Dumanski *et al.* 1998; Carlson *et al.* 2017; Mccollough 2022).

[2] Kevin McCullough and Erik Lilliskov, unpublished data

[3] Drever *et al.* (2021), Strack *et al.* (2019)

[4] Forest Resources Improvement Association of Alberta [FRIAA] (2022), assuming all areas treated and planted to date are peatlands.

[5] Rochefort and Garneau (2011)

[6] Canadian *Sphagnum* Peat Moss Association [CSPMA] (2022), note non-members of CSPMA are not accounted for

[7] NIR Denmark (2014)

[8] Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

* Statistics from the Quebec province only

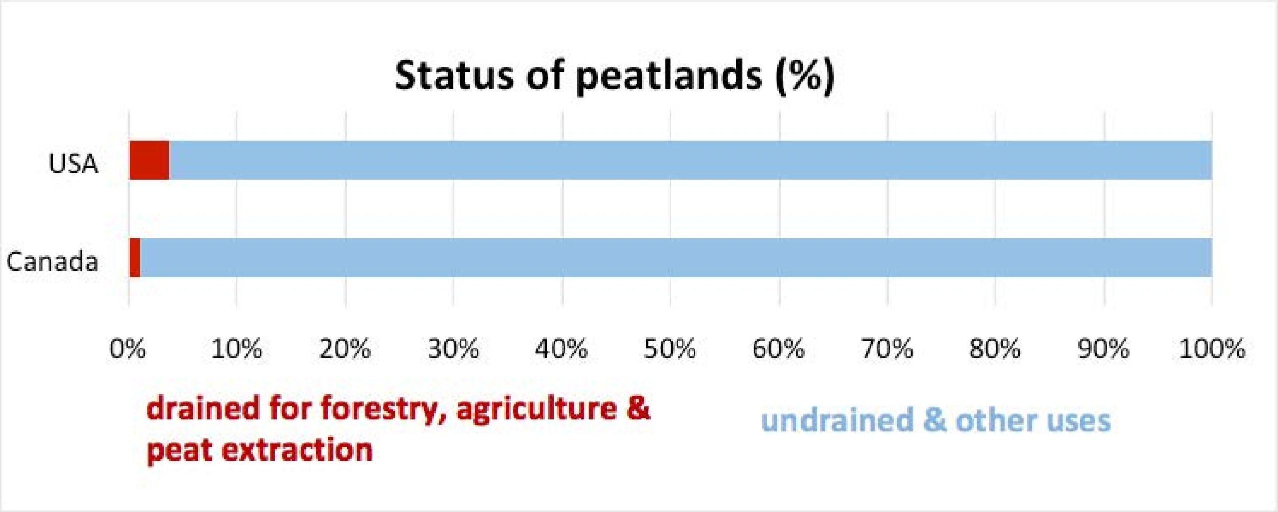

Figure 7.4. Proportion of drained (red) and undrained (blue) peatlands in North America per country (partly including organic soils). Calculations are based on the drained area for forestry, agriculture and peat extraction.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

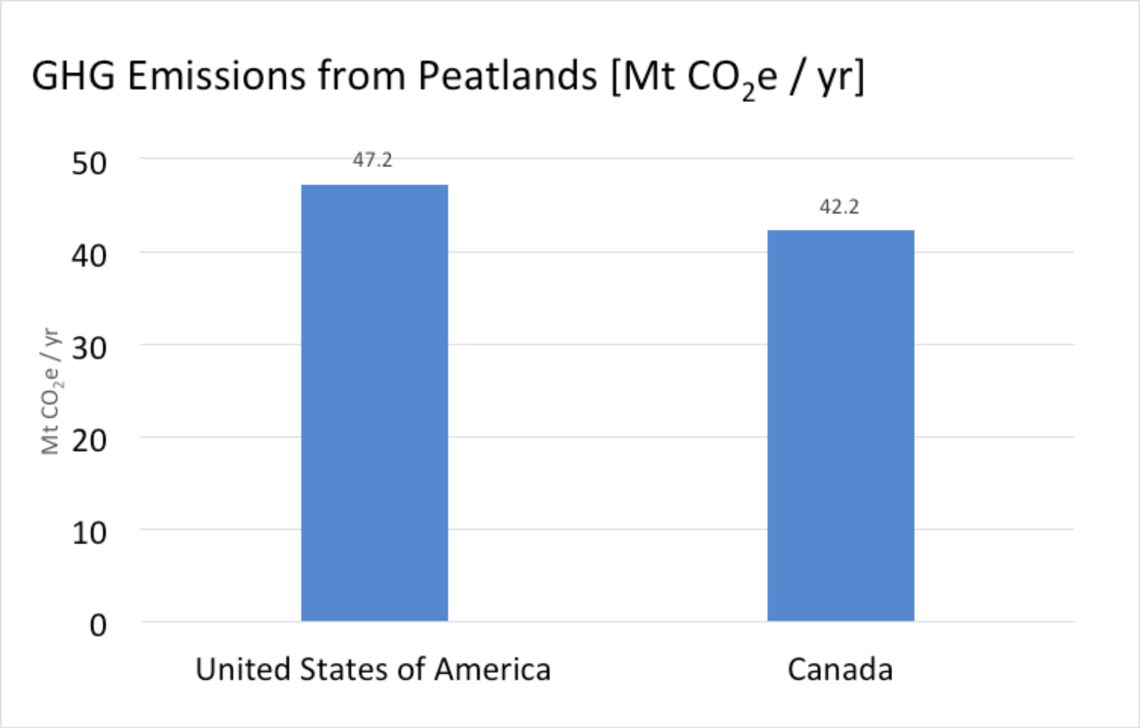

Figure 7.5. North American countries emitting GHG from peatlands, with USA representing 53% and Canada 47%. Calculations are based on the peatland drained area for forestry, agriculture and peat extraction and IPCC (2014) emission factors including CO_2, CH_4, N_2O, *DOC, and emissions from ditches. Includes only net, on-site GHG emissions. Wildfire emissions are not included.*

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Fig. 7.4 shows the proportion of drained and undrained peatlands in North American countries. In the USA, 3.7% of peatlands were drained for forestry, agriculture and peat extraction, whereas in Canada the percentage of drained peatlands is even lower, i.e., 1.1%.

Fig. 7.5 shows the annual GHG emissions from organic soils drained for forestry, agriculture and peat extraction in North American countries. The annual GHG emissions from organic soils in both countries (Canada and USA) correspond to a total of 89.4 Mt CO_2e.

Peatlands are protected by laws (see § 7.7.i Policy context) or by being located in protected areas. Peatlands are conserved by various types of protected areas across North America including national parks, provincial parks, territorial parks, state parks, land trusts and Indigenous Protected and Conserved Areas (IPCAs). Currently, there are no national inventories of protected peatlands. This makes the compilation of the total protected areas difficult (Table 7.4). Climate change is an overarching threat. It affects North American peatlands regardless of their protection status. Its impact continues to be investigated.

7.4.2. Drivers of Change

7.4.2.1. Agriculture

Peatlands are often drained and converted into agricultural fields or pastureland resulting in carbon loss (Armentano 1980) and soil subsidence (Knox *et al*. 2015). The Food and Agriculture Organization of the United Nations (FAO) estimates that approximately ~1 million hectares of peatlands have been converted to pasture and ~2 million hectares converted into cropland in North America (Table 7.3; FAO, 2022). These numbers are likely substantial underestimates as peatlands in some areas of North America are poorly mapped, especially in the western part of the continent. In addition to direct peatland conversion, an additional area of adjacent peatlands are impacted by agricultural operations through high water use and pesticide and fertilizer runoff (e.g., cranberry farms in Quebec, see Poulin *et al*. 2004).

Table 7.4. Protected peatland area (hectares) by Canadian provinces.

Provinces	Area (ha)	% Protected Areas
Manitoba[1]	9,396,900	44.6
Alberta	1,349,161	13.1
Quebec	1,301,605	8.1
British Columbia	109,697	3.3
Nova Scotia	43,830	25.0
New Brunswick	21,000	15.0
Prince Edward Island	942	12.5
Total	**12,223,135**	**10.2**

[1] Areas (4,021,800 hectares) withdrawn from quarry and mining dispositions

Sources: data gathered and compiled from Rochefort and Garneau (2011)

Canada and the United States have similar areas of peatlands impacted by agriculture, with some regional differences in use. In Canada, ~1 million hectares of peatlands are currently estimated to be drained and under cultivation, primarily for cultivation of vegetables and forage crops (Joosten and Clarke 2002; FAO 2022). An additional ~0.3 million hectares of peatlands have been drained for conversion into pasture. In the United States, peatlands are more strongly impacted by livestock than in Canada with ~0.65 million hectares of peatlands converted into pasture and another ~1 million hectares drained for cropland. Based on cross-referencing maps of agricultural and major soil types (NASS - National Agricultural Statistics Service and Natural Resources Conservation Service Soils), the primary crops on peatlands in the United States are maize, soybeans (predominantly in the Midwest and Great Plains), and sugarcane (primarily in the Southeast). Other regionally important crops include cranberries in the Northeast and blueberries in the Northwest. The largest areas for agriculture on peatlands in the United States are the Midwest and the Southeast. The Southeast also contains large historical areas of peatlands (e.g., bottomland hardwood peatlands, Pocosins, and Everglades) that have been degraded (Mitsch and Gosselink 2015). For instance, ~70% of the original area of the Pocosins has been impacted by historical deforestation, ditching and agriculture (Richardson 1983). The Everglades have lost 75% of peat stocks from drainage for agriculture and urban development (Mitsch and Hernandez 2013; Hohner and Dreschel 2015). These peatlands are also under additional threat from drainage-induced subsidence and from sea level rise that is driving salt-water intrusion and peat erosion (Sklar *et al*. 2019).

7.4.2.2. Oil Sands Development

The Western Sedimentary Basin, extending across the Canadian provinces of Saskatchewan and Alberta, represents the third largest known oil deposit in the world. It covers an area of 14 million hectares. As this region is also rich in peatlands, accounting for over 50% of the land area in some regions (Vitt *et al*. 2000), oil extraction has resulted in past and current peatland degradation. Open pit mining involves the stripping of all surface vegetation, soils and near surface geologic deposits. It currently covers a total area of 105,000 hectares (Alberta Environment and Parks 2022) and is expected to result in the destruction of 29,500 hectares of peatlands once completed (Volik *et al*. 2020). Closure plans recognize that integrated nature of the landscape has to be captured in their reclamation plans, but it is practically impossible to restore or recreate peatlands back to their former abundance as after open mining oil sand extraction as the landscape is too salty to support a peat ecosystem (Daly *et al*. 2012). Furthermore, closure plans do not address the cumulative effects of multiple mines. In addition, monitoring to assess ongoing impacts is notoriously problematic in this region (Cronmiller and Noble 2018; Ficken *et al*. 2022) and absolute footprint metrics quoted in Table 7.3 are likely not accurate (Cronmiller and Noble 2018; Ficken *et al*. 2022).

Many oil sands deposits are too deep for surface mining and are extracted by in situ methods that involve steam injection and subsequent pumping of bitumen to the surface. This involves the creation of well-pads (Fig. 7.6) and associated infrastructure such as access roads, pipelines, and processing facilities. Currently, 36,000 hectares of well-pads exist on peatlands in the region of Western Sedimentary Basin (Alberta Biodiversity Monitoring Institute [ABMI] Human Footprint Inventory 2019). However, in comparison to open mining, the carbon stock in the ground is less disturbed. Additionally, geologic exploration to map oil sands deposits and plan resource development has been widespread in the region, resulting in a network of narrow forest clearing called seismic lines that account for over 190,000 hectares of peatland disturbance (Strack *et al*. 2019).

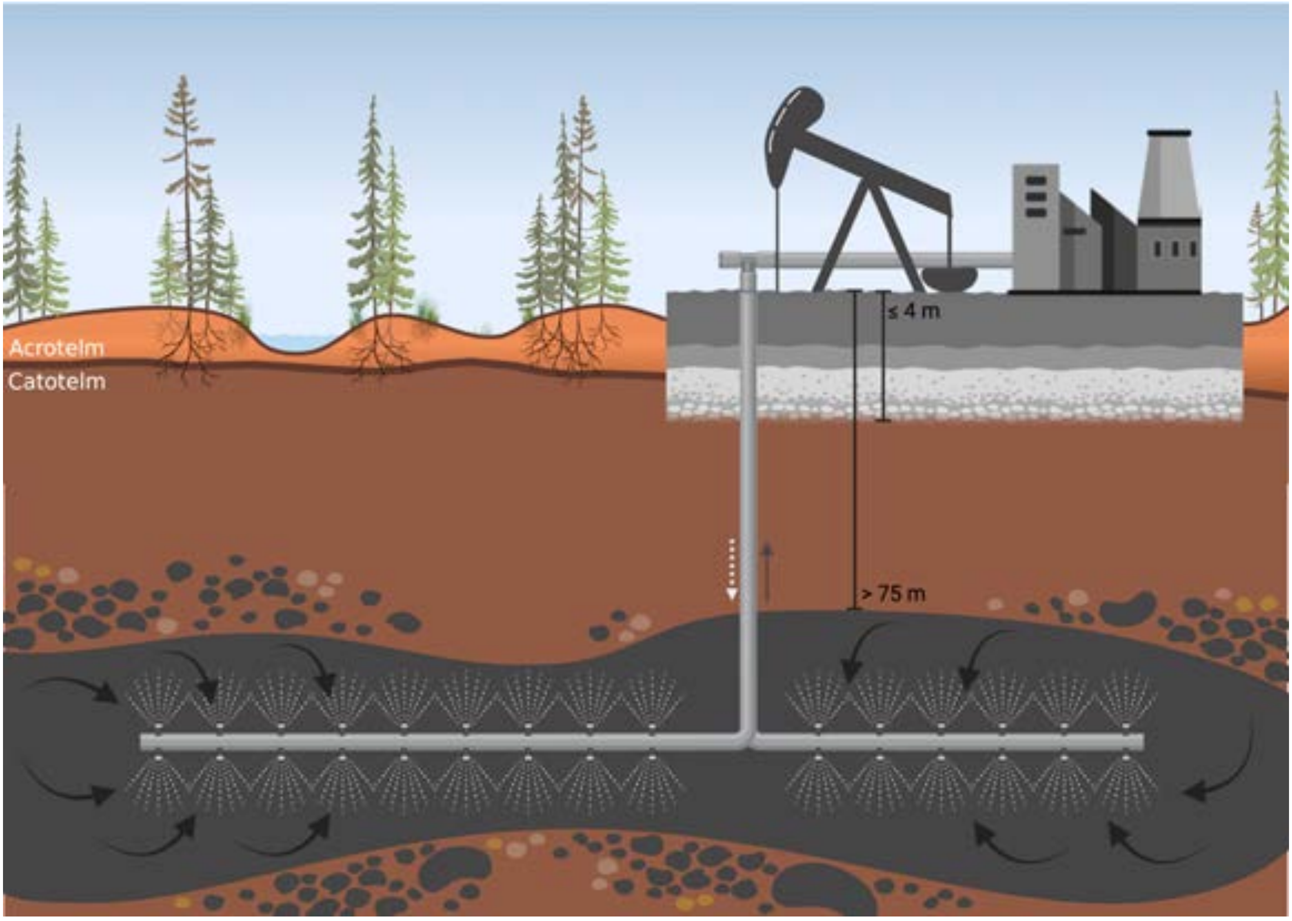

Figure 7.6. An in-situ oil pad built within a peatland. Notice how the mineral fill used to construct the pad is elevated above the surrounding peatland surface. Conceptually it is the same type of disturbance as for road construction or mining infrastructure facilities.

Source: Government of Alberta 2021.

Together with roads and pipelines, these linear disturbances account for the greatest area of disturbance across Canada's boreal forest (Pasher *et al*. 2013) and result in habitat fragmentation, hydrological and chemical disruptions, and changes to peatland carbon stocks and greenhouse gas exchange (Turchenek 1990; Latham *et al*. 2011; Plach *et al*. 2017; Saraswati and Strack 2019; Strack *et al*. 2019). However, greenhouse gas emissions arising from these types peatland disturbances remains unclear due to a lack of field measurements (Drever *et al*. 2021). Notably, linear disturbances have been linked to population declines of the threatened Woodland Caribou (James and Stuart-Smith 2000; Latham *et al*. 2011), a species that depends on intact forested peatlands of the region for habitat.

7.4.2.3. Northern development for natural resources

Mineral Exploration and Mining: Development of the Ring of Fire in Northern Ontario

The discovery of substantial mineral deposits in the so-called "Ring of Fire" in the northern part of the province of Ontario, within the Hudson Bay Lowlands region, has led to over 13,000 active mining claims that cover over 200,000 hectares (Ministry of Mines, Ministry of Northern Development, and Ministry of Natural Resources and Forestry 2022). Harris *et al*. (2022) estimate that development of mines on these peat-rich areas would result in emissions of 130-250 Mt carbon.

In addition to causing direct land disturbance on the footprint of mines, development of these resources will require construction of all-season roads in a wetland-rich landscape that is currently undeveloped and largely pristine. The impact of these roads on hydrology will be substantial. In general, expansion of mining across the peat-rich boreal and subarctic regions of North America could disturb large areas of peatlands in the coming decades. In fact, an evaluation of natural climate solutions for Canada identified avoiding of mining disturbances to peatlands between 2021-2030 as the largest peatland-related pathways for reducing greenhouse gas emissions from peatlands, accounting for 7.8 Mt of CO_2e in 2030 (Drever *et al*. 2021).

Hydroelectric Projects

In Canada, there are several hydroelectric developments projected to be in operation in the next few years or decades (Lower Churchill Project, NF; hydro in northern Quebec, QC; Keeyask, MB; Site C clean energy project, BC). Although hydroelectricity is considered to be a clean source of energy, construction of the dams results in the permanent flooding of large areas of peatlands that will then no longer be able to sequester carbon (Teodoru *et al*., 2012; Turetsky *et al*. 2002).

7.4.3. Hotspots of Change

7.4.3.1. Climate Change Impacts

Climate change has a number of direct and indirect effects on the peatlands of North America. First, climate warming enhances permafrost thaw that can have **negative impacts** on peatland structure and function. Climatic drying is known to generally promote peat oxidation and increase fire frequency and intensity, both of which lead to net carbon emission (Helbig *et al*. 2020; Zhang *et al*. 2020). Warming and drying also have a compounding effect on peatland hydrology (i.e., water table drawdowns; Swindles *et al*. 2019) that often leads to non-linear plant and microbial community changes and net carbon losses (Loisel *et al*. 2021; IPCC 2022). Third, climate-change-induced sea-level rise is expected to impact some low-lying coastal peatlands in the Atlantic regions by flooding and salt-water intrusion (not discussed here but see Guêné-Nanchen *et al*. 2020 for an example). Finally, climate change is expected to impact Arctic peatlands by increasing the primary productivity of vascular plants over the longer growing seasons, and this effect is subjected to interactions with herbivores (Gauthier *et al*., 2013; Gignac *et al*., 2022).

In contrast, climate change in northern North America could also have some **positive impacts** on peatlands. Indeed, in the Hudson Bay Lowlands, model simulations suggest increasing net carbon uptake across the region, due to warmer and wetter conditions that stimulate peat formation (Gallego-Sala *et al*. 2018; Qiu *et al*. 2020). Similarly, warmer and wetter conditions in eastern Canada have been shown to cause ecosystem shifts from fens to bogs which have higher rates of carbon accumulation (Magnan *et al*. 2022). Due to the potential for varying responses, the impact of climate change on northern peatlands is at the cutting edge of academic research (Helbig *et al*. 2020; Zhang *et al*. 2020) (Loisel *et al*. 2021; IPCC 2022). Below, we present changes in permafrost condition and wildfire regime impacting North American's peatlands.

7.4.3.2. Permafrost thaw

Permafrost underlays approximately 35-45% (~50 million hectares) of peatlands in North America (Tarnocai *et al*. 2011; Hugelius *et al*. 2020; Olefeldt *et al*. 2021), with its distribution seen in Fig. 7.8. There is strong evidence of ongoing and accelerating permafrost thaw due to climate warming (Payette *et al*. 2004; Camill 2005; Chasmer and Hopkinson 2017; Mamet *et al*. 2017; Gibson *et al*. 2021).

Permafrost thaw in peatlands is expressed both through a gradual deepening of the seasonally frozen near-surface peat layer (Quinton and Baltzer 2013) and through thermokarst processes where melting of excess ground-ice causes land surface subsidence or collapse (Vitt *et al*. 1994; Jones *et al*. 2017). Thermokarst in peatlands of the discontinuous and sporadic permafrost zones (e.g., in the Hudson Bay Lowlands, the Mackenzie River Basin and interior Alaska) causes 1-3 m vertical collapse along edges of peat plateaus and palsas, leading to the formation and expansion of thermokarst bogs, fens and ponds (Olefeldt *et al*. 2021). Thermokarst collapse has affected between 15-50% of permafrost peatlands in regions with discontinuous and sporadic permafrost over the last 35-50 years, and near-complete permafrost thaw in these regions is expected this century (Chasmer and Hopkinson 2017). Permafrost thaw is, and will be, slower in the continuous permafrost zone, but ice-wedge degradation in polygonal peatlands is currently widespread, e.g., on the North Slope of Alaska, and causes rapidly altered patterns of inundation and drainage (Liljedahl *et al*. 2017).

Permafrost thaw causes drastic shifts in peatland ecology, hydrology, and biogeochemistry, including thermokarst collapse (local wetting; Sannel and Kuhry 2011; Heffernan *et al.* 2020). It also increases peatland drainage and hydrological connectivity to downstream aquatic ecosystems (regional drying; Quinton *et al*. 2019). These changes in hydrology alter vegetation (from dominance of lichens, shrubs, and coniferous trees to mosses and graminoids) which then influence the greenhouse gas balance of peatlands (CO_2, CH_4, and N_2O), both by making previously long-protected soil carbon available for microbial processes and by influencing plant productivity through changes in environmental conditions and vegetation composition (Bubier *et al.* 1995; Liblik *et al.* 1997; Klapstein *et al.* 2014; Cooper *et al.* 2017; Pelletier *et al.* 2017; Hugelius *et al.* 2020; Nwaishi *et al.* 2020). Permafrost peatland integrity depends on the interconnections between peat, vegetation, hydrology and temperature. Seasonal dynamics also play a part in the delicate balance of permafrost peatlands. In summer, dry peat obstructs heat inflow because of its low thermal conductivity. But when peat is wet its thermal conductivity is 5 times higher and 25 times higher when frozen. These properties assist the penetration of winter cold into the soil, resulting in a ‘cold pump’ that creates and conserves permafrost under conditions in which it otherwise could not exist (UNEP 2019).

Figure 7.7. Examples of arctic polygonal tundra landscapes (Bylot Island, Nunavut). Photos: Line Rochefort.

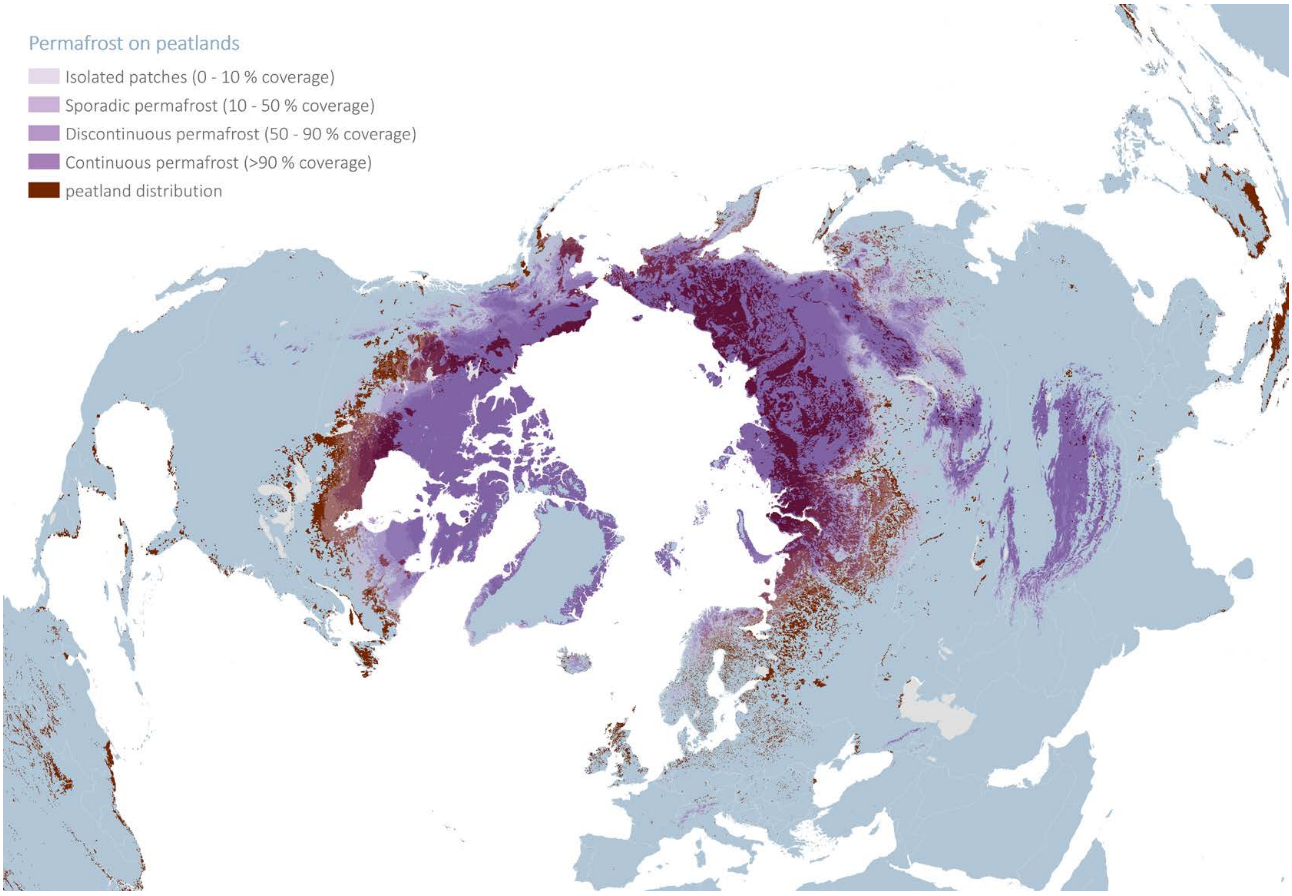

Figure 7.8. Peatland distribution in permafrost from the boreal regions of North America, Europe, and Asia.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III.3 Production of Thematic Maps.

7.4.3.3. Wildfire

Wildfire has historically affected ~ 0.5% of peatlands in North America annually, with the highest frequency in forested bogs and forested permafrost peat plateaus in subhumid regions of western Canada (Zoltai *et al.* 1998; Turetsky *et al.* 2004). Global hotspots of fire on peatlands during a strong El Niño (2015) and a moderate La Niña year (2020) can be seen in Chapter 4 (Fig. 4.11). The frequency and severity of wildfires is a key determinant of the long-term carbon balance of peatlands (Robinson and Moore 2000). Wildfires commonly burn 1-10 cm in peatlands (Walker *et al*. 2018; Guêné-Nanchen *et al*. 2022) with some deep peat burning being possible at peatland edges or during extreme droughts (Lukenbach *et al*. 2017). Average carbon loss from wildfires is 1-3 kg C m-^{2} (Benscoter and Wieder 2003; Shetler *et al*. 2008; Lukenbach *et al*. 2016), totalling ~5-10 Mt C per year across North America (Zoltai *et al.* 1998; Turetsky *et al.* 2004). This value is likely to increase with the expected increase of fire frequency resulting from climate change (Wotton *et al.* 2010; Turetsky *et al.* 2015; Whitman *et al.* 2019; Wilkinson *et al.* 2020). Climate change, disturbances, and droughts have the potential to increase both the area of peatlands burned and the combustion of soil carbon (Nelson *et al*. 2021), which could shift the net carbon balance of North American boreal peatlands from a carbon sink to a source (Robinson and Moore, 2000; Wieder *et al.* 2009; Turetsky *et al.* 2011, 2015) including the large HBL carbon stocks (Bona *et al*. 2020).

7.5. Policy Context, Options for Action and Hotspots of Response

7.5.1. Policy Context

7.5.1.1. Canada

In Canada, peatlands may have some limited protection or mitigation requirements through federal policies, or by the provincial or territorial government for other lands in each province or territory. Most Canadian provinces have a wetland policy or regulation (90% of the wetlands in Canada are peatlands (Tarnocai 1997) that was developed to manage wetland loss using compensatory mitigation programs designed to offset impacts through restoration. Some provinces and territories lacking a wetland policy have existing regulations that apply to activities in wetlands but were not developed to target wetland protection. A few provinces have a draft wetland policy that has not been formally adopted but is applied to some extent. A summary of provinces with wetland policies are presented in Table 7.5. British Columbia, Ontario, Saskatchewan, the Northwest Territories, Nunavut, and Yukon have a draft wetland policy or other regulations that control activities in wetlands.

No existing regulatory programme explicitly prohibits peatland development, and compensatory mitigation programs do not require peatland restoration so that other wetland types may be restored instead. Peatland protection generally is not prioritized over other wetland types. For example, peatland extent in Alberta is greater in northern regions and compensation through its in-lieu fee program is reduced relative to other regions partly due to wetland abundance. An exception to this rule is Quebec's financial compensation procedure, which makes peatland destruction significantly costlier, sometimes prohibitively so. Generally, operations that impact peatlands are not required to compensate until after operations cease, even if said operations persist for decades. Wetland function and value assessments used to determine payments into in-lieu programs do not consider carbon storage functions on the basis that climate change is addressed through other policies. These factors greatly limit policy effectiveness for peatland protection. Quebec's Regional Plans for Wetlands and Bodies of Water (including peatlands), include an action plan and follow-up measures that aim to preserve biodiversity, restore species or maintain ecosystem services. The implementation of these regional plans is a legal obligation.

Table 7.5. Summary of wetland policies of some Canadian provinces.

Province or Territory	Description	Department/Agency
Alberta	Alberta Wetland Policy (2013)	Alberta Environment and Parks
Manitoba	Amended Water Rights Act (2019)	Environment, Climate and Parks
New Brunswick	Wetland Conservation Policy (2002)	Environment and Local Government
Newfoundland and Labrador	Policy for Development in Wetlands (1997)	Environment and Climate Change
Nova Scotia	Wetland Conservation Policy (2011)	Nova Scotia Environment
Prince Edward Island	Wetland Conservation Policy (2003)	Environment, Energy and Climate Action
Quebec	Act respecting the conservation of wetlands and bodies of water (2017)	Ministry of Environment and Climate Change

Few examples of wetland conservation and restoration in the carbon market exist in Canada[1] with more examples related to upland forest and agriculture offsets (See § 9.3.2). Incentives may increase with financing mechanisms designed to incentivize protection of intact peatland carbon sinks (Harris *et al*. 2022), which would create significant opportunities and benefits beyond restoring previously impacted peatlands.

7.5.1.2. United States

Wetlands, which include peatlands (30% of total wetlands in the United States are peatlands; Kolka *et al*. 2018), are regulated nationally via the Clean Water Act (CWA). The CWA, enacted in 1972, prohibits the unauthorized discharge of pollutants into the waters of the United States, including wetlands. Permits must be obtained for discharging dredge or fill material into waters of the United States, including wetlands. Id. § 1341. The federal government has operated under a "no net loss" of wetlands policy since 1977 (see Exec. Order No. 11990 (1997)). The no net loss policy was further formalized after 1989 and promoted a more formal process to require mitigation when permitted projects do not appropriately avoid wetland loss, and, in some cases, compensation for impacts to wetlands (The Environmental Law Institute and Land Trust Alliance 2012). The policy resulted in a subsequent memorandum of agreement (MOA) between the U.S. Environmental Protection Agency and Department of the Army, the federal government follows a "mitigation sequence" to determine whether potential impacts to wetlands have been avoided "to the maximum extent practicable" and minimized "to the extent appropriate and practicable". Then, if any impacts are identified, they must be offset or compensated "to the extent appropriate and practicable" (U.S. Department of Army and U.S. EPA 1990). From this sequence the mitigation banking system has sprung, as well as voluntary, non-regulatory conservation programs (The Environmental Law Institute and Land Trust Alliance 2012). The no net loss policy has, through these multiple frameworks, generated a system of formal and informal processes for conservation and mitigation, which continue to be developed.

Carbon offsetting projects are one example of systems that have developed as a result of wetland mitigation policies. Carbon offset projects have been used increasingly since the 1990s after the establishment of the 404 (b) (1) guidelines. One of the largest such projects has currently been initiated by a research team at Duke University in North Carolina. Duke, as an institution of higher education, voluntarily committed to becoming carbon neutral by 2024 (Weiss and Vujic 2014). In order to achieve this, they established the Duke Carbon Offsets Initiative (DCOI) in 2009. Under the direction of Curtis Richardson, the University identified 4,000 hectares of privately owned lands in North Carolina to use for the carbon offset project (Richardson *et al*. 2018). The land is mostly coastal peatland (pocosins) that were drained and then further damaged due to lightning-strike-induced fires. The scientists identified a process for rewetting and restoring the peatlands to create a "carbon farm" where carbon credits could offset the university's net emissions to achieve neutrality. This strategy also presented an opportunity to sell excess carbon as credits (Kozak 2019).

Individual states regulate wetlands within their jurisdiction as both a part of the broader federal CWA regulatory scheme and any additional state-specific laws and policies (Environmental Law Institute 2007). Although the United States has a no net loss policy, the extent of wetland conservation and success of this policy faces continued challenges and periodic criticisms.

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[1] But see Quebec regulation specifically addressing the conservation of carbon stocks to mitigate climate change.

Most criticisms pertain to discrepancies in delineation, private versus public land use, exemptions for certain sectors particularly agriculture, exclusion of draining activities, and a lack of disincentive for developers (Congressional Research Service 2014). A lack of uniform and comprehensive policy and approach to wetland protection continues to pose a significant obstacle to wetland conservation (Congressional Review Service 2017). Nonetheless, there remains continued opportunity to further use voluntary mitigation programs. These include the creation of conservation land trusts, carbon offsetting programs, and mitigation banking to enhance and expand mitigation and conservation of wetlands and peatlands. Increasing awareness through education to help the public favour preservation initiatives in high priority wetland areas will support mitigation efforts as well.

7.5.2. Options for Action

7.5.2.1. Peatland Conservation: Indigenous Protected and Conserved Areas

Given the large proportion of intact peatlands in North America, peatland conservation is an important action to protect the ecosystem services upon which we depend. IPCAs are lands and bodies of waters where Indigenous governments have the primary role in protecting and conserving ecosystems through Indigenous laws, governance and knowledge systems (Indigenous Circle of Experts 2018). Several IPCAs have been established since 2018, including the Edéhzhíe Dehcho Protected Area/ National Wildlife Area that covers 1.4 million hectares of boreal forest in the Northwest Territories and the Thaidene Nëné Indigenous Protected Area that includes 2.6 million hectares of forest, peatland, and tundra in the Northwest Territories (Indigenous Leadership Initiative 2022). Several other Nations are advancing IPCAs. These include in the Kaska Dena Council's work to protect the largest intact area in British Columbia (Dene K'éh Kusān) comparable in size to Switzerland to support Kaska culture, create jobs, and shelter threatened species. Four First Nations and their Inuit neighbors in northern Manitoba are working to protect the Seal River Watershed so the next generation can engage in traditional practices and provide stewardship (Indigenous Leadership Initiative 2022). In Ontario, Kitchenuhmaykoosib Inninuwug have proposed the Fawn River Indigenous Protected Area that includes portions of the Hudson Bay Lowland. It is worth noting that IPCAs have been identified for other social and ecological values besides carbon accumulation, including biodiversity and water resource protection and recognition of Indigenous laws and land relations (Indigenous Leadership Initiative 2022).

7.5.2.2. Restoring Peatlands Impacted by Agriculture (US)

Restoring peatlands and wetlands from former agricultural lands is currently a common practice in the United States (Chimner *et al*. 2017). For instance, since 1992, private landowners in the United States have restored and conserved more than 1 million hectares of wetlands in agricultural lands through the Wetlands Reserve Program (WRP) and Agricultural Conservation Easement Program through the United States Department of Agriculture's (USDA) Natural Resources Conservation Service. Many of the restored wetlands are mineral soil wetlands but many peatlands are also included in this program. One of the main concerns when restoring peatlands from agriculture is the high level of nutrients and contaminants in the soil, which can cause offsite pollution when rewetted. Restoration of the Everglades is the most famous and large-scale projects of post-agricultural peatland restoration. Here, on-farm management, and the creation of treatment wetlands using a series of emergent macrophytes (plants rooted in shallow water), submerged aquatic vegetation, and periphyton (a mix of algae and microbes) proved highly effective in improving water quality from the restoration area (Sklar *et al*. 2005).

Once successful methods for improving water quality have been identified, work can proceed to restore hydrology and vegetation. For large-scale projects such as happening in the Everglades, landscape-scale models can be instrumental for setting targets and determining ideal hydrological interventions (Sklar *et al*. 2005). As always, the success of restoration projects will depend heavily on how goals are set. These goals should consider the potential impacts of climate change that may make it impossible to return a site to previous hydrological conditions - such as salt-water intrusion from sea level rise in coastal areas (e.g., Sklar *et al*. 2019). However, there is evidence that restoration of agricultural peatlands can reduce their role as carbon sources or convert them back to carbon sinks (Knox *et al*. 2015).

7.5.2.3. Restoring Peatlands Impacted by Industrial Infrastructure (mining, well-pads [in situ, exploration], winter road, road, seismic lines)

Progress has been made on reestablishing wetlands, including fens, on oil sands mines (Ketcheson *et al*. 2016). Pilot projects have resulted in the establishment of wetland/peatland plants (Borkenhagen and Cooper 2019; Hartsock *et al*. 2021), self-sustaining hydrological conditions (Ketcheson *et al*. 2017) and growing season net carbon storage (Clark *et al*. 2019; Popović *et al*. 2022). To date, fen construction projects have only occurred on a small scale but provide important knowledge on how to incorporate peatlands in mine closure plans.

Although the mining, oil, and gas sectors are lagging behind in restoration efforts, in Alberta, Canada, 1,300 hectares of peatland affected by oil and gas exploration and extraction activities have been restored. The majority of oil reserves in Alberta are too deep to directly mine and oil extraction can only be achieved through in-situ technologies such as steam-assisted gravity drainage (SAGD). The restoration of the numerous infrastructures needed for in-situ extraction and built within a peatland aims to re-establish hydrological and physicochemical conditions suiting targeted vegetation (Vitt *et al.* 2011; Gauthier *et al.* 2018). Proven successful techniques can be grouped under two categories. These include the partial removal of the mineral fill and the inversion of the underlying peat on top of mineral fill (Fig. 7.9). The aim is to level the former infrastructures to around 5-15 cm above the average depressions (hollows) of the surrounding undisturbed peatland (Fig. 7.9). The hydrological connectivity to undisturbed, adjacent peatland ecosystems has been proven the most important factor for the development of peatland characteristic vegetation communities, peat accumulation, and carbon uptake (Lemmer *et al*. 2020; Engering *et al*. 2022; Xu *et al*. 2022). The complete removal of the mineral fill, a common, intuitive approach that is often required by regulations, can create deep water bodies due to the partial inability of compressed peat to rebound after infrastructure removal (Elmes *et al*. 2021). This leads to invasion by aquatic plants such as cattails (*Typha latfolia*) and the development of non-peat-forming, marsh wetlands (Lemmer *et al.* 2022).

Industrial footprints such as seismic lines, winter roads, and exploratory well pads, do not require the placement of mineral fill but can compress the peat during construction and cause a shift towards sedge dominated communities due to wetter conditions (Davidson *et al*. 2020). Currently the common restoration approach is mounding with an excavator to create elevated mounds similar to natural variable microtopography of hummocks and hollows (Lieffers *et al*. 2017; Caners *et al*. 2019; Murray *et al*. 2021). The goal is to favour the return of trees (e.g., black spruce or tamarack), reduce habitat fragmentation and mitigate predatory pressure on the Woodland Caribou (Dyer *et al*. 2001; Filicetti *et al*. 2019).

Following reprofiling (i.e., changing the topography) to hydrologically reconnect to the adjacent, natural peatlands and restoring the surrounding, impacted areas (Lefebvre-Ruel *et al*. 2019), additional soil preparation may be necessary prior to plant reintroduction.

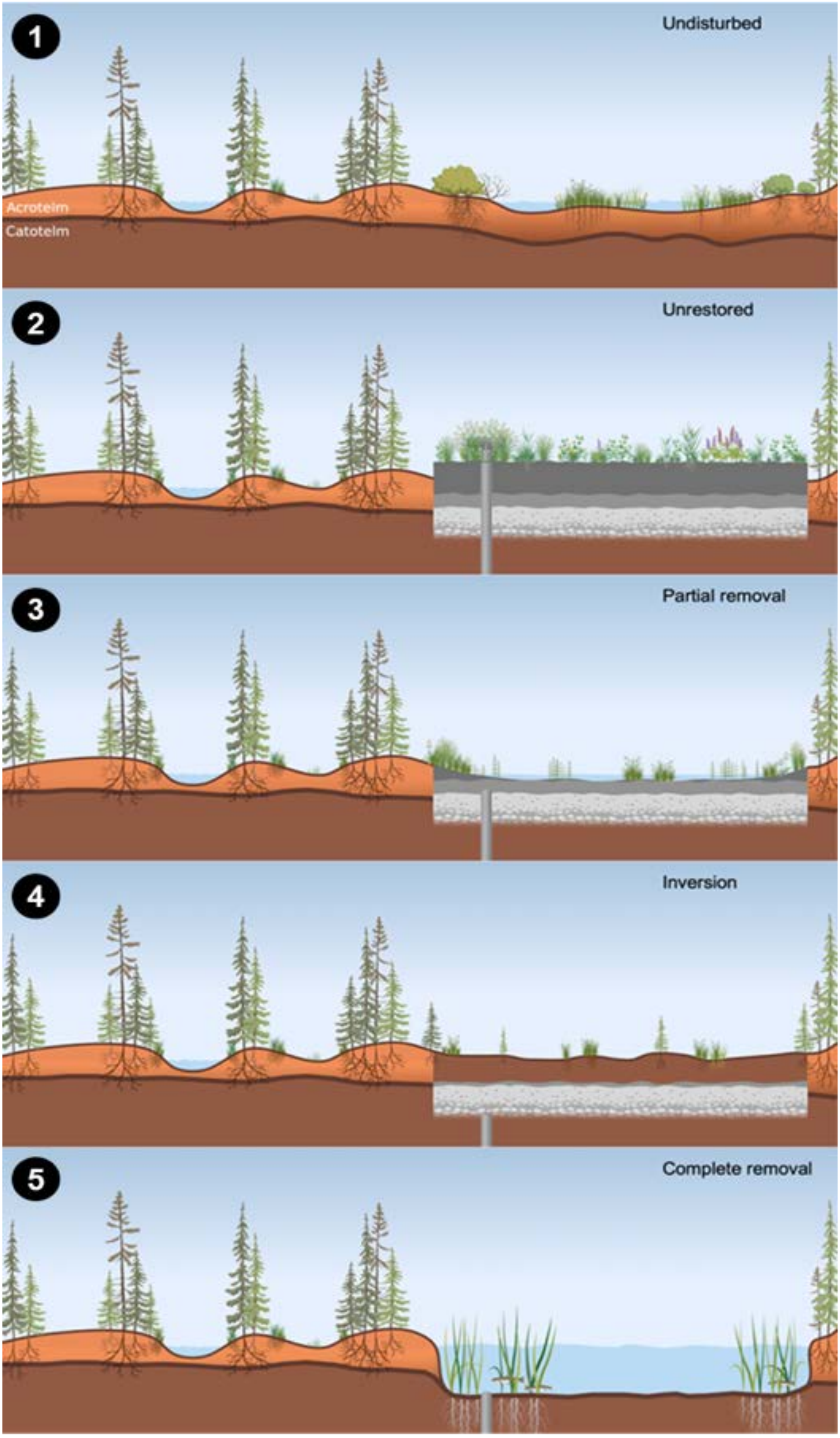

Figure 7.9. Schematic cross section of 1) a pristine peatland before disturbance, in comparison to the 2) unrestored peatland disturbed by infrastructures, and peatlands restored via 3) the partial removal of the mineral fill, via 4) the inversion of the mineral fill and the underlying peat, and via 5) the complete removal of the mineral fill, where a shallow open water area formed instead.

Source: Lemmer 2022.

Several trials have shown that capping residual mineral fill with peaty soil after reprofiling can increase acidity, reduce cation content, and improve soil moisture. All of this favours peatland plant establishment (Gauthier *et al.* 2018; Pouliot *et al.* 2021; Lemmer *et al.* 2022; Xu *et al.* 2022). A prompt, active reintroduction of peat mosses accelerates the return of carbon sequestration (Engering *et al*. 2022).

7.5.2.4. Reducing Fire Risk and Severity in Peatlands

Peatland rewetting and restoration were identified as efficient management strategies to reduce wildfire risk in drained peatlands (Granath *et al*. 2016). The re-establishment of a *Sphagnum* moss layer is paramount for the return of the negative feedback loops (Waddington *et al*. 2015) that control the water table level and confer fire resistance and resilience (Blier-Langdeau *et al*. 2022). Furthermore, in drained forested peatlands, trees can be cut to increase light availability, reduce water losses from evapotranspiration, and favour *Sphagnum* mosses over feather moss (Kettridge *et al*. 2013). Thinning the canopy also reduces aboveground fuel stocks and may reduce the severity of peat carbon losses (Wilkinson *et al*. 2018). The compression of the peat associated with the forestry activities can also reduce smouldering during fires (Deane *et al*. 2022). The effectiveness of these management strategies has been studied only in experimental plots and additional research is needed to assess their potential for reducing peatland wildfire risk and severity at larger scales (Miller and Davidson-Hunt 2010).

7.5.3. Hotspots of Response

7.5.3.1. A Case Study with the Canadian Horticultural Peat Industry

The Canadian horticultural peat industry has a small total footprint that has contributed to the disturbance of peatlands (35,315 hectares including some land-use changes other than restoration or equivalent to 0.03% of the peatlands in Canada) compared to other causes of degradation (Table 7.3), but they are playing an outsized role in facilitating the advancement of sciences in peatland ecological restoration (Alamenciak *et al*. 2022). They have been supporting academic research for more than 30 years allowing for the development of peatland restoration techniques and the establishment of a long-term monitoring program to evaluate successful successional trajectories and indicators (González *et al*. 2013; González *et al*. 2014; González and Rochefort 2014; González and Rochefort 2019). The 27 years of monitoring across 125+ restoration sites across Canada have produced a precious database for meta-analyses in the young science of ecosystem restoration. This long-term involvement in academia-industry partnership is also unique on the basis that in Canada there are no initiatives such as the Long-Term Ecological Research - National Science Foundation (LTER-NSF) program found in the United States. Based on scientific results, the Canadian horticultural peat industry has been proactive in responsibly managing this valuable peat resource (Friser 2019). So far, this horticultural peat industry has restored 74% of its historical footprint (since 1930, equivalent to 8,120 hectares) and they adopted a National Peatland Restoration Initiative to achieve 100% restoration (CSPMA, 2022). Likely the most impactful result for climate mitigation is the demonstration that prompt active restoration with moss reintroduction enables recovery of carbon sequestration to an average level of 75 g cm^{-2} per hectare within a period of 9 to 12 years and positively contributes to reducing the global warming potentials within 20 years (Nugent *et al*. 2018; Nugent *et al*. 2019). In term of life-cycle analysis, this does not account for the carbon emitted from the extracted peat, nor the carbon uptake by plants grown in peat-based growing media.

However, the Canadian horticultural peat industry is aware that it has to reduce its impact on peatlands and is currently investing in research to find practices to decrease the impact of peat extraction (Guêné-Nanchen and St-Hilaire 2022).

Box 7.1. Restoring *Sphagnum*-peatlands with the Moss Layer Transfer Technique (MLTT)

The reasons underlying each of the restoration actions involved in the MLTT are explained in the book chapters - Restoration of Degraded Boreal Peatlands (Rochefort and Lode 2006) and Restoration of Peatlands After horticultural Peat Extraction (Graf *et al*. 2012). The detailed technical guidelines of Quinty *et al*. (2020) about how to restore peat-extracted peatlands for horticulture can be freely accessed. A video produced by a peat company nicely illustrates the MLTT.

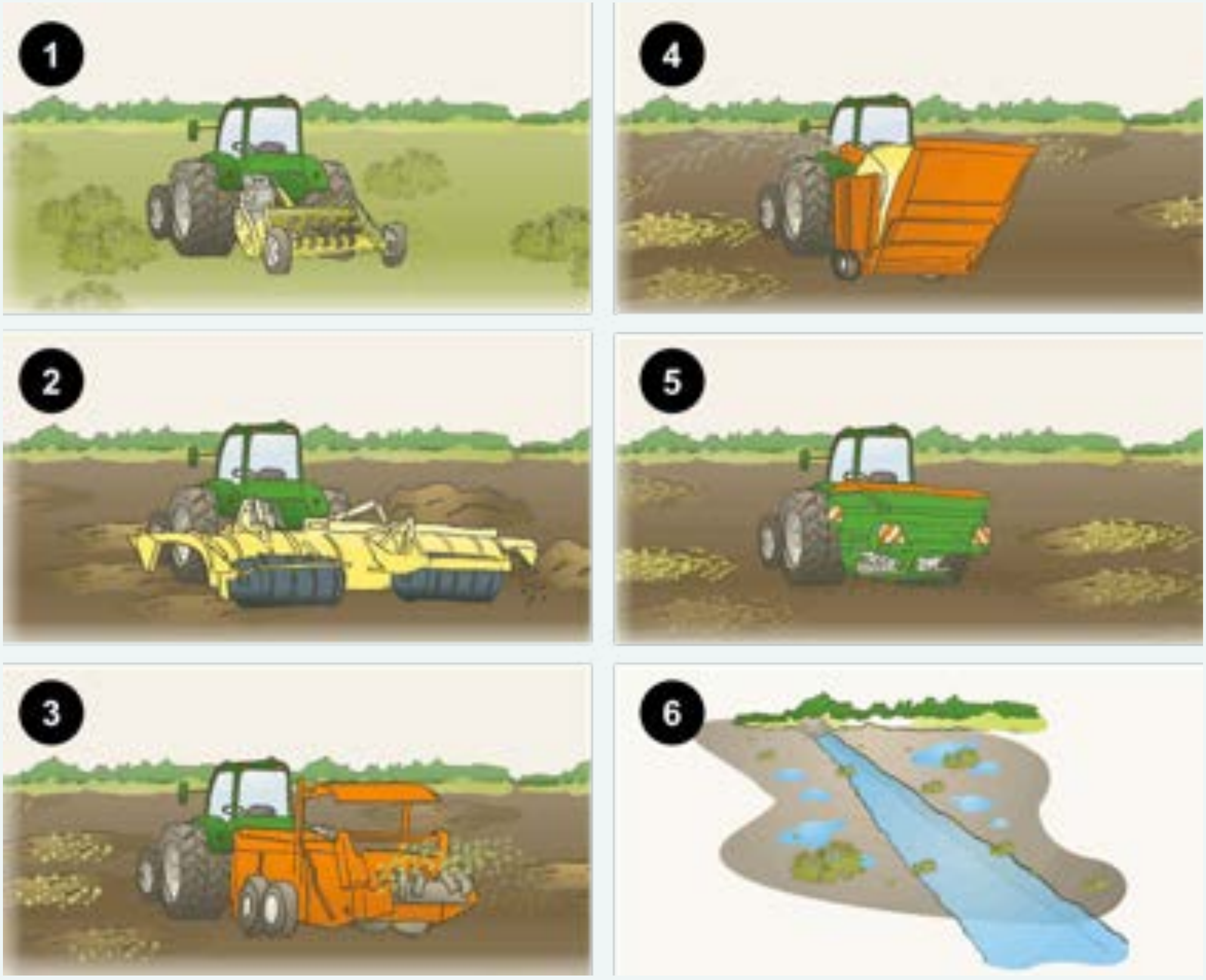

Figure 7.10. Steps of the MLTT: 1) collecting plant material, 2) preparing the surface for restoration, 3) spreading plant material, 4) adding a straw mulch, 5) adding a phosphate fertilizer and 6) blocking drainage ditches.

Source: CSPMA 2022.

7.6. Knowledge Gaps

Peatland coverage: While good mapping exists for some provinces or states, reliable estimates are missing for remote Sub-arctic and Arctic areas, for some mountain territories and forested peatlands. Better data on carbon stocks are also needed to refine estimates for North America.

Peatland area protected: Although many peatland conservation projects are occurring a lack of standardized database at national levels makes it difficult to evaluate the efforts to protect peatlands.

Peatland degradation: Outside of Alberta and Quebec, areas of peatland disturbed by a range of development pressures (e.g., roads, seismic lines, drainage for agriculture, ore mining industry, forestry, flooding by dams) are not well-known. In addition (section 7.5 Drivers of change), the full impact of many disturbances, including agriculture, roads, infrastructure development and permafrost thaw, on peatland function (particularly GHG emissions) is not well-quantified. Accounting for these impacts to mitigate climate change is consequently difficult.

Peatland restoration: In the United States, significant efforts have been made to restore large wetland complexes drained for agriculture or forestry such as the Great Dismal Swamps or the Everglades. In Canada, restoration of peatlands post-farming is less common. Peatlands drained for agriculture are usually fens, and restoration of fens is greatly challenged by poor understanding of the groundwater hydrology supporting fens. More information is needed on how disturbance and restoration alter hydrologic feedbacks that influence success of long-term fen restoration (Waddington *et al*. 2015). In general, more information on how to minimize invasive species during restoration is also needed.

Peatland policy enforcement: There are good approaches and guidelines available to restore peatlands impacted by seismic lines, roads (including winter roads), explorative and extractive oil sands well pads, post-peat extraction activity, post-cranberry farming, degraded mountain fens and post-drainage for forestry. It is our understanding that the regulators are not necessarily aware of where many peatlands are, what the most important drivers of peatland degradation are or which benefits for people and nature are lost when peatlands are disturbed. This includes a lack of knowledge on 1) C and greenhouse gas emission and sequestering abilities following many types of peatland degradation, 2) which peatlands can be restored, 3) what techniques are required for restoration, and 4) which peatlands cannot be restored (e.g., dam flooding, open pit oil sands extraction). Therefore, a forum of knowledge exchanges across states, provinces and territories with academia would permit better enforcement and amelioration of the wetland policies and ensure that they are aligned with global climate and nature goals. Additionally, policies and conservation efforts should be gender-responsive, ensuring that both women and men benefit from and contribute to these services.

Preserving the carbon that North American peatlands store will be critical to mitigating the negative effects that climate and land use change will have on the planet. So too will be the scaling up of restoration of degraded peatlands.

CHAPTER 8

Regional Assessment for Oceania

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CHAPTER 8

Regional Assessment for Oceania

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Regional Highlights

Key Facts

KEY REGIONAL DATA PRODUCED FOR THE GLOBAL PEATLANDS ASSESSMENT 2022[1]	
Total peatland area (hectares)	7,285,883 ha
Peatland cover over total region surface area (%)	0.9%
Degraded peatlands (%)	10.1%
Annual GHG emissions from peatlands (Megatons of carbon dioxide equivalent emissions per year)	27.6 Mt CO_2e / yr
Undegraded peatlands (%)	89.9%
Peatlands within protected areas (%)	25.7%
Top 5 Countries with largest peatland area (hectares)	1. Papua New Guinea (4,469,008 ha) 2. Australia (2,500,000 ha) 3. New Zealand (269,363 ha) 4. New Caledonia (20,000 ha) 5. Solomon Islands (10,000 ha)
ADDITIONAL DATA	
Total peatland carbon stock[2] (Megatons of carbon)	6,733 Mt C
Threatened peatland species[3] (VU = vulnerable; EN = endangered; CR = critically endangered)	Flora: 10 VU, 5 EN, 0 CR Fauna: 34 VU, 32 EN, 18 CR
Ramsar Wetlands of International Importance with peat[4]	18 sites (21.4% of total Ramsar sites in Oceania)

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[1] Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

[2] Joosten, H. (2009). The Global Peatland CO_2 Picture. Peatland status and drainage associated emissions in all countries of the World. Wetlands International, Ede, 10 p. + tables.

[3] Data extracted from the IUCN Red List of Threatened Species.

[4] Data extracted from the Ramsar Sites Information Service.

Peatlands cover an estimated 7.3 million hectares in Oceania and around 71 thousand hectares in the Sub-Antarctic Islands, representing approximately 1.5% of global peatlands. These estimates still have large uncertainty as comprehensive peatland mapping is only available in New Zealand, Papua New Guinea, and Australia. Oceania is a diverse region with continental, large-island and small island scales that supports a diverse group of peatland ecosystems. Peatlands often form part of IPLC's vision of interconnected lands, water and living things[1]. For example, in Australia, 39% of the peatlands are co-managed by Indigenous groups (mainly in Tasmania) and 8% are subject to special rights.

A suite of legislative and policy mechanisms has been implemented, mainly in Australia and New Zealand, with conservation and recovery plans. However, peatland degradation continues and a lack of information on the status and extent of degraded peatlands in the Oceania region hampers regional plans and action.


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[1] Examples include the Wanganui River and Te Uruwera forests which now are given equal legal status as people (personhood) to Indigenous land owners https://www.laneneave.co.nz/news-events/legal-personhood-for-nature-has-legal-ramifications/

8.1. Biomes and Ecological Zones

Oceania is a diverse region and contains peatlands from the following FAO Global Ecological Zones (Table 8.1). Note that 800 m.a.s.l. is the altitudinal boundary between lowland and mountain system peatlands. Fig. 8.1 shows the distribution of Oceanian peatlands by Global Ecological Zone.

Table 8.1. Peat forming vegetation, ecosystem types, and location according to FAO Global Ecological Zones classification.

Ecological Zone	Country	Traditional, scientific and/or common name (example dominant plant genera)	Selected publications
Tropical lowland peatland	Australia, Pacific Islands, Papua New Guinea	**Swamp forest:** Palm-dominant (e.g., *Metroxylon* and *Pandanus*), Melaleuca; **Herbaceous wetlands:** Tall grass, sedge/rush/fern fen and mire, fern/moss bog	(Mueller-Dombois and Fosberg 1998; Bourke and Harwood 2009; Department of Agriculture Fisheries and Forestry [DAFF] 2010; Whinam *et al.* 2012; Ono *et al.* 2015; Beer 2018)
Tropical mountain peatland	Papua New Guinea	**Swamp forest:** *Pandanus*, Podocarpaceae (*Dacrydium*) Cupressaceae (*Papuacedrus*); **Herbaceous wetlands:** Tall grass, sedge/rush/fern fens and mires, grass/fern/moss bogs, blanket bog, bog heath, cushion bog	(Whinam *et al.* 2012; Hope 2015)
Subtropical lowland peatland	Australia New Zealand, Pacific Islands	**Swamp forest:** *Melaleuca, Pandanus;* Wet heathlands; **Herbaceous wetlands:** Sedge/rush/fern fens and mires	(Whinam *et al.* 2012; Moss *et al.* 2015)
Temperate lowland peatland	Australia, New Zealand	**Swamp forest:** Araucariaceae, Podocarpaceae (*Dacrycarpus, Lagarostrobus*), Cupressaceae (*Athrotaxis/ Libocedrus*) Myrtaceae *(Eucalyptus/Melaleuca); Laurelia, Banksia, Acacia*; Nothofagaceae **Wet heathland:** Ericaceae (*Dracophyllum*). Myrtaceae (*Leptospermum/Melaleuca/ Syzygium*) **Herbaceous wetlands:** Tall grass (*Phragmites/Typha*), sedge (*Gymnoschoenus/Bolboschoenus/Eleocharis/ Scirpus* etc.), rush (*Empodisma/Juncus* etc.), fern (*Gleichenia*) fens and mires, fern/moss bogs/moorland, blanket bog, bog heath, cushion bog, mound springs	(Wardle 1991; Pannell 1992; Grant *et al.* 1995; Bridle and Kirkpatrick 1997; Costin *et al.* 2000; Balmer *et al.* 2004; Harris and Kitchener 2005; Whinam and Hope 2005; Whinam *et al.* 2012; TASVEG 4.0 n.d.)
Temperate mountain peatland	Australia New Zealand	**Swamp forest:** Podocarpaceae (*Halocarpus/ Lepidothamnus/Manaoa*), Cupressaceae (*Athrotaxis/ Libocedrus*) Myrtaceae *(Eucalyptus/Leptospermum*), Nothofagaceae **Wet Heathlands:** Myrtaceae *(Baeckia/Melaleuca*), Ericaceae (*Dracophyllum/Richea)*, bolster heath **Herbaceous wetlands:** *Sphagnum* and other non-vascular plant bog, fen and mire; blanket bog, cushion bog	(Kirkpatrick 1984; Grant *et al.* 1995; Bridle and Kirkpatrick 1997; Whinam *et al.* 2001; Balmer *et al.* 2004; Keith 2004; Harris and Kitchener 2005; Whinam and Hope 2005; McDougall and Walsh 2007; Whinam *et al.* 2012; Grover and Baldock 2013; TASVEG 4.0 n.d.)
Polar lowland peatland	Antarctica Sub-Antarctic Islands	**Moss bank:** Non-vascular plant peat **Wet heathland:** *Metrosideros/Dracophyllum;* bog heath **Herbaceous wetland:** *Sphagnum* and other non-vascular plant bog, fen and mire; blanket bog, cushion bog	(Meurk *et al.* 1994; McGlone 2002; Dykes and Selkirk-Bell 2010; Royles and Griffiths 2015)

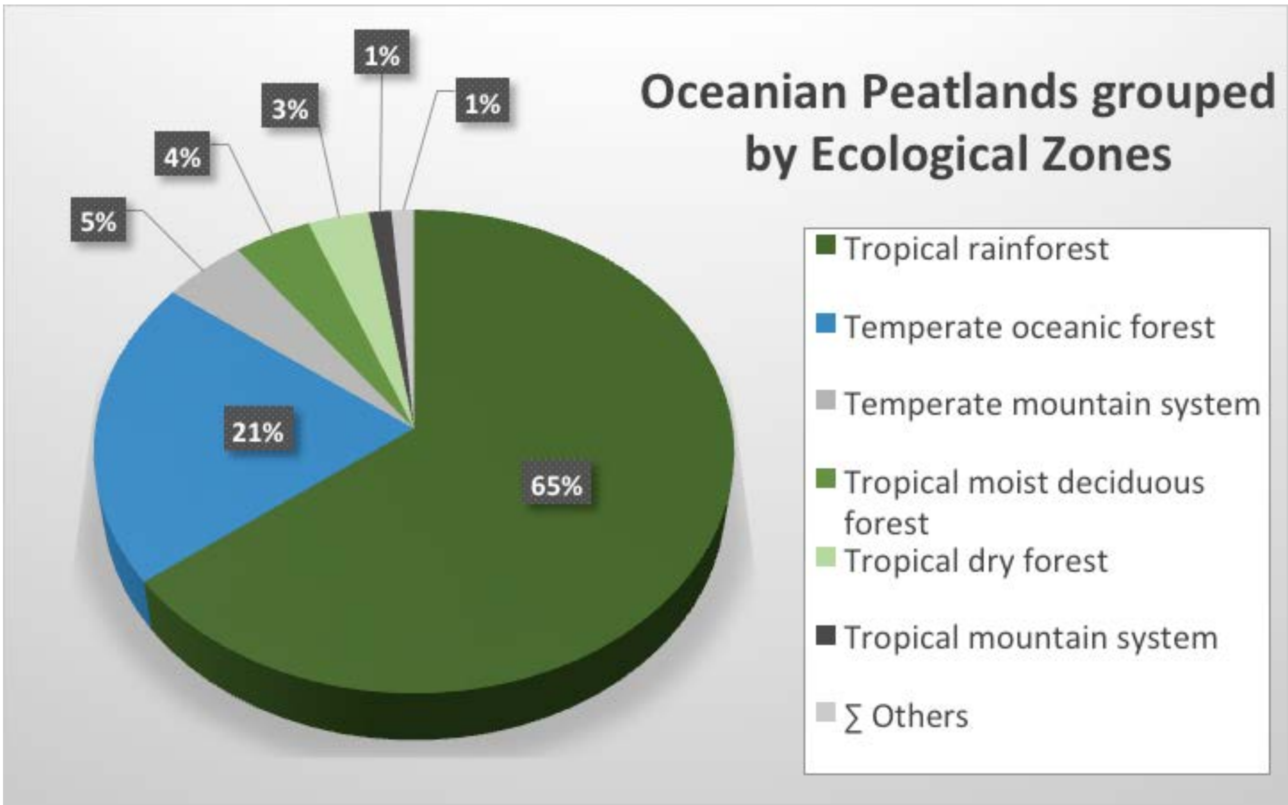

Figure 8.1. The distribution of Oceania's peatlands in aggregated FAO Global Ecological Zones.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

8.1.1. Australia and New Zealand

Peatlands in Australia occur from the wet tropics in the north, the arid in the centre and temperate zones in the south, the alpine regions in the south-east and the coastal plains in the southwest. Temperate montane peatlands are present under up to 10% of the snow-covered area in Australia (Hope 2012). The spatial extent of the peatlands is limited apart from in Tasmania which has extensive blanket bogs in the west of the island (Whinam and Hope 2005). The temperate-oceanic peatlands form globally rare mire systems (Grootjans *et al*. 2014). In particular, Restionaceae, Cyperaceae, Ericaceae and Myrtaceae plant families dominate the majority of Oceanian peatlands rather than *Sphagnum* mosses, with Australia and New Zealand containing some of the best-developed restiad-dominated bogs and fens in the world (Clarkson *et al*. 2017). Sedge and rush dominated coastal peatlands extend from subtropical Australia to Tasmania (including the Bass Strait Island) and South Australia, with similar communities situated in the coastal fringe of southwestern Australia, where rainfall is high enough to support peat development and can form relatively deep peat sequences (3 to 4 m in depth; Moss *et al*. 2015). One key peat-building genus found across temperate, sub-tropical and some coastal and sub-alpine locations in the region, is *Empodisma* (Clarkson *et al*. 2017). This genus consists of three species, *E. minus*, found in Australia and New Zealand; *E. robustum*, found in North Island New Zealand; and *E. gracillium*, found in far southwestern Australia. A unique characteristic of this genus is demonstrated by the fact that *E. minus* peatlands form the only known subtropical patterned fens in the world, which has been recognised as an Outstanding Universal Value for the World Heritage Listing of K'Gari (Fraser Island), as well as being a key component of Convention on Wetlands listed wetlands in the Great Sandy Strait Region of South East Queensland (Fig. 8.2) (Moss *et al*. 2016).

Another unique and important sedge-dominated peatland system is the buttongrass moorlands of western Tasmania (Fig. 8.3). These mires dominate large areas of western Tasmania and the critical peat forming species is *Gymnoschoenus sphaerocephalus* (Whinam and Hope 2005). Peat thickness is typically 30 cm for these communities (Bridle and Kirkpatrick 1997), although deeper sequences (>1 m) can occur in association with heath and *Sphagnum* communities in smaller areas of the buttongrass moorland landscape (Watson *et al*. 2022).

Figure 8.2. Wire rush peatland, K'Gari (Fraser Island). Photo: Patrick Moss.

Figure 8.3. Buttongrass moorland, Surrey Hills, Tasmania. Photo: Patrick Moss.

Paperbark (*Melaleuca*) forests can be important peat-forming ecosystems. These occur in temperate and tropical lowland areas across Oceania (e.g., Papua New Guinea). Within Australia, they occupy an area of about 750,000 hectares (Montreal Process Implementation Group for Australia [MPI] 2008; DAFF 2010). Paperbark forests generally occur in lacustrine and palustrine environments and are estimated to store between 158 to 286 tons of carbon per hectare in Australia (Tran *et al*. 2013).

In Australia, four peatland dominant communities, Alpine *Sphagnum* Bogs and Associated Fens, Temperate Highland Peat Swamps on Sandstone, Swamps of the Fleurieu Peninsula and Karst springs and associated alkaline fens of the Naracoorte Coastal Plain Bioregion, are nationally listed as Endangered Ecological Communities (EECs) (Threatened Species Scientific Committee [TSSC] 2003; TSSC 2005; TSSC 2009; TSSC 2020). The Alpine *Sphagnum* Bogs and Associated Fens ecological community is the only peatland dominant endangered community with a national recovery plan (Department of the Environment 2015). There are a number of listed EECs that have peatlands as a component with recovery plans (Fensham *et al*., 2010).

8.1.2. Pacific Islands Countries and Territories

The Pacific Island Countries and Territories can be categorised into four island types. These include mountainous islands (Papua New Guinea), volcanic islands (e.g., Fiji, Samoa), raised atolls (e.g., Tongatapu/Cook Islands) and low atolls (e.g., Tuvalu). Papua New Guinea holds Oceania's largest peatland area (4,469,008 hectares) and highest diversity of peatland types (Hope 2015). Tropical coastal and lowland, montane, subalpine and alpine peatlands can be found between sea level and 4,500 m at its highest peak (see Annex IV – Fig. IV.25. Distribution of Mountain Peatlands in Oceania by elevation). In the lowlands, a great diversity of herbaceous and arboreal tropical lowland peatlands and swamp types occur. In the montane zone, extensive peatlands formed on valley bottoms, behind levees of rivers or lake margins; they are dominated by montane swamp forests, tall grass fens, short grass fens, mixed sedge-grass fen and tall sedge fens. Whereas the montane peatlands are mostly groundwater-fed fens, sub-alpine peatland types are mainly rainwater fed bogs. Fig. 8.4 shows what peat accumulation over 40,000 years in a valley 2,000 meters above sea level looks like.

Figure 8.4. The result of 40,000 years of peat accumulation observed in an excavation at Pipikone, Ivane Valley, Central Province, Papua New Guinea (2000 m a.s.l.).
Photo: Matthew Prebble.

Within the tropics, raised atolls often hold peatlands dominated by *Acrostichum* and *Cyclosorus* ferns, palms, *Pandanus* or *Eleocharis/Scirpus/Schoenoplectus*, built up between concentric raised reefs and the volcanic island core (makatea) (Mueller-Dombois and Fosberg 1998). For example, on the small (800 hectares) tropical makatea island of Rimatara (French Polynesia), peatlands impacted by anthropogenic fire and agricultural activities make up around a third of the area and are built upon >15 m depth of pre-human settlement-aged peat composed of plant detritus and seabird guano (Prebble and Wilmshurst 2009). On tropical high islands, from the Solomon Islands to French Polynesia, coastal peatlands have mostly been highly modified for agricultural production since initial human colonization (Hope *et al* 2009; Whinam *et al*. 2012). Less degraded peatlands are found within the considerable number of volcanic calderas located across the Pacific Islands, which are either infilled with peat mires dominated by Cyperaceae sedges, *Scirpus* or *Schoenoplectus* rushes or are currently lakes but retain extensive floating peat-forming mats of sedges and rushes. Radiocarbon dating of peat from floating mats on Rapa Nui has revealed materials over 1,000 years old (Butler *et al*. 2004).

The least degraded peatlands with high biodiversity value include the tropical montane cloud forests of the larger high islands (Meyer 2011). The subsided volcanic caldera of Tagamaucia on Taveuni Island, Fiji (Wetland of International Importance) (Fig. 8.5), holds about 200 hectares of peatlands and floating mat vegetation (Hope *et al*. 2009). High rainfall and steep topography have helped this peatland avoid the threat of large-scale wildfires. Its steep slopes also make it unsuitable for agricultural production (Whinam *et al*. 2003).

Figure 8.5. Eleocharis dominant peatland at Tagamaucia, Taveuni, Fiji (800 m.a.s.l.). Photo: Matthew Prebble.

8.1.3. Antarctica and Sub-Antarctic Islands

Small, rare, slow accumulating Antarctic peatlands are known as moss peat banks. Two moss species, *Chorisodontium aciphyllum* and *Polytrichum strictum*, form occasional banks of peat that can be 2 meters deep and 6,000 years old on small islands to the north of the Antarctic Peninsula (Royles and Griffiths 2015). Further south, these moss peat banks are shallower and younger (0.3 m deep and 150 years old), (Royles *et al*. 2013). Permafrost occurs approximately at 0.3 m depth. The length of the growing season has increased with earlier snowmelt and later snowfall, but drought potentially limits growth in summer (Royles *et al*. 2013). Sub-Antarctic peatlands are quite different, with greater plant diversity and a predominance of vascular plants as the peat-forming species. Peatlands occur on most of the Sub-Antarctic Islands (Meurk *et al*. 1994; Smith 1994; McGlone 2002; McGlone *et al*. 2007; McGlone 2009; Dykes and Selkirk-Bell 2010). Peat stored in the peatlands of the Sub-Antarctic Islands are formed from the leaf litter of small trees, shrubs, grassland, megaherbs or tundra vegetation (Van der Putten *et al*. 2009). On Campbell Island, peat covers nearly the entire 11,300 hectares land surface (McGlone *et al*. 2007). Numerous oligotrophic bogs hold peat down to 6 m in depth or more, accumulated since the Last Glacial Maximum (McGlone 2009).

8.2. Peatlands Distribution and Extent

Fig. 8.6 shows the geographic distribution of peatlands in Oceania as per the GPA data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. Fig. 8.7 shows the proportionate distribution of peatlands by countries in the region, with 61% located in Papua New Guinea. The proportion of peatland areas on Sub-Antarctic Islands is shown in the Fig. 8.8.

The three areas of peatlands in Oceania that are well mapped are in Papua New Guinea, Tasmania and New Zealand, with Papua New Guinea containing the largest peatland area in the region. Peatlands in mainland Australia are not extensive. Because of their small extent, many peatlands do not appear on soil maps, and there is currently no accurate estimate of their extent in mainland Australia. According to the Australian Soil Classification (Isbell 2002), peats are considered Organosols with an estimate of about 150,000 hectares in mainland Australia. However, this number increases to around 481,672 hectares when including areas from a variety of mapping sources and scales. In Tasmania, a 'hybrid' Digital Soil Mapping (DSM) approach was used to predict peat areas using new and existing soil site data, intersected with a range of environmental spatial datasets (Minasny *et al*. 2019). This new digital map primarily provides decision support for fire management and suppression activities in these remote environments (Kidd *et al*. 2022). For the Tasmanian mapping, organic soils were defined based on their burn risk with > 12% SOC and depth > 5 cm (Kidd *et al*. 2022). Thus, peat soils cover about 1.3 million hectares in Tasmania, with 90% in conservation/natural environment areas. A further 0.5 million hectares of rainforest area was modelled to have peat and organic soils (or surface litter accumulations), however these estimates are low in confidence owing to a lack of site data (Kidd *et al*. 2022).

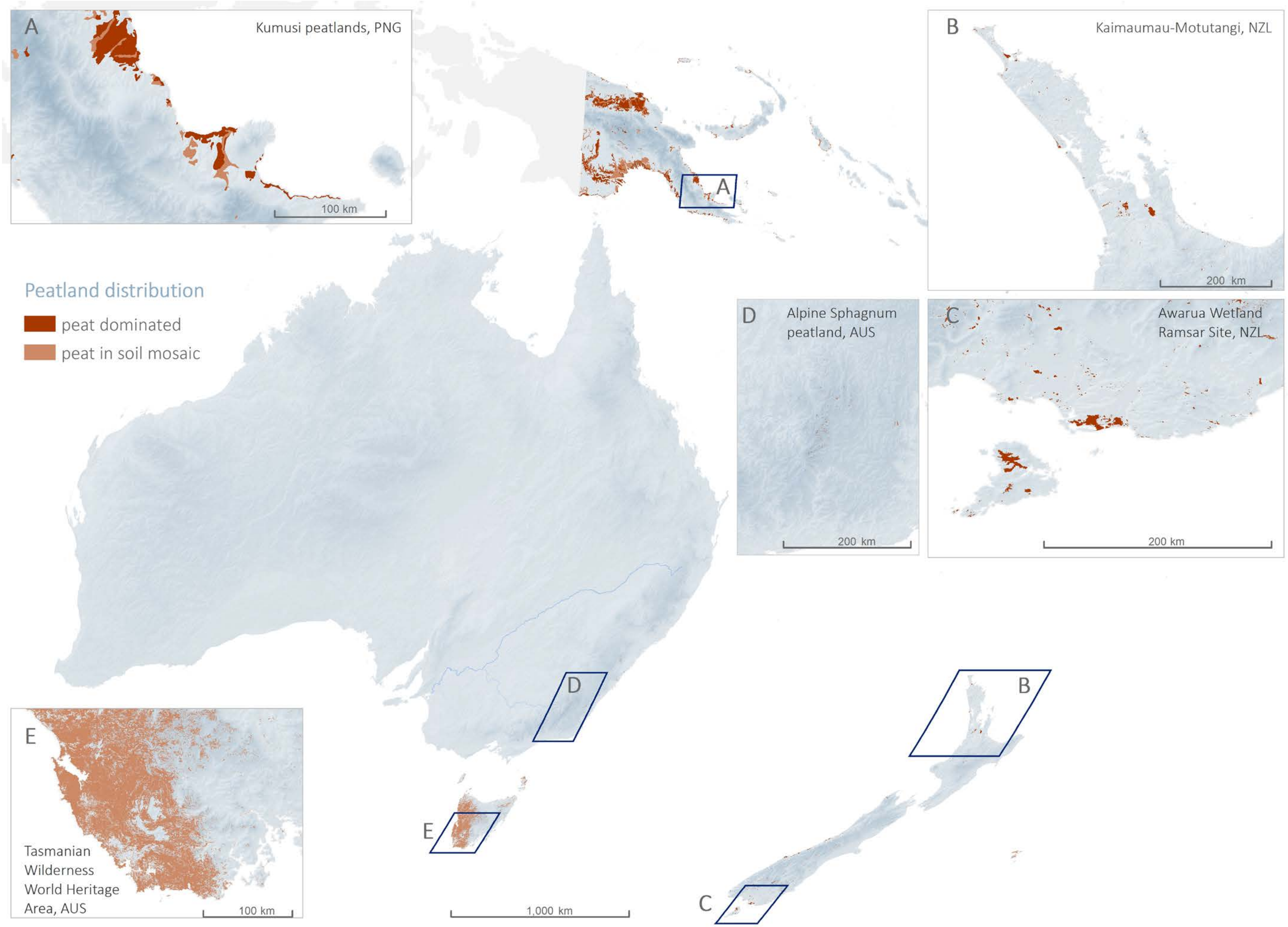

Figure 8.6. Peatland distribution in Oceania (partly incl. organic soils).

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. For more details on the methods and references used for this map, see Annex III. Production of the Global Peatland Map 2.0.

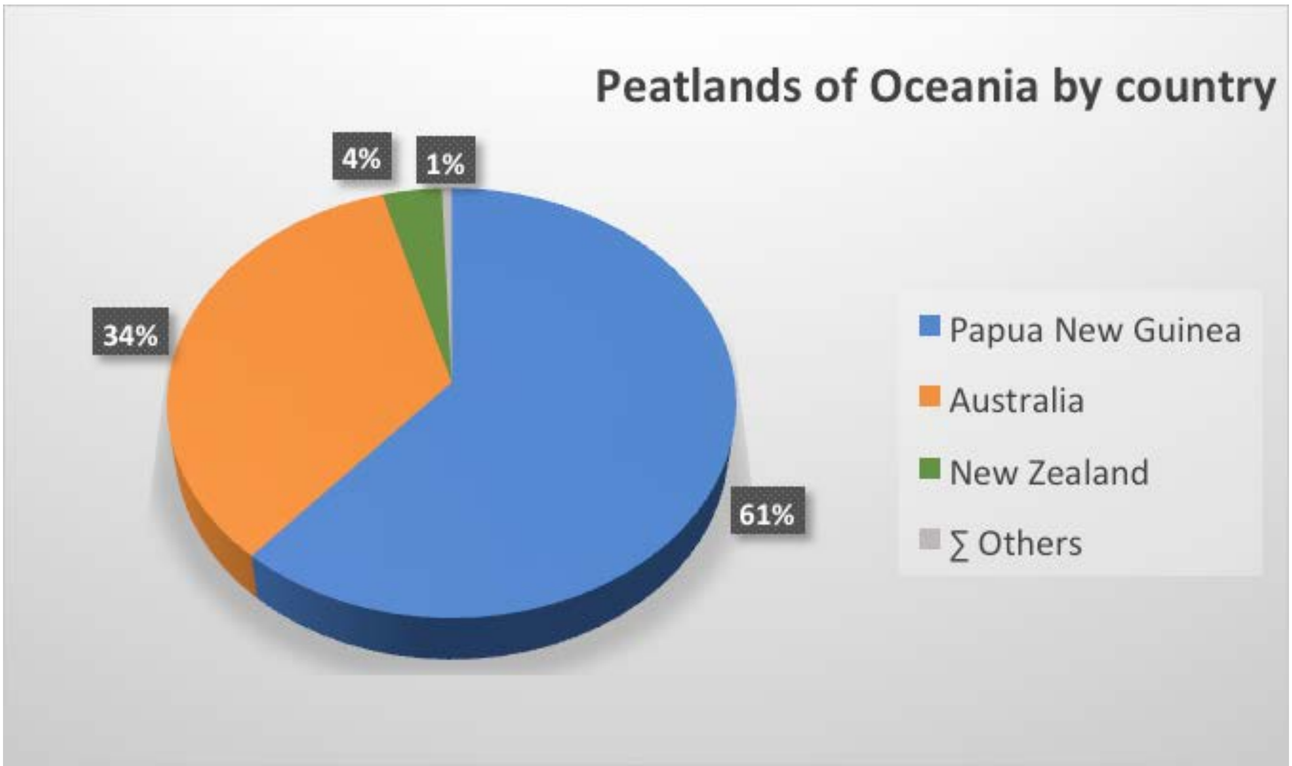

Figure 8.7. Proportion of Oceania's total peatland area per country.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

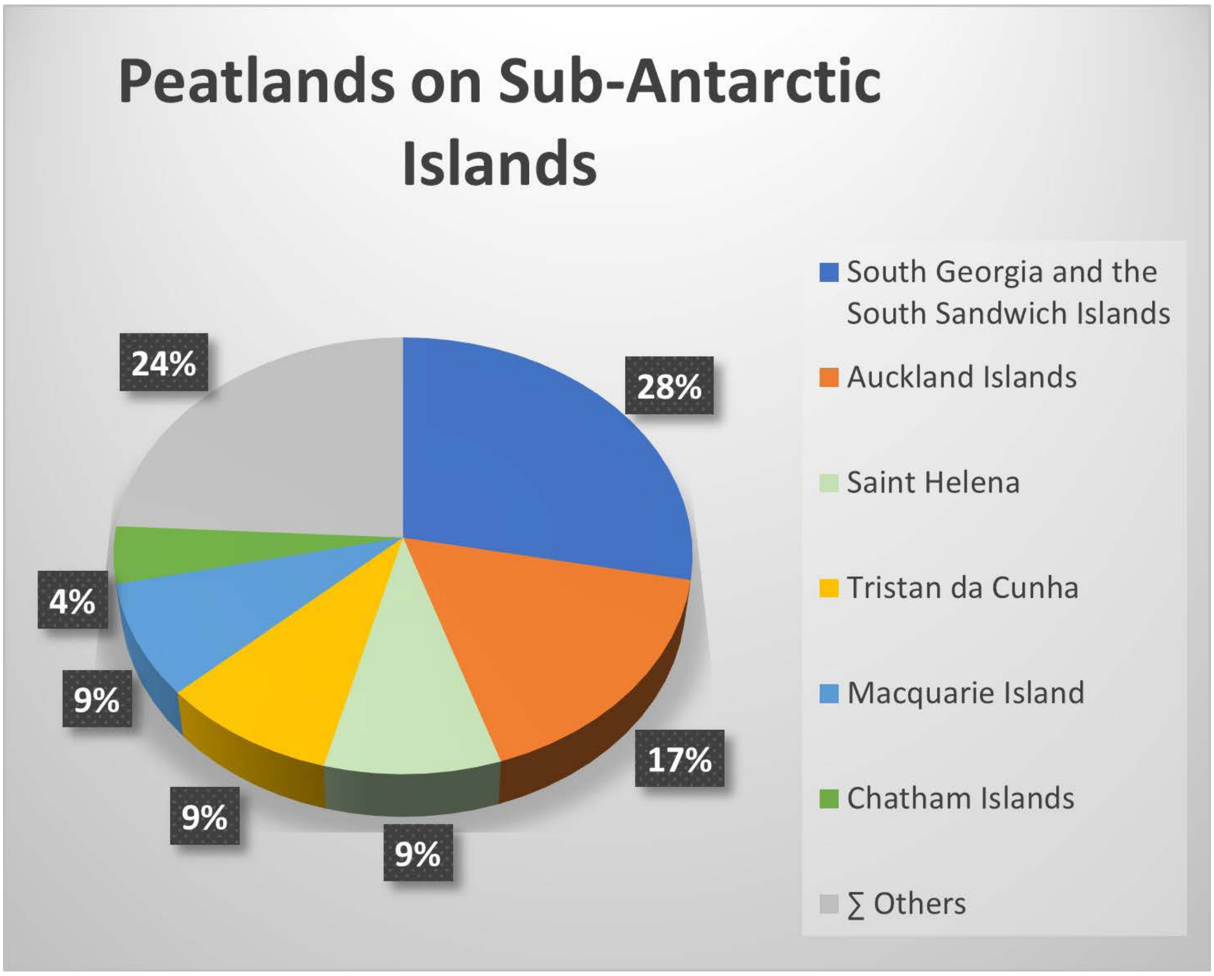

Figure 8.8. Proportion of peatland areas on Sub-Antarctic Islands.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Analysis using the Australian Land Use Mapping (ALUM) indicates that the vast majority of peatland areas (around 81%) are classed as 'conservation or natural environments' (Table 8.2), and 70% having a tenure of 'nature conservation reserve' (Table 8.3). Despite being culturally significant to many Australian First Nations communities, only around 0.22% of Australian peatlands are formally classified as 'Indigenous Protected Areas (2022)'. Around 9% of Queensland's peatlands are Indigenous Protected Areas (Table 8.4), and 39% of the area (mainly in Tasmania) are co-managed by Indigenous groups.

Table 8.2. Australian Peatland Area by Land Use.

Landuse (ALUM)	Area (ha)
1 Conservation and natural environments	1,886,350
2 Production from relatively natural environments	159,146
3 Production from dryland agriculture and plantations	176,331
4 Production from irrigated agriculture and plantations	13,042
5 Intensive uses	16,838
5 Production from irrigated agriculture and plantations	0
6 Intensive uses	4
6 Water	62,8489
Not assigned	506
Grand Total	**2,315,066**

Table 8.3. Australian Peatland Area by Land Tenure.

Tenure	Area (ha)
Nature conservation reserve	1,625,548
Freehold	360,464
Multiple-use public forest	133,301
Other Crown purposes	130,568
Other Crown land	29,063
Pastoral term lease	15,971
Other perpetual lease	11,868
Other lease	3,153
Freeholding lease	2,476
Other term lease	2,214
No data/unresolved	262
Not assigned	168,980
Pastoral perpetual lease	9
Grand Total	**2,315,066**

Table 8.4. Australian Peatlands by Indigenous Protected Area (IPA).

Jurisdiction	IPA	Non-IPA	Area (ha)
Australian Capital Territory	0	5,480	5,480
New South Wales	20	57,249	57,269
Northern Territory	0	133	133
Other Territories	0	224	224
Queensland	4,560	45,176	49,736
South Australia	26	173,272	173,298
Tasmania	569	1,832,825	1,833,394
Victoria	0	64,056	64,056
Western Australia	0	131,475	131,475
Grand Total	**5,175**	**2,309,891**	**2,315,066**

In New Zealand, peatlands are covered in the national-scale soil maps at the 1:50,000 scale as part of the New Zealand Land Resources Inventory (NZLRI) (Dymond *et al*. 2021) and available as an online digital map. Peat soils cover 250,500 hectares, about 1% of New Zealand's mainland area. The Waikato region has the largest area of peatlands (43% of the total peatland area), with Southland (extreme south of the South Island) and Northland (extreme north of the North Island) being the two other regions with a substantial peatland cover. Most peat soils (169,000 hectares, or 67% of the peatland area) are under intensive agriculture, mainly high-producing grassland with around 8,200 hectares under irrigation (Dymond *et al*. 2021).

Various governmental and international researchers and agencies have conducted soil survey and mapping throughout several Pacific Islands. Some of the maps showing the extent of peats or peaty soils for some Pacific Islands are available at the Pacific Soils Portal (Pacific Soils Portal n.d.). The information on peatland distribution in the Pacific Island Countries is still sparse and requires a well-coordinated effort to centralise them. According to GPA mapping, there is about 44,000 hectares of peatland in the Pacific islands, however this estimate is highly uncertain due to the coarse scale of the maps.

Additional spatial inventory, mapping and modelling of Oceania peatlands will be necessary to appropriately assess and conserve these ecologically important environments. A recent inventory of existing mapped or modelled peatlands throughout Oceania and the sub-Antarctic and Antarctic areas show that global mapping areas are underestimating peatlands throughout the region.

- Many areas are too small to be represented on a global peatland map but are locally ecologically significant. For example, the Pacific Islands, and the arid mound springs in central Australia (Figs. 8.9 and 8.10).
- New Zealand degraded peatlands are not comprehensively mapped (as per many other Oceania countries). Further work is required to better identify these areas to prioritise rehabilitation activities.
- Peat-bank locations are known and described in Antarctica (e.g., particularly on the offshore islands e.g., Moe), but are also relatively unmapped. Mapping or spatial modelling of these areas will be important for future analysis of these fragile ecosystems with respect to climate change.

Figure 8.9. Bonatoa Bog freshwater peatlands, Viti Levu, Fiji Islands, encroached by urban development.
Source: Ash and Ash 1984.

Figure 8.10. Arid Zone spring mound and associated peatland, McLachlan Springs, Lake Eyre South, Central Australia. These mounds form from wind-blown sands deposited around wet vegetation, which expands over time. The wetland vegetation deposits organic matter, resulting in gradual peat formation at the vent.
Source: Brake et al. 2019.

8.3 Biodiversity, Nature's Contributions to People and Hotspots of Value

8.3.1. Biodiversity

Peatlands in the region provide habitat for many unique plants and animals that are key to ecosystem services, as described in previous sections. However, extractive use of peat and conversion to agriculture coupled with climate change, threaten biodiversity housed in Oceania's peatlands. There are many threatened species, but there is a lack of monitoring and quantification of the state and trends of these species. Here we highlight some unique animals and plants.

The acid frogs of the Wallum wet heathlands of South East Queensland and northern New South Wales are a highly specialised group. They are well adapted to the low nutrient acidic soils and groundwater dependant wetlands. These include the extensive peatlands that occupy the sand masses of the region. The four key species, *Crinia tinnula, Litoria cooloolensis, L. freycineti* and *L. olongburrensis* are listed by the IUCN as Vulnerable to Endangered with the main pressures threatening them associated with land use intensification (Fairfax and Lindsay 2019; Filer *et al*. 2020).

The Sunset Frog (Fig. 8.11) is an endemic, monotypic genus of frog, wedded to wetlands with significant organic-rich sediments in the coolest and wettest part of southwestern Australia. *Spicospina flammocaerulea* represents an ancient lineage of frogs in the family Myobatrachidae dating from 33-36 million years ago (Roberts *et al*. 1997). The Sunset Frog is known from around 20-30 locations, is a short-range endemic and is vulnerable to climate change and land use impacts (Edwards and Roberts 2011).

In sub-alpine peatlands of Australia's high country, brightly coloured yellow-green striped Corroboree frogs are found (Fig. 8.12). There are two species. The Southern Corroboree Frog (*Pseudophryne corroboree*) found in the southern part of the snowy mountains and the Northern Corroboree Frog (*P. pengilleyi*) found in the northernmost part of Australia's alpine and subalpine area. Both species are listed as critically endangered, with populations declining since the 1980s due to chytrid fungus. This disease has caused numerous frog species' populations to decline or become extinct worldwide (Hunter *et al*. 2010).

The Wallum wet heathlands are also an important habitat for the vulnerable False Water-Rat (*Xeromys myoides*), two endangered fish species (*Nannoperca oxleyana* and *Pseudomugil mellis*) and the distinctive Ornate Rainbow Fish (*Rhadinocentrus ornatus*). All three species are adapted to the highly acidic waters of the patterned fen areas (Fairfax and Lindsay 2019). The heathland is also a habitat of three key bird species, including Lewin's Rail *(Lewinia pectoralis)*, Southern Emu-Wren *(Stipiturus malachurus*) and the Eastern Ground Parrot (*Pezoporus wallicus wallicus*) (Fairfax and Lindsay 2019).

Tasmania is a global hotspot for endemic burrowing crayfish (34 species in 3 genera) (Hansen and Richardson, 2006). Many of these species live in organic-rich soils. Their burrows provide a type of habitat, known as "pholoteros", for a community of invertebrate species (Brown *et al*. 1993). Two species of syncarid shrimps, *Allanaspides hickmani* and *Allanaspides helonomus,* are of particular scientific interest because they are very primitive among the higher crustaceans and have origins that reach back to the ancient supercontinent of Gondwana (Carle 1995; Driessen *et al*. 2014). In addition, Buttongrass moorlands of western Tasmania are the stronghold for the Eastern Ground Parrot *Pezoporus wallicus*, one of only five ground-dwelling parrots in the world (Driessen 2008).

Figure 8.11. Sunset Frog.
Photo: Rob Davis.

Figure 8.12. The Southern (left) and Northern (right) Corroboree Frog has striking brightly coloured stripes that are believed to be a signal to predators that they are toxic.
Photos: David Hunter.

Another unique ecosystem is created by cushion plants, a group of shrub species that can form vegetation associations known as Bolster Heaths (Kirkpatrick and Bridle 1999). Different species cooperate, growing together to form one solid canopy in an unusual mosaic pattern (Fig. 8.13). They have such tight canopies that it is impossible to see the branches underneath. This adaptation protects growing tips from the icy winds that blow from Antarctica. Increased wildfire frequency in Tasmania due to climate change poses a significant threat to these plant communities as most cushion plants grow very slowly, are severely damaged by fire and take a long time to recover (Gibson and Kirkpatrick 1992; Kirkpatrick *et al*. 2021).

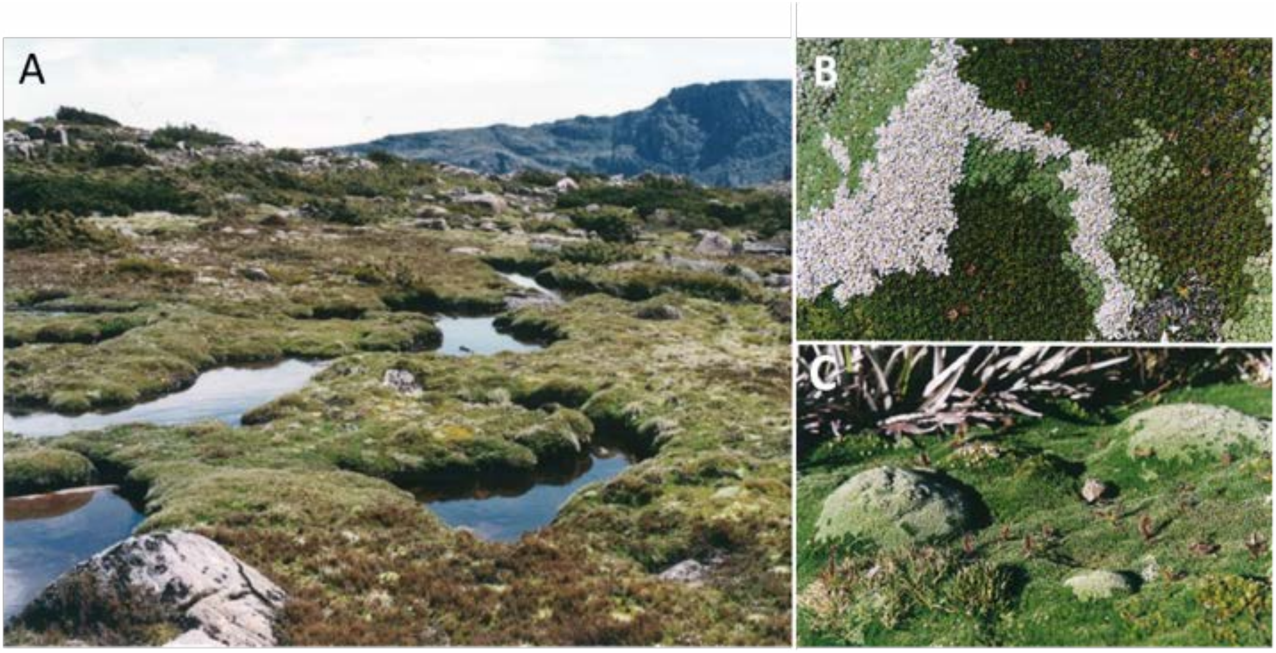

Figure 8.13. A: An example of cushion moorland dominated by cushion plants in Mt Field National Park in Tasmania, Australia. Cushion plant canopies grow so tightly that they can divert water flow to create pools as shown here. B: A mosaic pattern develops as the canopies of many different cushion plant species grow together. The canopies of different species (different coloured leaves) of cushion plants grow together to form a solid shield from the cold winds and protect the sensitive growing tips of the plants. C: The cushion plant canopy surface provides habitat for other plant species to grow including sundew species (red emerging leaves) and small grasses and rushes (bottom left corner).

Photos: Joslin Moore

8.3.2. Nature's Contributions to People

Indigenous First Nation perspectives on peatlands in Oceania are as diverse as the peoples within the region. Peatlands often form part of cultural origin traditions. They are frequently believed to be the dwelling places of important deities or ancestors and are often regarded as sacred. A common thread that runs across most indigenous societies of Oceania, prior to colonisation, is that peatlands were commonly used to preserve, through the burial processes that take place within them, treasured items that would normally rot away over time, like wooden items including canoes (Phillips *et al*. 2002).

The vital contributions provided by lowland peatlands in Australia and New Zealand as seasonally rich native food sources and gathering places to contemporary First Nations peoples are increasingly being recognised. Reengagement with traditional practices of food and other resource procurement in peatlands supports increased recognition of local identity and emphasises the aspirations of indigenous communities to take responsibility for the management of peatlands (Pyke *et al*. 2021). Furthermore, the most extensive peatlands found in Oceania provide the main substrate for staple crop production for rural communities across the intermontane basins and coastal and lowland river deltas of Papua New Guinea (Bourke and Harwood 2009), and in the valleys of many of the Pacific Islands high islands. The inherent sustainability of traditional food production (e.g., sago –*Metroxylon sagu* and taro –*Colocasia esculenta*) is increasingly being recognised. However, rampant development and increased dependence upon low-cost imported foods are undermining this food security. As women and girls in rural areas are often charged with taking care of domestic needs within the home, depleted natural resources mean that Indigenous women and girls often spend more time collecting water, biomass or other peatland products. It is therefore crucial to adopt gender-responsive approaches that specifically consider the needs and contributions of Indigenous women and girls who have the least adaptive capacities.

Aside from holding a rich biodiversity (section 8.4.1), peatlands of the Temperate Montane Zone provide support for people in the form of water regulation, electricity provisioning via significant hydroelectricity infrastructure and climate regulation through carbon storage and sequestration. They also provide material goods like fresh water and cultural amenities like recreation. Peatlands of the Temperate Coastal zone are used for agricultural food production (especially in New Zealand), peat extraction (small scale, confined to private land), flood mitigation and coastal recreational amenities like bird watching and water sports. While peatlands of Oceania demonstrably provide significant contributions to both the people of the region and to people globally, the current status of peatlands in Oceania and their ability to continue to provide these contributions has not been adequately surveyed.


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8.3.3. Hotspots of Value

Box 8.1. Case Study – Restoration of the Blue Mountains Swamps to Return their Benefits to People and Nature

The Blue Mountains Swamps are located in the headwaters of the World Heritage listed Blue Mountains Area. These swamps provide important contributions to people and to nature absorbing and filtering water thus regulating baseflows to watercourses, moderating peak flow events and purifying water. Besides these hydrological services, several nationally endangered animal species including the Blue Mountains Water Skink and Giant Dragonfly, and many threatened or regionally significant plants including *Carex klaphakei, Lepidosperma evansianum, Almalaea incurvata* and *Boronia deanei* have these swamps as their habitats (Hensen and Mahony 2010).

Part of the Blue Mountains Swamps have been impacted by urban development. One example was the impact promoted by the development of Katoomba, a township named from the First Nations Gundungurra and Darug people *kedumba*, meaning *shiny, falling waters*. Its development has caused several impacts in the surrounding swamps, namely a reduction of recharge to aquifers that support ground water dependent ecosystems; erosion and channelisation within swamps; delivery of nutrient-rich sediment; changes in floristic composition and increased vulnerability to weed invasion (Hensen and Mahony 2010).

In 2005, a restoration Program of these swamps was put in place by the Blue Mountains' City Council which has gradually brought these biodiverse peatlands back to their glory (Fig. 8.14). The 'Save our Swamps' project aims at enhancing the condition and extent of degraded swamps across the Blue Mountains and Lithgow local government areas. Focused on rehydrating desiccated swamp systems to restore their natural hydrological conditions, thereby allowing natural swamp regeneration to occur, while also tackling the drivers of degradation happening at the catchment level, the program allowed to return the swamps to a condition where they can provide the essential benefits to people and nature (Hensen and Mahony 2010).

In August 2020, the "Blue Mountains Upland Swamps" project has officially started aiming at developing a monitoring and adaptive management program and a decision support tool for assessing climate change impacts and adapting management of restoration action. In April 2021, the project started researching the ecological importance and water storage functions of these peatlands (Blue Mountains World Heritage Institute [BMWHI] n.d.). On the Blue Mountains World Heritage Institute's website, a video (BMWHI 2021) about "Why swamps matter?" illustrates how these peatlands have value for the region.

Figure 8.14. Katoomba peatland; urban greenspace hotspot of value. Restoration infrastructure installed in 2010 (left), sedges establishing in 2012 (middle) and successful hydrological and vegetative restoration in 2014 (right).

Photos: Shane Grundy.

A recent study has valued the carbon stock ensured by the "Temperate Highland Peat Swamps on Sandstone (THPSS)" where the Blue Mountains Swamps are included. Using the carbon abatement price of $16 Australian Dollars (~€10 Euros) per ton of CO_2e, the total value of THPSS is over $404 million Australian Dollars (~€263 million Euros) which makes a strong economic case for the restoration of these swamps (Cowley and Fryirs 2020).

Box 8.2. Papua New Guinea Spotlight Case - Kumusi Peatlands, Oro Province

The peatland complex of the Kumusi-Mambare coastal plain north of the provincial capital Popondetta is amongst the largest ombrotrophic coastal peatland complexes found in Papua New Guinea. It extends over approx. 80,000 hectares of the interfluvial areas between the Kumusi and Mambare rivers and holds a vegetation gradient from the edges to the central parts (Beer 2018). On shallow peat sometimes extensive *Metroxylon sagu* stands with mineral topsoils alternate with herbaceaous H*anguana anthelmintica* – *Mapania sumatranum*-formations on peat soils, which successively change to swamp savannah and low pole swamp forests with *Syzygium* sp., *Palaquium amboinense* and *Stemonurus ammui* further to the central peatland parts with indications of peat dome formation. Peat thickness reaches 10 meters and is surprisingly young, with layers at 8.5 m depth being only 2500 years old and carbon stock estimated at approximately 3,200 tons of carbon per hectare (Beer 2018). Limited human impacts on these peatlands might be due to their remote location and the land tenure system by the local communities in PNG (Beer 2018).

8.4. Status of Peatlands, Drivers of Change and Hotspots of Change

8.4.1. Status of Peatlands

Around 10% of the peatlands in the region are degraded, according to the GPA data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre. Fig. 8.15 shows the proportion of drained and undrained peatlands in countries of Oceania (partly including organic soils). More than 70% of New Zealand's peatlands have been drained for forestry, agriculture and peat extraction. For all other countries, the proportion of drained peatlands is less than 15%.

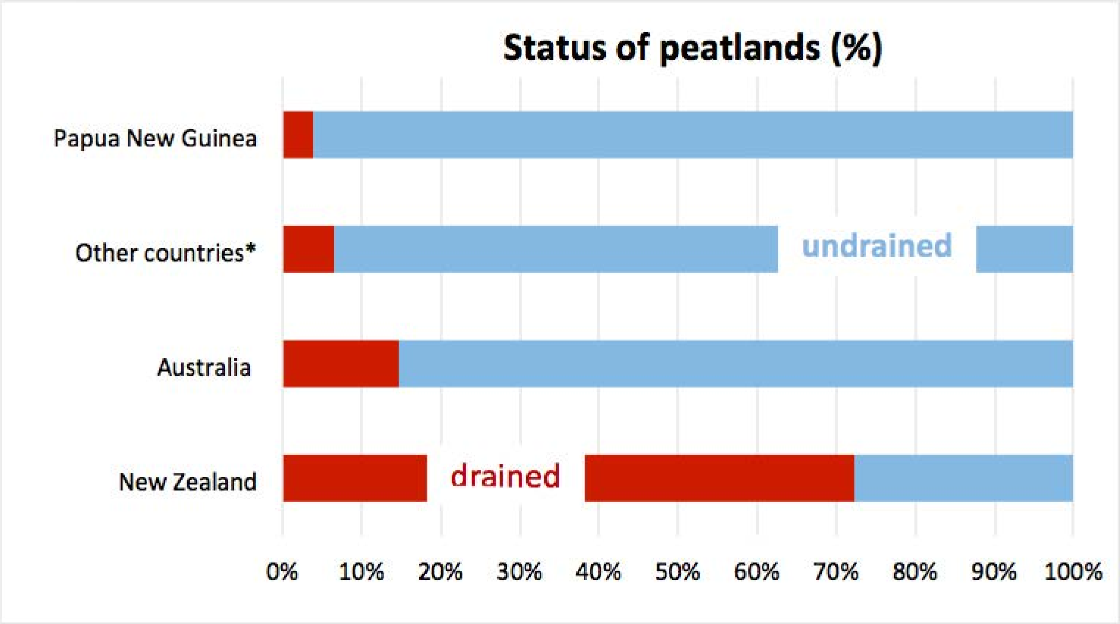

*Figure 8.15. Proportion of drained (red) and undrained (blue) peatlands in Oceania per country (partly including organic soils). Calculations are based on the drained area for forestry, agriculture and peat extraction. *Sum of Oceanian countries with less than 100,000 hectares of peatland area.*

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Although evidence is limited, it is likely that coastal tropical lowland peatlands of Papua New Guinea, particularly sago palm (*Metroxylon sagu*) peatlands, were heavily exploited for food and fibre by the earliest human societies (Barrau 1958). The earliest evidence for the use of peatlands in Oceania actually comes from the intermontane basins of Papua New Guinea as these areas were occupied by indigenous Papuan speaking communities at least 40,000 years ago. In the Ivane Valley (Central Province), karuka *Pandanus* nuts have been found within buried peat deposits along with stone tools. These assemblages have been radiocarbon dated to 45,000-30,000 years old (Summerhayes *et al*. 2006; Fig. 8.16). At Kuk Swamp in the Wahgi Valley (Western Highlands Province), a World Heritage Site, complex drainage ditch systems excavated within buried peat deposits containing evidence for Musaceae banana and aroids have been excavated and dated up to 7,000 years old (Golson *et al*. 1967; Denham *et al*. 2003). While intermontane peatlands were globally important independent centres of agricultural origin in the Holocene, the introduction of new dryland crops (e.g., I*pomoea batatas* and *Manihot esculenta*) has resulted in the abandonment of some peatlands in the last few centuries (Hope 2015). Current land use in peatlands in Papua New Guinea includes palm oil and rubber plantations (Bourke and Harwood 2009). Traditional forms of production continue to varying degrees in most tropical island nations, limited by the low-cost importation of intensively produced food products such as rice, or the conversion to cattle or copra production or other dryland crops (Wairiu *et al*. 2011).

Figure 8.16. Left: Metroxylon sagu grove, Embi Lakes, Oro Province, Papua New Guinea (50 m asl), and Right: The remains of a Metroxylon sagu trunk with the pith extracted for starch, Koil island, East Sepik Province Papua New Guinea (10 m asl).
Photos: Matthew Prebble.

Kurnell in Sydney was extensive peatland and occupied by Indigenous Peoples (IP) for several thousand years. There was evidence of the use of fire to promote the growth of edible herbs, bulbs and bracken (Martin 1994). Before European colonisation, the peatlands of the small tropical and sub-tropical Pacific Islands and northern temperate New Zealand, were used by IPs for agricultural production of wetland crops such as taro (*Colocasia esculenta,* e.g., Prebble *et al*. 2019). IPs throughout Oceania have also used peatlands for the preservation of wood and fibre technologies including canoes identified during archaeological excavations (e.g., Phillips *et al*. 2002). A drastic change in the vegetation was observed following the arrival of humans. An increase in fires and deforestation led to higher erosion and sedimentation rates, which transformed valley peatlands into swamps with mineral topsoils (Prebble and Wilmshurst 2009). Hamilton/Kirikiriroa and Christchurch/Ōtautahi cities are built on extensive peatlands. Current uses of peatlands in New Zealand include horticulture (e.g., blueberry farms, Waikato, Southland), moss harvest (West Coast), apiculture (e.g., mānuka honey) and flood water storage (Waikato). Other notable factors that affect peatlands, particularly in Australia and New Zealand, include mining, forestry and the presence of invasive plants and animal species, such as horses, deer, pigs and willow.

Fig. 8.17 shows the annual GHG emissions from peatlands in Australia, Papua New Guinea and New Zealand, totalling close to 28 Mt CO_2e per year.

8.4.2. Drivers of Change

The key drivers of change in peatlands common across Oceania are agricultural conversion, altered hydrology, climate change and fire. Other notable drivers in specific areas are peat extraction, pollution, and invasive alien plant and animal species. In Antarctica, changes in seal and penguin populations associated with climate change are potential drivers of change in the moss peat banks (Amesbury *et al*. 2017).

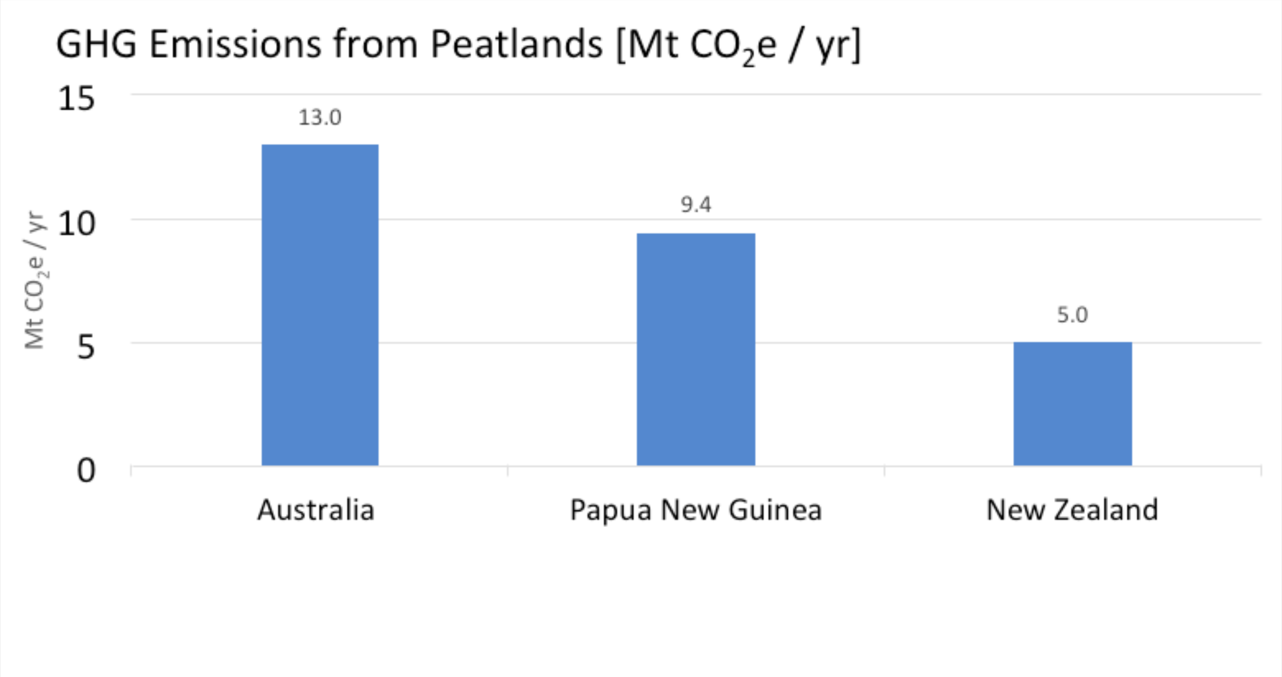

Figure 8.17. Oceanian countries emitting GHG from peatlands, with Australia representing 47%, PNG 34% and New Zealand 18%. C Calculations are based on the peatland drained area for forestry, agriculture and peat extraction and IPCC (2014) emission factors including CO_2, CH_4, N_2O, DOC, and emissions from ditches. Includes only net, on-site GHG emissions. Wildfire emissions are not included.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Since European settlement in New Zealand, around 146,000 hectares of peatlands have been converted to agriculture, potentially contributing between 0.5 and 2 Mt CO_2 per year to New Zealand's greenhouse gas emissions (Ausseil *et al*. 2015). Due to the substantial loss of natural peatlands in New Zealand, the remaining peatland ecosystems support a relatively high number of threatened or at-risk species, many of which are endemic to New Zealand. Critically, the rare and threatened taxa include peat-forming species like the 'relict' *Sporadanthus ferrugineus*, which now only occurs within small pockets of the most intact restiad peatlands, and the 'at risk-declining' *Empodisma robustum*, which is under increasing threat from disturbance (Clarkson *et al*. 2021). Various other species adapted to peatlands are also at risk of ongoing population decline, such as the 'nationally critical' orchid *Corybas carsei,* 'nationally critical' Australasian bittern/matuku (*Botaurus poiciloptilus)* (O'Donnell and Robertson 2016) and several species of mudfish (e.g., *Neochanna heleios, N. diversus* and *N. apoda*) (Allibone *et al*. 2010) and Trichoptera invertebrates (Collier 1993).

The proportion of peatlands within protected areas, including bog, fen, gum land and swamp wetland types on peat soils, is relatively high for New Zealand (Robertson 2016). There are 79% of remaining bogs, 47% of fens and 83% of gumlands/pakihi occurring within protected areas. However, when considering the historical extent of peatlands, the percentage in protected areas decreases substantially (only 20% of bogs and 9% of fens are in protected areas based on the historical, pre-human extent (McGlone 2019). Further, the legal protection of peatlands is biased towards large systems, with very few small (<20 hectares) areas contained in reserves or conservation areas in New Zealand (Robertson 2016).

Over the past 10 years, there has been an increased focus on restoring peatlands in New Zealand. The national Arawai Kakariki wetland restoration programme, for example, is working in partnership with councils, local iwi (Māori tribe), the Department of Conservation and research organisations to restore vulnerable peatland ecosystems at Whangamarino Wetland (7,000 hectares raised bog-swamp complex, Wetland of International Importance), Awarua Wetland (20,000 hectares blanket bog, coastal lagoon complex, Wetland of International Importance) and Kaimaumau-Motutangi (3000 hectares gumland-dune complex). Various local restoration initiatives are also taking place throughout New Zealand. However, the overall scale of restoration is modest and there has been no national assessment on the effectiveness of these activities.

Changes in fire management have had a dramatic impact on peatland ecosystems across Australia. For instance, there has been an invasion of shrubs into buttongrass moorlands (Fig. 8.18) since a shift from indigenous fire management to European fire suppression practices over the last 150 to 200 years in Tasmania. This has also been documented in palaeoecological research in the Surrey Hills region (Fletcher *et al*. 2021). A similar disturbance has been observed in the subtropics of eastern Australia (K'Gari/Fraser Island) with the invasion of wire rush peatlands by paperbark forest between the late 1950s and mid-2010s (Stewart *et al*. 2020). Climate change poses ongoing threats to alpine and sub-alpine Australian peatlands, including droughts, increased fire frequency and intensity, and invasive species. Alpine peatlands are also subject to substantial legacy impacts associated with grazing and the development of hydroelectric schemes (MacPhee and Wilks 2013; Department of the Environment 2015; Australian Capital Territory Government 2017; Vernon 2017).

In Papua New Guinea (PNG), road construction and infrastructure expansion accelerate risks of increased deforestation, fire and GHG emissions from peatland drainage by granting easier access to the largest and most remote parts of the country (Alamgir *et al*. 2019).

Figure 8.18. Shrubs invading buttongrass moorland in Surrey Hills (Tasmania), after changes in fire management approaches since European settlement. Photo: Patrick Moss.

8.4.3. Hotspots of Change

8.4.3.1. Human-induced Fires in Papua New Guinea, New Zealand and Australia

Climate change and human-induced fires have led to catastrophic loss of habitat for indigenous species, loss of carbon via GHG emissions and vegetation disturbance. In Papua New Guinea, during the El Niño year of 1997, conflagrations enveloped huge areas of both the lowland and highlands, including vast areas of peatland (Hope 2015). Palaeoecological evidence shows that periods of intense El Niño Southern Oscillation (ENSO) and heightened human activity in the past have resulted in increased biomass and peatland burning (Haberle *et al*. 2001). Hotspots of fire on global peatlands during a strong El Niño (2015) and a moderate La Niña (2020) year can be seen in Chapter 4 Figure 4.11. In New Zealand, during the summer of 2021-22, fires due to prolonged dry conditions and human activities led to large-scale (more than 1000 hectares) fires at two of its largest peatlands, the Awarua Wetland of International Importance in Southland and Kaimaumau-Motutangi in Northland (Fig. 8.19). The wetland systems are also under pressure from drainage that lower water tables and enables fire-adapted invasive species (e.g., *Hakea* and *Acacia* species at Kaimaumau) to become more dominant. While the palaeoecological record (McGlone 2009) indicates peatlands in New Zealand have been subject to infrequent fires well before the arrival of humans, the increase in the frequency of fire due to human activities is a concern for vulnerable biodiversity, cultural values (e.g., taonga species) and carbon emissions.

Figure 8.19. Kaimaumau-Motutangi, a 3000 hectares peatland (gumland) in northern New Zealand that was affected by human-induced fire in 2021-22. More than 70% of the peatland was burnt.

Photo provided by the Coordinating Lead Authors.

Australia experienced the impact of climate change first hand on its peatlands following the catastrophic bushfires in 2019-2020 that burned 17 million hectares of land across the continent (Fig. 8.20). As a result, the Australian Government commissioned an independent ecological assessment to determine the sensitivity and exposure of vulnerable ecosystems to multiple fire-related threats (Keith *et al*. 2022). As part of the national assessment, Alpine *Sphagnum* Bogs and Associated Fens (in ACT, NSW and Victoria) and the Temperate Highland Peat Swamps on sandstone (Blue Mountains NSW) threatened ecological communities were identified as "at risk" post-fire. A suite of candidate management actions such as limiting feral animals and providing buffer areas were identified to respond to these impacts.

Figure 8.20. Peatland loss from wildfire, Musselroe Bay, Tasmania, 2017; Parks and Wildlife Service, Tasmania. Photo provided by the Coordinating Lead Authors.

8.5. Policy Context, Policy Options and Hotspots of Response

8.5.1. Policy Context

8.5.1.1. Australia

In Australia, the responsibility for peatland conservation and management is shared across the Commonwealth, State and local governments, catchment and conservation organisations and individual landholders. At the national level, the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) regulates development activities that may have a significant impact on matters of national environmental significance (MNES). This includes peatland systems that are listed as endangered ecological communities, designated Wetlands of International Importance, and listed as National Heritage or World Heritage sites.

National programs like the National Landcare program provide funding support for wetland conservation and rehabilitation projects and threatened ecosystem and species-focused research that can support peatlands management.

State and territory governments have important statutory responsibilities for the protection of peatlands (Australian Government n.d.). State legislation also provides the framework for local government's land use planning activities and development controls guiding peatlands restoration and management. Australia's ability to conserve and manage its peatlands outside of protected areas is hampered by the absence of a comprehensive national wetland inventory to inform decisions about the protection of peatlands. The vast majority of Australian alpine and sub-alpine peatlands are on publicly managed land and are now protected in National Parks or State Forests with restrictions on the activities that can be undertaken. The alpine and sub-alpine peatlands are nationally listed as an endangered ecological community under the Environment Protection and Biodiversity Conservation Act 1999.

8.5.1.2. New Zealand

The policy framework for the management of peatlands in New Zealand is similar to Australia, it comprises national (Department of Conservation) and regional organisations (e.g., councils) that have responsibility for managing and restoring relatively large areas of peatlands within public conservation land. However, the regulatory and cultural framework that guides peatland management is more specific to New Zealand.

The most significant recent advancement in environmental policy was the enactment of the National Policy Statement for Freshwater Management 2020 (New Zealand Government 2020) and the associated National Environmental Standards (NES-Freshwater). This contained a major policy shift to increase the regulatory protections for all wetlands (including peatlands). The overarching national policy was amended to, in effect, avoid peatland loss and promote restoration.

In addition, the cultural principle of *Te Mana o te Wai* was embedded in the legislation. This recognises the vital importance of water and states that, by protecting the health of water (including peatlands), the health and well-being of people and ecosystems are also protected. In essence, this requires local regional authorities to consider *Te Mana o te Wai*, through discussions with *tangata whenua* (local Māori) and communities. Therefore, cultural perspectives on natural resource management are critical in current and future peatland management.

The first New Zealand emissions reduction plan, Te hau māoroki ki anamata, was released in May 2022 (Ministry for the Environment 2022), specifically identifying peatlands' important function as Nature-based Solutions to climate change and the need to rewet degraded peatlands to help reduce emissions.

8.5.1.3. Papua New Guinea (PNG) and Pacific Countries

Efforts are underway in PNG to enhance information on peatlands and increase awareness towards improved climate policies, e.g., including peatland emissions in the Nationally Determined Contributions (NDCs).

In the Pacific Islands, seven countries are contracting parties to the Convention on Wetlands, with eleven Wetlands of International Importance designated at the national level, covering a total combined area of 807,580 hectares (Nanettew 2022). The State of Environment and Conservation in the Pacific Islands 2020 Regional Report revealed that coastal habitats in the region, which include wetlands, are essential but in decline.

In the Pacific islands, climate change poses the most serious threat, particularly rising sea levels on the low-lying atolls. Agricultural expansion is also presenting a challenge in the region effecting already degraded lowland peatlands. The South Pacific Community (SPC)'s strategic plan 2022-2023 broadly addressed key focus areas of Resilience and Climate Action and Natural Resources and Biodiversity, however, there is no explicit mention of peatlands (South Pacific Community [SPC] 2022).

8.5.1.4. Antarctica and sub-Antarctic Islands

Antarctica is subject to a series of legally binding international agreements collectively known as the Antarctic Treaty system. These aim to protect and conserve the environment, including more generically wetlands. The main agreement pertinent to peatlands is the Protocol on Environmental Protection to the Antarctic Treaty (Hughes *et al*. 2018).

8.5.2. Policy Options

Oceania is a diverse region, encompassing continental, large-island and small-island scales that supports a similarly diverse suite of peatland ecosystems. Loss and degradation of peatlands continue in Oceania, despite a range of legislative and policy mechanisms and management tools. A priority for the region is to increase efforts to put in place policy and management programmes to provide global goals for peatland conservation, restoration and sustainable management. For example, the Convention on Wetlands (Convention on Wetlands 2021) calls on governments, financing institutions and the private sector to ensure that drainage-based agriculture and forestry do not expand further into peatland areas, and to undertake large-scale peatland rewetting and restoration to achieve national and international climate change mitigation targets. The Convention further recommends mainstreaming a gender perspective in its implementation and this also applies to peatland-related activities. Improved national and regional policies and strategies are also urgently needed to prioritise efforts to protect and restore wetlands.

8.5.3. Hotspots of Response

8.5.3.1. Case Study – Local Advocacy and Science for Peatland Conservation, SW Australia

Southwestern Australia (SWA) is losing its extensive peatland ecosystems to climate change, fire, and damage from invasive species. A unique and slow-forming habitat harbouring endemic microbes, plants and animals, wetlands with organic soils are increasingly impacted by declining rainfall and groundwater.

These processes are drying soils, which enables severe and often irreparable damage to peatlands from fire. The Walpole-Nornalup National Parks Association (WNNPA) formally sought to recognise these threats. The WNNPA is a local community group established in 1987 to increase the understanding and awareness of positive interactions and engagement with the natural values of the lands and waters that make up the Walpole Wilderness Area. The group first nominated *Empodisma gracillimum*-based peatland communities of the high rainfall zones of southwestern Australia for listing as a Threatened Ecological Community, under the Australian Government's Environmental Protection and Biodiversity Conservation Act, in 2017, and then renominated it with additional information in 2019. The Ecological Community was then placed on the Finalised Priority Assessment List for the period commencing 1 October 2019 as "*Empodisma gracillimum* based peatlands of southwest Western Australia". Since then, consultant scientists have sought to define the ecological community accurately, and the Australian Government's Department of Agriculture, Water and Environment, has been working to gain Ministerial approval for the national government, with the goal of authorising recovery actions to prevent further decline.

8.6. Knowledge Gaps

Peatlands in Oceania are amongst the most threatened and least understood ecosystems. This is because they are rare and restricted in distribution due to their biogeography and, at the same time, unique because of the way they were formed. Knowledge of the peatlands of Oceania is best in New Zealand, followed by Tasmania and then mainland Australia. While there is a comprehensive peatland map of Papua New Guinea, knowledge of the peatlands there is still thin, especially in the tropical mountain systems. Likewise, peatland information on the Pacific Islands is limited. Polar lowland peatlands have been the focus of more research than their tropical counterparts.

Improving the knowledge of the distribution, values and benefits of peatlands in Oceania would assist in their conservation, restoration and sustainable management and ensure that they continue to provide services for planetary health. Oceania's peatlands provide important contributions to people and function as hotspots for biodiversity with numerous unique and endemic plants and animals found in them, many of which are threatened. Specifically, mapping efforts of Australia's lowland peatlands (temperate, sub-tropical and tropical) are very sparse and incomplete. Across the inhabited region, degraded peatlands are very poorly known, hampering restoration efforts. The peatlands are threatened by increasing human pressure on the land through conversion to agriculture, altered hydrology, climate change, fire and invasive alien plant and animal species. There is little information on carbon accumulation rates or greenhouse gas emissions from peatlands in the region with the exception of exemplar New Zealand sites (e.g., Goodrich *et al*. 2017). The risk of landscape scale bushfires across Oceania is increasing but there is still lack a comprehensive understanding of the relative carbon losses in burnt peatlands. Currently, there is no consistent regional monitoring of the state of peatlands or their biodiversity status. Most 'intact' peatlands in New Zealand and Australia are protected via regulations, but there is a large gap in protected areas elsewhere.

Knowledge of the peatlands of the Pacific Islands is scarce and a significant knowledge gap exists for the region. Support and resources to develop a unified and trusted Pacific Island soil information system, knowledge resource and monitoring program are crucial to assess these peatlands as a natural asset and carbon sink. Global collaboration is urgently required to address this inequity. Indeed, the threat that peatlands in Pacific Island countries will disappear before they are even documented is very real.

CHAPTER 9

Policy and Governance Options for Peatlands Conservation, Restoration and Sustainable Management

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CHAPTER 9

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More effective governance of peatlands can deliver a triple win for the climate, people and the planet, but action is needed immediately.

9.1. Introduction

In an era of high uncertainty, rapid environmental change, and increased recognition of the coupling of social and ecological systems, it is clear that there are limitations to current peatland policy and governance. As policy goals, and biophysical, social and political conditions differ between locations, the governance of peatlands needs to be tailored to each national, regional, and local context. This governance must also be adjusted for the needs and interests of the human populations and other species that depend upon these habitats (Ostrom 2010; Astuti 2020; Narendra *et al*. 2021). The adoption of gender-responsive approaches that take into account the needs of both women and men especially those from lower socioeconomic status, are thus crucial if we are to make progress towards environmental sustainability.

This chapter reviews a range of policy and governance instruments that can halt further degradation and destruction of peatlands and facilitate their conservation, restoration and sustainable management. This assessment defines "policy" broadly as sets of rules and procedures that are typically used by public institutions to make decisions or take actions to achieve defined goals (Lerche and Said, 1971; Fox and Meyer 1995). This assessment defines "governance" as the formulation and implementation of rules, procedures, and processes. These can be informal (e.g., cultural norms) or formal (e.g., international agreements) and aim to achieve environmentally sustainable outcomes through multi-level interactions (from local to international) among state, market, and civil society actors (Folke *et al*. 2005; Lebel *et al*. 2006; Cundill and Fabricius 2010). Therefore, governance includes the implementation of policies as well as other modes of decision-making. It involves both policy-makers and other actors as they interact to make and enact decisions about the natural environment (Patterson *et al*. 2017).

Governance instruments that can facilitate the conservation, restoration and sustainable management of peatlands include regulatory, financial, and market mechanisms, as well as partnerships and co-management approaches. Alongside these instruments are approaches that are more educational and social in nature, like capacity building and behavioural change programmes. Any one approach in isolation is unlikely to deliver the changes necessary. This chapter therefore reviews evidence for each of these instruments, as they have been operationalized in a range of different contexts and considers how each might play a role in managing, protecting, and restoring peatlands.

The combination of instruments relevant in each peatland context will differ depending on many factors. These will include the drivers of degradation being tackled, the condition, the extent and the location of the peatlands in question; the contributions to people that the given peatlands provide that are most highly valued by society, the objectives of different rights holders and whether an area has protected status. Economic, social and cultural barriers to protection must be considered. The mix of policy instruments will also depend on policy objectives, and the role peatlands play in reaching net zero climate/carbon or nature/biodiversity targets.

9.2. Regulatory Approaches

Regulatory instruments can protect the important functions that peatlands perform and control the use of peatland resources. Many of these regulations relate to protecting biodiversity, including rare and threatened habitats and species, the role of peatlands in providing a supply of freshwater and mitigating flood risk and in protecting terrestrial carbon stocks. However, policy incoherence is a global problem; policies to conserve, protect or restore peatlands are often undermined by other policies managed by different governing bodies or institutions, often driven by economic priorities (Carmenta 2017; Ekardt *et al*. 2020). In addition, there is a need to adopt gender-responsive approaches across global environmental policies as emphasized in the Paris Agreement, the Sustainable Development Goals, the Post-2020 Global Biodiversity Framework as well as the Ramsar Convention on Wetlands. Government subsidies to agriculture and fossil fuels amount to almost $600 billion US Dollars per year, which is more than five times the amount spent globally on nature conservation by both the public and private sector (OECD 2019; OECD 2020a; OECD 2020b). For example, agricultural policies typically prioritise food production and welfare of farming communities, but many agricultural activities on peatlands require drainage and the consequence is a loss of carbon, biodiversity and hydrological functions (Regina *et al.* 2015; Buschmann *et al.* 2020). Energy policies to replace fossil fuels with biofuels have caused uncontrolled expansion of bioenergy crops and massive peatland degradation in some countries, and in other countries peat is still mined for large-scale energy production (Meijaard *et al*. 2020). Transport electrification demands more and more mineral mining for battery metals and other critical minerals, causing a threat to peatlands in some regions (Lassila *et al*. 2021). Wind farms can cause significant damage to peatlands and are often located in peatlands because these sites are usually windy, remote, and generate low returns from agriculture and other land uses (Heal *et al*. 2020). However, fossil fuels and the continued exploration and exploitation of oil and coal pose equal threats to global peatlands.

The challenges of coordinating transboundary peatland policy are even greater than developing coherent peatland policies at national scales, but there are examples of successful policy coordination between nations with different environmental law and legal systems, for example the UK Peatland Strategy in the UK (IUCN UK Peatland Programme 2018; Reed and Barbrook-Johnson, in press) and between the ASEAN's Member States.

ASEAN has adopted policies and guidelines to facilitate coordinated action to address peatland degradation and large-scale fires and associated transboundary haze pollution. The ASEAN Agreement on Transboundary Haze Pollution and ASEAN Peatland Management Strategy (2006-2020) led to a large number of actions by all 10 ASEAN Member States (ASEAN 2021b) including the adoption of National Action Plans on Peatlands in five member states such as the Indonesian National Plan for Protection and Management of Peatland Ecosystems 2020-2049 (Ministry of Environment and Forestry 2020). In 2016, ASEAN adopted the ASEAN Guidelines for Peatland Fire Management (ASEAN 2021a) which has guided member states to re-allocate resources from peatland fire control to prevention.

The protection and conservation of peatlands is complicated by historic property regimes, which may include a mix of state and private land ownership, with differing levels of access and usage rights (Quinn *et al.* 2010). Indonesia, for example, has large areas of peatland that are owned by the State, which has extensive decision-making powers in terms of land use and access.

This can include the allocation of concessionary land uses under licence (e.g., for plantation agriculture), but with requirements and regulations that provide guidelines for management, conservation and restoration. In other countries, including many in Europe, most peatlands are under private ownership, and it is the owners who determine the land use or are responsible for leasing the land for various uses (e.g., drainage-based agriculture, forestry, peat extraction, etc.). Many land use policies, such as the EU Common Agricultural Policy (CAP) and national legislation to implement the CAP, provide strong incentives to drain peatlands and can disincentivise rewetting and the shift to more sustainable, peat-conserving land management practices by private landowners and users.

9.2.1. Protected Areas

Peatland ecosystems across the globe remain largely unprotected from infrastructure development, mining, and conversion to agricultural use and are highly vulnerable to land use change (Turetsky *et al.* 2015; Harris *et al.* 2021; Qiu *et al.* 2021; Cole *et al*. 2022). Where protected peatlands are intact and subject to minimal disturbance, these areas tend to be small remnant patches in an otherwise disturbed and managed landscape. Where more extensive areas of high-integrity peatlands are protected, their extent is typically limited in comparison to the extent of surrounding unprotected areas, and there are rarely sufficient resources for effective conservation (Kingsford *et al*. 2021). Where sites have been impacted by drainage, logging, fire, invasive species or other forms of exploitation or disturbance, they may need active interventions to conserve or restore their key features and functions, and this can be resource intensive.

The nature of legal protections that peatlands receive, and the relevant designations, vary by country. The designation "Wetland of International Importance" can be applied by the 172 countries that are parties to the Convention on Wetlands. To date, 657 Wetlands of International Importance have been designated with one of the four inland wetland categories containing peat: forested peatlands, non-forested peatlands, alpine wetlands, and tundra wetlands (Ramsar, 2012). The Convention on Wetlands provides the only international mechanism for protecting wetlands specifically, and resolutions and recommendations on peatland conservation and sustainable use adopted by its COP have led to the establishment of important protected areas around the world.

For example, in 2017, the governments of the DRC and the Congo agreed to cooperate in sustainably managing a large portion of the central Congo River Basin peatlands, being a single transboundary site comprising three Wetlands of International Importance and containing 45% of the peatland area in the basin (Complexe Transfrontalier Lac Télé - Grands Affluents - Lac Tumba) (Dargie *et al.* 2019).

Recognizing the multifunctional uses of peatlands and the overlapping property regimes under which many peatlands are managed, it is critical that peatland protected areas as well as other policies with implications for peatlands are co-developed with Indigenous Peoples and Local Communities. Indigenous Peoples have been custodians of 80% of the earth despite only representing 6% of the population and thus there is much that the world can learn from them.

The Venice Agreement on Peatlands was created by inviting multiple local initiatives and Indigenous communities from all around the world responding to the call by all member states in the UNEA-4 Resolution on Peatlands. It articulates needs and emphasizes the importance of coordinating and supporting multi-disciplinary efforts by their custodians to better "conserve and restore global peatlands locally". Indigenous communities are leading on conservation activities via community-based monitoring and establishing protected areas using their own governance structures.

In some areas, use and access are restricted (e.g., sacred sites). The Selk'nam people from Tierra del Fuego in Patagonia regard their peatlands as sacred, as their ancestors are buried there. In other areas, Indigenous practices, such as hunting and gathering, are permitted. Other sites allow non-Indigenous uses, for example in buffer areas around sensitive zones selective logging, micro-hydropower and artisanal small-scale mining take place.

Partly as a result of the complexity of tenure regimes and their associated usage rights, peatlands with formal legal protection are often still subject to drainage and other practices that lead to their degradation. Examples include peatlands protected under the Natura 2000 network introduced in the European Union in 1992 under the Habitats Directive.

Peatlands feature prominently in this network, which provides protection for rare and threatened (semi)-natural habitats and species. The Habitats Directive obliges Member States to "establish the necessary conservation measures" such as management plans and "avoid damaging activities that could significantly disturb these species or deteriorate the habitats of the protected species or habitat types". Unfortunately, no specific obligation is set regarding water levels in peatland sites so that even in national and international protected areas (e.g., Natura 2000 sites) drainage is a common feature, which is little addressed so far (Peters and von Unger 2017). As a result, legal protection is not always enough to conserve peatlands, and other regulatory mechanisms may be needed. These are particularly relevant to the majority of peatlands that are currently outside protected areas.

In addition to the protected areas designated by governments, such as national parks, nature reserves, wildlife sanctuaries, etc., peatlands are also conserved within the lands and territories of Indigenous Peoples and Local Communities (IPLCs). The recent Report on the State of Indigenous Peoples' and Local Communities' Lands and Territories (WWF *et al.* 2021) confirmed that IPLCs are vital custodians of the world's remaining natural landscapes. In total, 91% of IPLC lands are in good or moderate ecological condition and 42% of all global lands in good ecological condition are within IPLC lands. When overlaps with protected areas under the governance of any actor other than IPLCs are excluded, IPLC lands in good ecological condition cover 17.5% of the world's terrestrial surface. IPLCs are therefore very important stewards of many peatlands around the world, but this has yet to be fully assessed or documented. Peatlands in IPLC lands include large peatland areas in Canada, Russia, Southeast Asia, Papua New Guinea, Africa and Latin America. Noon *et al.* (2022) indicated that IPLCs are stewards of some of the most important peatland stores of "irrecoverable" carbon (i.e., carbon from natural ecosystems that if lost could not be recovered through conservation action before 2050). 50% of all irrecoverable carbon lies within a concentrated area covering 3.3% of the land comprising primarily of peatlands, mangroves, tropical wetlands and tropical forests. 46.7 Gt (33.6%) of irrecoverable carbon is found in IPLC lands, while 32.0 Gt (23.0%) is within formal protected areas, with an overlap of 11.6 Gt. This clearly indicates a great importance of IPLC lands to protect terrestrial ecosystem carbon stocks including those in peatlands.

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Communities can also play an important role in government controlled protected areas such as through co-management or partnership agreements. For example, a community-based organization (Friends of North Selangor Peat Swamp Forest) was established in 2012 by residents from four villages to help protect and rehabilitate portions of the adjacent 81,000-hectare North Selangor Peat Swamp Forest in Malaysia (Nath *et al.* 2017; Alam *et al.* 2021). They undertake daily patrols to monitor land clearing and fires, establish community tree nurseries, and block drains in the forest and adjacent lands to prevent fires and restore forests. They have helped the State Forestry Department reduce the extent of forest fires in the area by 98% between 2014 and 2022.

9.2.2. Other Regulatory Mechanisms

Peatlands outside of formally designated protected areas may be afforded some level of statutory protection if they form part of planning zones, including buffer zones in which a wider range of extractive activities may be permitted. Buffer zones are increasingly common around protected areas, providing access for certain uses to local communities to protect core areas while enabling sustainable livelihoods. In peatlands, this may include wetland buffer zones to filter out nutrients from surrounding agricultural land (Walton *et al.* 2020).

For example, Sri Lanka's largest wetland, the Muthurajawela peatlands, contains a 1,777-hectare Wetland Sanctuary dedicated to protecting several endemic and nationally threatened species (IUCN Sri Lanka 2004). The site includes a 400-hectare recreational buffer zone and has been estimated to have an economic value of Rs 726 million Sri Lankan Rupees (~€2.03 million Euros) per year, attributed to its role in providing drinking water, fishing opportunities, and protection from flooding for nearby settlements (Emerton and Kekulandala 2003).

In the EU, the Water Framework Directive (2000) highlights the importance of peatlands as 'buffer habitats' for water purification. Peatland management and restoration areas have to be considered when formulating legally required River Basin Management Plans and any peatlands adjacent to water bodies should be included in spatial planning. Unfortunately, this final requirement has been largely neglected (Peters and von Unger 2017).

In some countries, a key barrier to the development of peatland strategies and policies is a lack of distinction between the peat soil and its overlying vegetation. As a result, many peatlands with trees are classified as forests, and forest policy may not be sensitive to the requirements of peatlands, for example allowing drainage in an attempt to increase the forest carbon sequestration, which increases emissions from peat soils. Alternatively, distinctions may exist, and yet still drive perverse policy outcomes. For example, in Chile, peat and its overlying vegetation were considered as separate products for which exploitation was regulated by different government entities. This led to a contradiction between the Mining Code, operated by the Ministry of Mining, which prevented the exploitation of peat as a fossil resource, and Ministry of Agriculture regulations, which managed *Sphagnum magellanicum* as a non-wood forest product that can be exploited and commercialized under regulation. As a consequence, to protect peatlands in Chile it was first necessary to legally define the peatland as an ecosystem where vegetation and peat are inherently associated. At present, as the result of a close collaboration between government, academia, NGOs, and society, a Peatlands Protection Law is being discussed in the Senate of Chile. This law removes peatlands from the Mining Code and prohibits the extraction of *Sphagnum magellanicum.* It further states that peatlands are a key ecosystem for mitigation of and adaptation to climate change, as well as essential for the conservation and protection of biodiversity and ecosystem services.

Regardless of their statutory protected status, the state may decide to impose moratoria, regulations and controls, including provision for increased resource protection (e.g., to prevent additional drainage, conversion and damage). The state may also establish strategies for sustainable management and active restoration. Licensing may be aimed at preventing or eliminating damage to the site's intrinsic values, or to limiting off-site pollution (e.g., of waterways) arising from some form of peatland land use (e.g., peat cutting, drainage, tree planting, fire use, etc.).

For example, in 2010, the government of Indonesia suspended all new concessions for conversion of peatland and primary forest areas to other uses (namely, oil palm, pulpwood and logging concessions) in line with the country's commitment to reduce greenhouse gas emissions and adapt to climate change. The moratorium was implemented in 2011 on a temporary, two-year basis. It was subsequently renewed on several occasions and then made permanent in 2019.

The effectiveness of the moratorium and other regulations aimed at preventing peatland degradation has been the subject of some debate. Several studies have highlighted limited effectiveness in reducing forest loss, drainage and forest fires (Dohong *et al.* 2018). Others have concluded that the moratorium led to a reduced rate of peatland conversion. For example, over the period 2015-2018 in South Sumatra, the moratorium led to a 24% reduction in peatland conversion compared to the first decade of the century, with a decreased number of peat fires (Budiman *et al.* 2021).

Following widespread forest and peatland fires in 2015, the Indonesian government also established a Peatland Restoration Agency (known as Badan Restorasi Gambut or BRG) with the goal of restoring 2.4 million hectares of degraded peatland by 2020 and an additional 1.2 million hectares by 2024 (Wicaksono and Zainal 2022). In 2014, the Indonesian government introduced the comprehensive Government Regulations on the Protection and Management of Peatland Ecosystems, which was further strengthened in 2016. These regulations require that all peatlands in the country be identified and mapped using a Peatland Hydrological Unit (PHU) approach delineating the peatlands and adjacent land to the nearest river and coastline as a management unit. At least 30% of this PHU must be designated for conservation including all areas deeper than 3m and all areas of importance for biodiversity conservation. In practice, more than 50% of the 24 million hectares of PHUs in the country have been designated as conservation areas.


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Outside the conservation zones, peatlands can be designated as utilization zones, where their use is permitted provided strict sustainable management requirements are followed. In the utilization zone, water levels must be strictly managed to maintain them at no more than 40 cm below the surface, aiming to minimize subsidence and the risk of fire. This is to be done by installing a system of weirs and water gates in all peatland plantations. To ensure water levels are maintained properly a network of nearly 12,000 monitoring sites is maintained with 15% of the sites having real time data transmission (Ward *et al.* 2020; Budisusanto *et al.* 2021).

Other countries are also moving to regulate activities on peatlands that increase the risk of fire and carbon loss, and to actively promote peatland restoration. In the United Kingdom, there are controls on the use of fire as a management tool on peat soils. Landowners must apply for a licence to burn vegetation on peat greater than 40 centimetres thick and on peat of any depth within a designated conservation area. A licence can only be obtained if they meet certain conditions and provide evidence that the use of fire will not damage the site's integrity.

In Scotland, funding through the Peatland Action Programme has led to the restoration of over 25,000 hectares of peatland since 2013. The current Scottish peatland restoration target is 20,000 hectares per year (to result in restoring 250,000 hectares by 2030) and is supported by an investment of £250 million Sterling (~€284 million Euros) over a ten-year period. In England, the government's Peat Action Plan (2021) has the goal of funding at least 35,000 hectares of peatland restoration by 2025 as the initial stage in a 25-year programme. This will ensure peatlands contribute towards the UK Net Zero Strategy, which outlines how the government plans to deliver its emission target of net zero by 2050, while also contributing to other environmental goals, including natural flood management, improvements in water quality, and protection of biodiversity and the historic environment (DEFRA 2021). Currently, EU legislators are negotiating the EU Nature Restoration Law, which will set legally binding targets for all Member States for the implementation of the EU Biodiversity Strategy 2030. The current draft[1] also includes binding targets for the restoration and rewetting of managed peatlands in and outside of protected areas that need to be reached by 2030, 2040 and 2050.

Some forms of peatland protection and conservation may be compatible with certain productive uses and supporting the livelihoods of local communities (Parish *et al.* 2008; Medrilzam *et al.* 2017; Roucoux *et al.* 2017; Dargie *et al*. 2019; Schulz *et al.* 2019; Simangunsong *et al.* 2020).

In 2021, the Government of Peru issued a supreme decree on the multisectoral and decentralized management of wetlands. This acknowledged the importance of peatlands and promoted their sustainable use, including for hunting and the collection of plant resources (Roucoux *et al.* 2017; UNEP 2021). In the Amazonian peatlands of Peru, the collection of palm fruits (Aguaje, *Mauritia flexuosa*) can contribute to between 15% and 22% of family incomes, but there are concerns that collecting fruits by tree felling, rather than climbing, is unsustainable (Pizango *et al.* 2022). Recognition of the negative impact of intensive tree cutting resulted in the introduction of communal management systems that were initiated by dialogue between local communities, NGOs and government institutions. In peatlands with a national protection designation, the collection of palm fruits is now regulated by the Protected Areas National Service (SERNANP), while there are also efforts to regulate harvesting on peatlands outside protected areas by issuing permits (Pizango *et al.* 2022).

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[1] https://environment.ec.europa.eu/publications/nature-restoration-law_en

Paludiculture (the cultivation of crops on wet or rewetted peatland) has the potential to make a significant impact on the achievement of climate and biodiversity goals while providing income for farmers who have previously practised drainage-based agriculture through the production of high-quality fibres and biomass for a growing bio-economy (Wichtmann *et al*. 2016). In the EU Common Agricultural Policy, paludiculture was largely excluded from receiving payments for development, maintenance or expansion of agricultural activity. This contradiction has been resolved in the next funding period (2023-2027), where paludiculture will qualify for funding, including specific conditions to preserve peatlands (European Environmental Bureau 2022). Germany recently started four large scale paludiculture projects with a duration of 10 years and with total funding of €48 million Euros to showcase and develop different paludiculture practices[2]. More long-term paludiculture projects are planned to start in 2023.

In conclusion, designating more intact and high-integrity peatland ecosystems, engaging local communities as partners in peatland protection within protected areas, and imposing moratoria on land use activities that degrade, drain, and burn peatlands represent important initial steps. However, for these policies to be effective, they must be sufficiently comprehensive and supported by effective programmes for peatland mapping, monitoring, and enforcement (FAO 2020; UNEP 2021).

When combined with strict sanctions and penalties on non-compliance, these policies could also reduce illegal peatland conversion (UNEP 2021).

9.3. Financial and Market Instruments

Regulatory mechanisms, such as land use planning for conservation and land tenure reform, can be an important first step in countries where there is limited protection for peatlands, or where land tenure systems undermine attempts to increase the sustainability of peatlands management. However, in addition to regulatory approaches, economics often play an important role in preventing further degradation, by funding restoration or inducing changes in peatland management (e.g., via removal of perverse incentives). This is particularly true in locations where restoration is costly and there are opportunity costs associated with switching to more sustainable land uses or management strategies. Incentives and other payments may be provided by governments via public funding mechanisms, by the private sector via payments for ecosystem services or through a combination of public and private funding. Similarly, removal of perverse incentives that encourage drainage of peatlands or increase the number of grazing animals can reduce the pressures on and degradation of peatlands.

9.3.1. The Case for Public Funding

Many businesses are ultimately reliant on natural capital and ecosystem services and may therefore invest in peatlands to protect the private goods that they rely upon. However, it is more difficult to justify investing in public goods that will also benefit competitors. Using peatlands for agriculture, forestry or peat extraction can lead to private goods for the producer, while generating environmental costs, such as flooding, that must ultimately be met by governments. It is often more expensive to manage peatlands in ways that do not generate these environmental costs. To protect intact peatlands and pay for sustainable practices that benefit the public over the long-term, rather than focussing on short-term private benefits, funding may be offered to peatland owners and managers from either public or private sources. However, few governments have sufficient funding to meet the scale of the challenges outlined in previous chapters of this report.

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[2] https://www.z-u-g.org/aufgaben/pilotvorhaben-moorbodenschutz/

It is estimated that it would cost between $19-46 billion US Dollars per year between 2022-2050 to rewet (merely) 40% of drained peatlands by 2050 (UNEP 2021). Conservation and restoration of tropical peatlands alone could cost $40 billion US Dollars but could reduce global greenhouse gas emissions by 800 million tons CO_2e per year (equivalent 1.5% of annual global emissions) (UNEP 2021).

For Scotland, one study considered the provision of ecosystem services such as drinking water noting that net benefits of peatlands restoration alone would lead to £191 million Sterlings (~€217 million Euros) savings a year for the government (Glenk *et al.* 2021).

One way of reducing the cost of restoring peatlands is to act now rather than postponing action, immediately limiting the mounting costs of degradation to society, which will be much greater the longer degradation is allowed to continue.

In recognition of the many valuable public benefits provided by peatlands, a growing number of countries are introducing peatland policies and strategies, many of which include public funding for peatland conservation, restoration and sustainable management.

For example, the forthcoming programme for nature climate solution action (Aktionsprogramm Natürlicher Klimaschutz[3]) by the German government is funded with €4 billion Euros over the next four years to prioritize peatland action with half of this budget aimed at peatlands restoration alone. Public funding for peatland action includes grants to establish or maintain protected areas, integration of restoration and sustainable management of peatlands in agri-environment schemes, and the replacement of perverse incentives.

In addition to directing public funding towards development and demonstration of sustainable peatland use and removing perverse subsidies, taxes may be introduced to reduce pressures on peatlands and to generate revenue. Building on work by Barbier *et al.* 2020 and Barbier and Burgess 2020, UNEP (2021) suggested introducing taxes in order to further reduce the likelihood of damage and reinvest tax revenues into restoration and community initiatives.

Despite recent efforts to invest in peatlands, there is likely to be a gap between the funding available in the public sector and the funding needed to protect, restore and sustainably manage peatlands at the scale needed to meet our climate and nature goals. It has been estimated that in the UK alone, the gap between committed or planned environment spending and the spending required to reach net zero targets and other nature-related outcomes by 2050 is between $57-120 billion US Dollars (Green Finance Institute 2021). To fill the financing gap to restore peatlands, there is a need for the international and donor community to provide financial and technical assistance to low- and middle-income countries to help them adopt policies and strategies to protect, restore and sustainably manage peatlands. Much of this funding may also be supplied by the private sector, which is increasingly investing in peatlands in response to a number of risks and opportunities (Reed *et al*. 2022). For example, the ASEAN Secretariat, with assistance from the International Fund for Agricultural Development (IFAD) and the Global Environment Centre (GEC), is currently developing an Investment Framework for Haze-free Sustainable Land Management in ASEAN, aiming to leverage $1.5 billion US Dollars to support the implementation of the ASEAN Peatland Management Strategy for 2022-2030.

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[3] https://www.bmuv.de/download/dl-aktionsprogramm-natuerlicher-klimaschutz

Box 9.1. Market Mechanisms that can Support Peatland Restoration and Sustainable Management

Carbon markets include the international compliance market (Article 6, Paris Agreement), international voluntary markets (e.g., Gold Standard, Verra) and national/sub-national compliance (e.g., cap and trade or emissions trading schemes in California and the EU) and voluntary markets (e.g., Germany's MoorFutures, the UK's Peatland Code and max.moor in Switzerland). This can include:

- Offsetting, where companies buy carbon credits to compensate for any emissions they are unable to avoid, or to contribute to reaching national climate targets. Carbon credits, must be transparent and verified. They can arise from emission avoidance and carbon sequestration and storage.
- Insetting, where companies buy raw materials or energy with zero (or even negative) emissions to be used within their production chain to reduce or compensate for their unavoidable direct, indirect and wider supply chain emissions.

Ecosystem markets pay for other public goods and include:

- Place-based schemes at a local, landscape or regional scale that may improve water quality or reduce flood risk through catchment management.
- Voluntary and compliance biodiversity offsetting markets that compensate for biodiversity loss and result in a net gain in biodiversity in a new location.
- Investments that prevent deforestation and forest degradation, and so reduce emissions while meeting conservation objectives.

Green finance mechanisms are designed to provide a return on investment by funding projects that deliver public goods (including via carbon and ecosystem markets). Common mechanisms include:

- Green bonds that generate repayable investment to pay for environmental projects.
- Loan-based schemes and repayable finance facilities that pay for peatland restoration. Debt for nature swaps may also be used to promote peatland conservation or restoration (UNEP 2021). It may also be possible to reduce the cost of debt where companies or assets are exposed to risks (e.g., subsidence) that could be mitigated through peatland restoration, providing further financial incentives to invest in restoration.
- Insurance products that incentivize environmental activities (including habitat restoration) that reduce risks to those who are insured from natural disasters like tidal flooding. In the same way that restoration may reduce the cost of debt where risks arise from peatland degradation, it is possible that discounts may be offered for insurance policies where these risks have been mitigated.
- Credits from carbon or ecosystem markets that can be sold in the future at a profit on secondary markets. These may finance projects in carbon and ecosystem markets, either directly to project developers who then keep the credits, or indirectly by providing finance to intermediaries or brokers who pay project developers and keep the credits for sale to their customers (Reed *et al*. 2022).

9.3.2. Private and Blended Finance Mechanisms

Private investment in peatlands may come from carbon and other ecosystem markets (e.g., for water quality or biodiversity). It may also come from green finance mechanisms such as insurance products that incentivize restoration and reduce risks to the insured, green bonds and other loan-based mechanisms (Box 9.1; for more details, see UNEP 2021 and Reed *et al*. 2022).

Although peatland carbon has been extensively discussed in the literature, less attention has been given to the use of ecosystem markets and green finance mechanisms to acquire multiple benefits from peatlands. There are two ways that this can be done: bundling or stacking (Lau 2013; Joosten *et al*. 2015; Torabi and Bekessy 2015). Bundled carbon targets buyers who have done everything they can to reduce emissions at source and want to restore peatlands to offset or inset their remaining emissions. Peatland carbon is unlikely to be the cheapest available due to the costs of restoration, but it offers important co-benefits, like biodiversity and water quality, and these benefits can be bundled with the carbon and reflected in the price. As a result, bundled schemes are sometimes referred to as “premium carbon” or “carbon+”. Alternatively, instead of selling a bundle of co-benefits around a premium carbon product to a buyer who is interested primarily in the carbon, it is possible to unbundle the co-benefits, selling the carbon to one buyer, and each of the co-benefits to other buyers (effectively “stacking” one payment on top of another). Although this can increase the overall funding available, it can be complex because each market may have additionality rules that prevent stacking (Robertson *et al*. 2014).

The goal of blending public and private funding for public goods is to increase the overall level of funding available for peatland restoration, letting markets pay for as many outcomes as possible so that public funding can be prioritized for those actions not appropriate for private funding. Blended finance might also be used to integrate other community-based initiatives that safeguard the needs of the most vulnerable groups in society, including women. There are three models for blending public and private finance for peatlands, outlined in Box 9.2.

The delivery of multiple outcomes, whether via stacking or bundling, has tended to focus on the delivery of multiple ecosystem services, where possible reducing and mitigating trade-offs between these services (e.g., Galicia and Zarco-Arista 2014; Zheng *et al*. 2019). Increasingly, however, schemes are being developed that go beyond the indirect benefits that accrue to society in the long-term, to ensure community engagement and provide short-term, direct benefits to local communities (Box 9.3). These considerations are important given distributional justice concerns, and the need for a just transition to net zero for peatland communities.

Box 9.2. Blended Finance Models

Broadly speaking, there are three approaches to blending public and private finance to fund peatland restoration and sustainable management:

- Full public-private co-procurement of public goods, in which public and private finance are integrated into a single fund at a landscape scale designed to deliver multiple outcomes.
- Co-ordinated public-private funding of public goods, delineated in space or time, enabling the market to pay for as much as possible, while public payments focus on market failures and those who are not prepared to accept private finance.
- Business as usual, whereby private funding pays for services that are not already being procured by public funding, with limited coordination. This is the scenario in most countries.

Box 9.3. Delivering Community Benefits as Part of a Just Transition

Policy mechanisms to facilitate community benefits from peatland ecosystem markets may include:

- The development of guidance on rights and responsibilities for investors entering land markets and considering formal approval processes for land acquisitions.
- The establishment of gender-responsive participatory and collaborative approaches to natural capital investment, including guidance and training on community engagement for project developers, to improve decision outcomes for communities. This may also include reforms to land tenure. There may also be a role for community natural capital funds, to ensure benefits from investment are shared fairly between public, private and community interests.
- Addressing barriers to tenants and other rights owners engaging in ecosystem markets (e.g., encouraging contracts that allow tenants to participate in natural capital schemes).

9.4. Creating an Enabling Governance Environment

Recent insights into governance arrangements for addressing the interconnected biodiversity and climate crises, encompassing peatland degradation and loss, advocate for governance modes that are interactive (consciously interacting with power centres to define and achieve goals) and reflective (reassessing practices and adjusting steering mechanisms) (Meadowcroft 2007; Frantzeskaki *et al.* 2010). This may lead to adaptive polycentric governance arrangements across scales, sectors and groups (Chaffin *et al.* 2014; Carmenta *et al.* 2017). While these forms of governance can increase inclusion and creativity, it can also lead to uncoordinated responses across scales and between different interested/affected groups (Jefferson *et al*. 2020). Again, differences in ideologies, worldviews and values often have to be articulated and reconciled, with a variety of interventions likely the way forward as there is no one-size-fits all solution (see Carmenta *et al*. 2017 discussing these challenges with fire management interventions in Indonesian peatlands). Specific efforts to ensure that women from marginalised communities and from lower socioeconomic status are included at all levels of governance is crucial.

In addressing the governance of complex social-ecological systems, such as peatlands, particular stress has been put on: leadership by individual actors, the use of networks to coordinate actors across multilevel governance systems, and the need to activate the social memory stored in such networks (Oberthür and Gehring 2006; Olsson *et al*. 2006; Gehring and Oberthür 2008). If done well, this can lead to coordination between interested/affected parties, which is critical if governance systems are to be adaptive in the face of complexity and uncertainty (Boyd *et al*. 2015). However, this can be challenging because those who are interested in or affected by peatland issues are so wide-ranging in the values that they hold.

As a result, a range of participatory and co-management approaches has been developed to support this coordination, allowing for the incorporation of diverse values of peatlands in decision-making processes.

This is particularly important when trying to understand and negotiate potential conflicts that may arise between rights-holders and other parties as a result of management interventions, like restoration. For example, in Indonesia where blocks are placed in drainage canals as part of peatland restoration efforts, this may cause conflicts where canals are used by local communities for transport and/or fishing (see Suyanto *et al.* 2009; Thornton 2017; Harrison *et al.* 2020).

The need for coordination between these diverse parties is also evident in examples of successful peatland restoration in Southeast Asia, which has highlighted the need to revitalize local livelihoods and include community led monitoring and reporting as integral elements of restoration and fire-reduction interventions (Terzano *et al.* 2022).

Joosten *et al.* (2012) describes how communities in Russia have prevented peatland drainage in efforts to safeguard their berry and mushroom harvesting areas. Building capacity and trust across levels of governance, and ensuring transparency is key to increasing community participation in peatland management (Newaz and Rahman 2019; Narendra *et al.* 2021). This approach should be gender-responsive and participatory as per the Paris Agreement. Part of this involves ensuring fair distribution of benefits, accountability, and making certain that management objectives align with needs of interested/affected parties (Ostrom 2010; Harrison *et al.* 2020 and see Narenda *et al.* 2021 for an example of participatory watershed management). These are all challenging to achieve, and it takes time to establish effective governance and co-management approaches (Newaz and Rahman 2019).

Both coordination and learning can be enhanced via “boundary organizations” that bring in new knowledge and resources (Brown 1991; Abel *et al.* 2019) that help communicating, translating, and mediating between different knowledge systems (Stewart and Tyler 2019).

For example, in the Netherlands, Stuurgroep Groene Hart acts as a boundary organization at the interface of government agencies and those with an interest in peatlands (van Hardeveld *et al.* 2018). Another example, captured by Reed and Barbrook-Johnson (in press), shows the pivotal role that the IUCN UK Peatland Programme played in advancing new, evidence-based peatland policy and practice in the UK. This success was driven by its ability to convene different interested parties and facilitate knowledge exchange between networks that would otherwise have had limited engagement. This resulted in the creation of a financial mechanism (the Peatland Code) to fund the achievement of the group’s aims. Such organizations can operate at multiple scales, enabling collective action for peatland conservation and restoration on many levels (Gustafsson and Lidskog 2018; Norris *et al.* 2021). They may also bring different parties together through voluntary certification initiatives such as the Roundtable on Sustainable Palm Oil. This initiative has adopted clear policies of development and management of oil palm on peat with a ban on development of new plantations on peat since 2018 and mandatory application of best management practice guidelines for existing plantations as well as gradual phase out of plantation activities based on analysis of long-term subsidence risk as a result of drainage (Parish *et al.* 2019a, 2019b).

9.4.1. Enabling Behaviour Change

In addition to regulatory, financial and market-based mechanisms, it may be possible to harness a number of “softer” mechanisms to support changes in land use and management. Studies in psychology have demonstrated that human behaviour follows predictable patterns (Michie and Johnston 2012), depending on the contexts in which they occur (Davis *et al.* 2015). By understanding behaviour change processes it may be possible to better incentivize or “nudge” people towards behaviours that could protect peatlands. The most widely applied theories (e.g., Theory of Planned Behaviour, Norm Activation Theory, and Value-Belief-Norm Theory, Klöckner 2013) share the understanding of individual decision-making as a largely rational or linear process. However, this approach is not as well-suited to the complexities of environmental decisions as other approaches, such as social practice theory (Hargreaves 2011).

In reality, it is possible to draw on a range of approaches to understand behaviour change, as long as attention is paid to the social, cultural, political and historical contexts in which they are applied (Michie and Johnston 2012; Breadsell *et al.* 2019).

A number of studies has shown that to be successful, peatland conservation and sustainable management must pay attention to human behaviour.

For example, a study in Finland (Grammatikopoulou *et al.* 2019) that explored how citizens made sense of debates about peatland extraction versus conservation, found that considerations ranged from the personal (people harvest berries to feed their family), to the national (groups use energy produced from peat) and the global level (peatlands need to be protected for their carbon stock).

This wide range of perceptions reflects individual versus collective responsibilities, and how social norms may influence behaviours. Praharawati *et al.* (2021) identified the importance of religious leaders in triggering peatland restoration in Indonesia through Islamic moral rulings (fatwas) that prevented burning based on religious text. Trihadmojo *et al*. (2020) found that Indonesian farmers were often aware of the consequences of burning but denied their direct responsibility for the impacts of it. It has been argued that an effective response to global issues like climate change requires nothing less than a wholesale shift in social norms (Levin 2010; Kinzig *et al*. 2013). Over extended time frames, the question becomes not just one of initiating behaviour change (Steg and Vlek 2009) but also of sustaining or maintaining change over time (Kwasnicka *et al*. 2016).

9.4.2. Engaging Diverse Worldviews, Values, and People

More equitable and sustainable policy outcomes are more likely to be achieved when decision-making processes recognize and balance the representation of the diverse values of nature and address social and economic power asymmetries among actors (de Vente *et al*. 2016; Reed *et al*. 2018). The imbalance of power relations should also take into account factors such as gender and age which further impact how resources are re-distributed and the levels of engagement and leadership that individuals have access to. Nevertheless, with collaboration comes the risk of mismatches between, for example, perspectives of conservationists, industrialists, policy-makers and local and Indigenous communities (Sayer *et al*. 2018) unless these parties are engaged from the outset.

These mismatches can occur at both spatial scales and across power hierarchies. The challenges of connecting the global and local have long-been recognized.

For example, in Ireland, Bullock and Collier (2011) describe the long-standing 'turbary rights' held by lease-holders that permit peat to be extracted for domestic fuel. They also record how the tradition of hand-cutting peat that once involved whole communities during the summer, has mostly been replaced by large-scale mechanical extraction. Their study revealed a complex relationship between local people and fragile peatland landscapes. The people may recognize the fragility of the land and the need for conservation, yet, at the same time fiercely defend their right to extract peat for domestic consumption.

Byg *et al*. (2017) described this as an ‘ambivalence’ towards peatlands where those with lives closely bound-up in these landscapes see them in complex and sometimes contradictory ways. For Byg *et al*., this diversity needs to be not just recognized but accommodated if policy-making is to have the support of both local people and the wider public.

Achieving collaboration across power hierarchies can be even more challenging. For example, in the tropical peatlands of Indonesia, Miller (2021) drew attention to the asymmetric power relations impacting the development of emerging market-based commons where the traditional 'adat' system of land-tenure that incorporated inter-generational knowledge about safe burning practices conflicted with corporate legal understandings that sought a one-size-fits-all enforcement of fire-free commons. Cole *et al*. (2012) cautioned that the value of tropical peatlands for those in direct interaction with them seems "much greater when the ecosystem is in an ecologically degraded condition i.e., deforested and drained", thereby highlighting the potential contradiction between global aspirations and local needs and practices. For Fleming *et al*. (2021), the challenge of restoring damaged and degraded peatlands in Indonesia will require an "integrated research" approach that brings together different disciplines across multiple scales to support the "transformational change" in behaviours, and shift in social norms of local communities and wider interested/affected parties. The contributions of women in peatland research should be encouraged and acknowledged. Women have unique perspectives that would complement existing policies and practices and thus make them more effective. It is also worth recognising that women face unique challenges and barriers in peatland research, and these should be addressed accordingly to ensure that their much-needed knowledge and contributions are not under-utilised, ultimately impeding progress towards environmental sustainability.

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9.4.3. Recognizing and Integrating Diverse Knowledge Systems

Conservation and environmental management cannot be sustainable or ethical if research and practice do not consider community knowledge systems, perspectives, priorities and values (Tengö *et al*. 2017). Local ecological knowledge comprises observational knowledge, knowledge acquired through practical experience, and knowledge in the form of people's beliefs (Berkes *et al*. 2000; Merten *et al*. 2020). Integrating different forms of knowledge can enable research outcomes to be more relevant in the local social context and can be useful in detecting and understanding more long-term environmental changes that may be missed by shorter-term 'scientific' measurements (Merten *et al*. 2020). Based on this, the UN Declaration on the Rights of Indigenous Peoples (UNDRIP) and the CBD (1992) have encouraged governments to recognize and protect traditional ecological knowledge and Indigenous knowledges for environmental management and conservation (Fabiano *et al*. 2021 for the CBD see Articles 8(j) and 10(c)). Global initiatives such as the Millennium Ecosystem Assessment (2005), The Economics of Ecosystems and Biodiversity (TEEB) and the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) have also highlighted the importance of traditional ecological knowledge and Indigenous knowledges with IPBES giving special attention to the culturally specific relational values that connect humans with their natural environment (Fabiano *et al*. 2021; IPBES 2022; Box 9.4). Methodological guidance that takes into account the gender dimension of the interactions between society and the environment is required. Using a gender lens is crucial to ensure that everyone's needs, rights and contributions are considered irrespective of their gender, age, or socioeconomic status. Integrated approaches for 'People and Planet' are crucial if we are to progress towards environmental sustainability and the SDGs by 2030.

Different forms of knowledge (e.g., Indigenous, informal and localized, as well as scientific, formal and universalized knowledge) may be reconciled by seeing each as context specific (Merten *et al*. 2020). There is therefore a push for co-produced research through collaboration and efforts to connect and speak across knowledge systems, designing policies in such a way that enables practical application of knowledge, and dealing with the power asymmetries that persist between knowledge systems (McElwee *et al*. 2020).

Box 9.4. Indigenous Stewardship of Peatlands

In Southeast Asia, 534 plant species of known human use have been recorded in lowland swamp forests (Giesen 2015) including 222 used for timber, 221 medicinal plants and 165 used for food. Some indigenous communities in this region have specific traditional laws (adat) to guide the harvesting and use of these species as well as fish and other peatland resources. These rules include specific seasons for harvesting, limits on the levels of harvest, establishment of protected sites and fish sanctuaries. As peatlands have been developed, communities have adopted rules to guide land-use practices and the use of fire, including imposition of fines on community members that allow fire to spread out of their own lands and damage crops of others or areas of peat swamp forest.

In Indonesia, the Dayak communities in Kalimantan have developed an elaborate system of peat management. In Ngaju Dayak thinking, inheritable natural resources are those that have awan pailangek ('hand print'), that is, where someone has invested work or money in the land and thus staked a claim to it that entitles them to bequeath the land to others. Under this rule, the Ngaju Dayak cannot bequeath resources that have never been managed, whether they are areas of land (petak) or water bodies (danau). This ensures the continuation of common property regimes for the management of peatlands (Thornton *et al*. 2020).

One such example comes from Patagonian peatlands, where a diverse, and growing number of local actors, public, private, Chilean and Argentinian, inspired and supported by global actors like the Global Peatlands Initiative (GPI), have been working together to establish a Patagonian Peatlands Initiative, a ground-based effort to promote the protection of these austral high integrity peatlands.

However, integrating Indigenous knowledges into peatland policy and management remains challenging (Fabiano *et al*. 2021) and Indigenous and local systems of knowledge and governance are still excluded from policy processes in many countries (Asia Indigenous Peoples Pact *et al.* 2022). In response to this, there have been calls for an 'ecology of knowledges' that recognizes epistemological diversity, and which redistributes power to non-Eurocentric forms of wisdom (Santos 2015). The specific needs and contributions of Indigenous women should also be taken into account as per SDG target 2.3. Indigenous women are one of the most vulnerable groups. With the knowledge that their livelihoods are closely tied to peatland resources, capacity building and economic empowerment, targeting Indigenous women would significantly help improve their adaptive capacities to climate change and depleted natural resources. Many frameworks linking different forms of knowledge also exist (e.g., including Indigenous metissage, Two-eyed seeing, Living on the ground and Indigenous cultural responsiveness theory (Levac *et al*. 2018)), and mixed methods and interdisciplinary research approaches, including storytelling, arts-based methods and critical ethnography, can be effective ways of eliciting and explicitly considering different ways of knowing (Levac *et al*. 2018).

A good example of such an approach towards peatlands is the Chilean pavilion at the 2022 Art Biennale in Venice "Turba Tol Hol-Hol Tol". The pavilion curated by the artists collective Ensayos features multiple aspects of Patagonian peatlands by integrating Indigenous knowledge and culture, in this case Selk'nam, ecological science, conservation activities and artistic practices involving natural and technical designs and co-productions reinforced by the international call for the conservation, restoration and sustainable management of peatlands.

Learning and drawing from different forms of knowledge require researchers and policymakers to challenge their own biases and assumptions regarding what constitutes 'evidence' and 'truth'. This requires the ability to unlearn and reimagine how we produce and value knowledge (Thambinathan and Kinsella 2021).

9.5. Conclusions

Strategies and policies to protect, restore and sustainably manage peatlands have now been introduced in at least 23 countries. Together, these countries are responsible for over half of global peatland emissions (Reed *et al*. 2019). However, it is estimated that at least 169 countries contain peatlands (Kirpotin *et al*. 2021), and although not always extensive, they often provide essential ecosystem services and important habitats that are lost through degradation. When peatlands are drained and degraded they are responsible for significant GHG emissions as well as loss of biodiversity and ecosystem services.

More effective governance of peatlands can deliver a triple win for the climate, people and the planet, but action is needed immediately.

This chapter has discussed examples of governance failure and reviewed a range of policy and governance options that are being implemented around the world. However, no single approach is likely to work in isolation to facilitate the conservation, restoration and sustainable management of peatlands. Instead, a mix of instruments is needed considering the following aspects:

- Protected area systems need to be expanded to include important peatland habitats, drawing on information presented or referenced in this assessment.
- Outside designated sites, buffer or planning zones should be established in which certain activities can be regulated in collaboration with local communities, carefully balancing the provision of nature's contributions to people for society with local needs for sustainable livelihoods.
- Peatlands need to be managed in an integrated, multi-stakeholder manner using a landscape approach with critical attention to maintaining or restoring the natural hydrology of the system.
- Where necessary, legal definitions of peatland should be clarified to ensure they can be appropriately managed in an integrated manner. Attention will need to be paid to conflicts between forest and peatland policies in forested peatlands, which can lead to the degradation of peatlands via drainage or fire.
- Policy instruments need to be informed by the best available science and data, on peatland extent, condition, uses and jurisdiction, etc. It is therefore critical that systems for collecting and applying such data are developed and strengthened. This includes improving local and regional peatland inventories establishing the Global Peatland Inventory and strengthening the National Wetland Inventories[4] prepared by the parties of the Convention on Wetlands.
- Peat extraction, afforestation, plantations and other land use on peatlands need to be tightly regulated. Licensing of remaining activities or ongoing practices must require more sustainable practices through actions like the restoration of former extraction sites and the maintenance of higher water tables under plantations to protect carbon stores and stop subsidence. In addition, afforestation efforts need to assess the impact of planting trees on the peat carbon stock. Planting trees on peatlands where trees have never grown before has negative impacts on their biodiversity being at the same time ineffective for climate change mitigation purposes (Temperton *et al.* 2019).
- The priority should be protecting peatlands from being converted, drained and/or modified (Fleischman *et al.* 2020). Activities that continue to drain and degrade peatlands need to be phased out. Damaged peatlands need to be rewet and restored to conserve carbon stores and enable the recovery of ecosystem services.
- Subsidies that incentivise practices that degrade or convert peatlands to other land uses (e.g., certain agricultural activities, forestry and mining) need to be identified and removed or changed, where possible redirecting savings to pay for and incentivise restoration of degraded sites.
- The creation of gender-responsive policies that devolve control as much as possible to local communities while coordinating activities that empower and engage vulnerable and marginalized populations.
- Enhanced recognition and support needs to be given to Community Conserved Areas (CCAs) and other areas protected by Indigenous Peoples and Local Communities (IPLCs) and Other Effective Conservation Measures (OECMs) to expand the area of protected peatlands. The rights of IPLCs in peatland areas need to be recognised and they should be better supported and empowered for the effective management of the systems.

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[4] The Convention on Wetlands National Wetland Inventories are tools for collecting information on wetlands. They support monitoring and assessment, inform national planning and decision-making, and aid in national reporting on the implementation of the convention and global tracking. This is reflected in the strategic plan of the convention which includes a specific target on development of national wetland inventories (and associated indicators).

- The identification and operation of financial and market instruments that have the potential to pay for and incentivize conservation, restoration and sustainable management of peatlands. These will likely include carbon and other ecosystem markets as well as a range of green finance mechanisms that provide returns to investors from nature-based solutions.
- The design of a system that blends public funding for peatlands with private payments for ecosystem services, to de-risk and leverage finance to ensure fair access to funding and benefits to local communities.

Each of these policy and governance options need to be considered holistically. Interactions between these options and existing policies, governance, biophysical contexts and local cultures and practices must be taken into account. The analysis of policy options also needs to consider how these interactions may play out across different time and spatial scales, as well as across different social groups. To support these advances in peatland governance, where necessary, the international community should provide financial and technical assistance to countries seeking to develop strategies and policies to conserve, protect, restore and sustainably manage their peatlands, in line with global peatland resolutions and commitments.


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Glossary

A

Adaptation – In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects (IPCC 2018).

Adaptive management - A systematic process for continually improving management policies and practices by learning from the outcomes of previously employed policies and practices. In active adaptive management, management is treated as a deliberate experiment for purposes of learning (Hassan *et al*. 2005a; IPBES 2017).

Afforestation - Planting of new forests on lands that historically have not contained forests (IPCC 2018).

Agrobiodiversity - Agricultural biodiversity includes all components of biological diversity of relevance to food and agriculture, and all components of biological diversity that constitute the agricultural ecosystems, also named agro-ecosystems: the variety and variability of animals, plants and micro- organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agro- ecosystem, its structure and processes (CBD 2000; IPBES 2018a).

Agroecology - The science and practice of applying ecological concepts, principles, and knowledge (i.e., the interactions of, and explanations for, the diversity, abundance, and activities of organisms) to the study, design, and management of sustainable agroecosystems. It includes the roles of human beings as a central organism in agroecology by way of social and economic processes in farming systems. Agroecology examines the roles and interactions among all relevant biophysical, technical and socioeconomic as well as socio-political components of farming systems and their surrounding landscapes. (IPBES 2019a).

B

Before Present - A term used in geological and archaeological dating which refers to the 14C time scale that is in years BP (Before Present, i.e., AD 1950). This time scale needs to be calibrated in order to obtain historical ages (cal AD, cal BC, cal BP) (Mook and van der Plicht 1999).

Biodiversity - The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part. This includes variation in genetic, phenotypic, phylogenetic, and functional attributes, as well as changes in abundance and distribution over time and space within and among species, biological communities, and ecosystems (IPBES 2019a).

Biodiversity offset - A tool proposed by developers and planners for compensating for the loss of biodiversity in one place by biodiversity gains in another (IPBES 2019a).

Biofuel - Liquid, solid, or gaseous fuel produced by conversion of biomass. Examples include bioethanol from sugar cane or corn, charcoal or woodchips, and biogas from anaerobic decomposition of wastes (OECD 2002).

Biome - A set of naturally occurring communities of plants and animals occupying an environmental and/or climatic domain, defined on a global scale. IPBES biomes (e.g., tropical and subtropical forests, shelf ecosystems, inland waters) are broader and more aggregated than many purely biological classification systems. Where biomes are transformed into anthromes, the pre-impact range of the biome may still be relevant for analysis. 'Natural biome' may be used to distinguish from 'anthropogenic biome' or 'anthrome' (IPBES 2019a).

Biotope - Habitat of a community of fauna and flora living in the wild. The term is applied in conservation assessments, and it is regarded as operational synonyms of ecosystem type (Nicholson *et al*. 2009; Riecken *et al*. 2009; Bland *et al*. 2015).

Bog - A type of peatland which is rainwater fed and therefore acidic and nutrient poor (Ramsar Convention on Wetlands 2018a).

Bolster Heath - a specific formation of Tasmanian's alpine vegetation. The different formations of Tasmanian's alpine vegetation are not only largely floristically distinct, but also visually easily perceptible (Kirkpatrick and Bridle 1999).

Buffer zones - Areas between core protected areas and the surrounding landscape or seascape which protect the ecological network from potentially damaging external influences and which are essentially transitional areas (Bennett and Mulongoy 2014; IPBES 2019a).

Buttongrass moorlands (or Tasmanian blanket bogs): a peatland system which are formed under a heathy-sedgeland or sedgeland-heath vegetation. This type of peatlands is unique to Tasmania and have contributed to the listing of the Tasmanian Wilderness World Heritage Area. The buttongrass flora is comprised of 272 vascular species including adventitious species. About 202 species from 50 families are typical of buttongrass moorlands, of which 30% are endemic to Tasmania (Whinam and Hope 2005).

C

Capacity building [*Capacity development*] - The process through which individuals, organisations and societies obtain, strengthen, and maintain their capabilities to set and achieve their own development objectives over time (UNDP n.d.).

Carbon sequestration - The process of storing carbon in a carbon pool (IPCC 2018; IPBES 2019a).

Carbon sink (the same as *sink*) - any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere (IPCC 2018).

Climate change - Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.' The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes (IPCC 2018; IPBES 2019a).

Climate feedback - An interaction mechanism between processes in the climate system is called a climate feedback when the result of an initial process triggers changes in a second process that in turn influences the initial one. A positive feedback intensifies the original process, and a negative feedback reduces it (IPCC 2018). So, in climate change, a feedback loop is the equivalent of a vicious or virtuous circle – something that accelerates or decelerates a warming trend. A positive feedback accelerates a temperature rise, whereas a negative feedback decelerates it (What are climate change feedback loops? 2011).

Climate target - Refers to a temperature limit, concentration level, or emissions reduction goal used towards the aim of avoiding dangerous anthropogenic interference with the climate system. For example, national climate targets may aim to reduce greenhouse gas emissions by a certain amount over a given time horizon, for example those under the Kyoto Protocol (IPCC 2018).

CO_2 equivalent (CO_2e) emission - The amount of carbon dioxide (CO_2) emission that would cause the same integrated radiative forcing or temperature change, over a given time horizon, as an emitted amount of a greenhouse gas (GHG) or a mixture of GHGs (IPCC 2018).

Coastal sand masses - a type of groundwater dependent ecosystems (GDEs). There are two types of coastal sand masses. (1) Coastal sand masses (high dunes), which usually contain one or more unconfined, unconsolidated sedimentary aquifers, where groundwater is stored and transmitted through inter-granular voids between sand particles. These unconsolidated sedimentary aquifers may be perched due to the presence of low permeability layers within the coastal sand mass (e.g., layers of coffee rock or beach rock);

(2) Coastal sand masses (beach ridges), which have developed along the Queensland coastline. They are largely comprised of coastal sands and typically support a single, unconsolidated sedimentary aquifer, where groundwater forms a freshwater lens in the intergranular voids of the coastal sand mass. Perched aquifers may also occur over low permeability layers within the sand mass (Queensland Government 2017a; Queensland Government 2017b).

Co-management - Process of management in which government shares power with resource users, with each given specific rights and responsibilities relating to information and decision-making (OECD 2002; IPBES 2019a).

Community-based monitoring - Processes involving the participation of community members in a range of observation and measurement activities to maintain awareness of ecological and social factors affecting a community (Bliss *et al*. 2001; IPBES 2019a).

Community-based natural resource management - A process by which local groups or communities organize themselves with varying degrees of interaction with state agencies and outside support so as to apply their skills and knowledge to the care of natural resources while satisfying livelihood needs (Pretty and Guijt 1992; IPBES 2019a).

Conference of the Parties (COP) - The supreme body of UN conventions, comprising parties with a right to vote that have ratified or acceded to the convention (IPCC 2018).

Cultivated system - Areas of landscape or seascape actively managed for the production of food, feed, fiber, or biofuels (Hassan *et al*. 2005b).

Cultural values - Shared social values and norms, which are learned and dynamic, and which underpin attitudes and behaviour and how people respond to events and opportunities, and affects the hierarchy of values people assign to objects, knowledge, stories, feelings, other beings, forms of social expressions, and behaviours (IPBES 2019a).

Cushion bogs – non-raised bog communities or cushion plant bogs, dominated by *Donatia fascicularis* and *Astelia pumila*, according with the three main groups of peatlands defined in the classification system of Pisano (Pisano 1977). One of the four groups of peatlands, according with the classification system of Amigo and collaborators (Amigo *et al*. 2017). Cushion bogs are dominated by pulvinate-cushion plant communities, where the water table is near to the surface and several small pools are formed. The dominating plant species (i.e., *Donatia fascicularis* and *Astelia pumila*) are adapted to amphibious life, with highly developed root systems (around 2 m depth), transporting oxygen into the peat layer and creating oxic microzones at the rhizosphere (Fritz *et al*. 2011).

Cushion peatlands - peat-accumulating ecosystems that form on slopes below spring outlets, below groundwater seepages in the lower part of fluvio-glacial debris fans and in shallow valley bottoms, threaded with streams fed from springs along the valley margin. They can also form the vegetation belt along the shores of high-altitude lakes. In the Latin America and the Caribbean region, they are referred to as "bofedales", "oconales", "vegas" or "ciénagas" (Schittek *et al*. 2012).

Cushion plants – a key form of flora which comprise about 338 species within 34 plant families and are widely distributed in polar and alpine regions such as the South American Andes, Rockies, Tibetan Plateau, Alps, Tasmania, New Zealand, and Tierra del Fuego (Arredondo-Núñez *et al*. 2009).

Customary land tenure - The socially-embedded systems and institutions used within communities to regulate and manage land use and access, and which derive from the community itself rather than from the state (IPBES 2019a).

D

Decision-maker - A person whose decisions, and the actions that follow from them, can influence a condition, process, or issue under consideration (Hassan *et al*. 2005b).

Deforestation - Human-induced conversion of forested land to non-forested land. Deforestation can be permanent, when this change is maintained and definitive, or temporary when this change is part of a cycle that includes natural or assisted regeneration (IPBES 2019a).

Degraded lands - Land in a state that results from persistent decline or loss of biodiversity and ecosystem functions and services that cannot fully recover unaided within decadal timescales (IPBES 2019a).

Drivers of Change - Drivers of change refer to all those external factors that affect nature, and consequently, also affect the supply of nature's contributions to people. The IPBES conceptual framework includes drivers of change as two of its main elements: indirect drivers, which are all anthropogenic, and direct drivers, both natural and anthropogenic (IPBES 2019a).

E

Ecological disturbance (natural and anthropogenic) - An event that can disrupt any ecological level, environmental component as well as the organizational status of a biological cycle of organisms. Disturbances are an important aspect in the natural selection and the whole biological evolution, as they modify the environment in which every living being performs its vital functions (Battisti *et al*. 2016; IPBES 2019a).

Ecological Zones (EZ) - A zone or area with broad yet relatively homogeneous natural vegetation formations, similar (not necessarily identical) in physiognomy. Boundaries of the EZs approximately coincide with the map of Köppen-Trewartha climatic types, which was based on temperature and rainfall. An exception to this definition are "Mountain systems", classified as one separate EZ in each Domain and characterized by a high variation in both vegetation formations and climatic conditions caused by large altitude and topographic variation. See also the definition of "Global Ecological Zones (GEZ) Classification System" (FAO 2001).

Ecosystem - A dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit (Convention on Biological Diversity 1992; IPBES 2019a).

Ecosystem degradation - A long-term reduction in an ecosystem's structure, functionality, or capacity to provide benefits to people (IPBES 2019b).

Ecosystem function - The flow of energy and materials through the biotic and abiotic components of an ecosystem. It includes many processes such as biomass production, trophic transfer through plants and animals, nutrient cycling, water dynamics and heat transfer (IPBES 2019a).

Ecosystem integrity - The ability of an ecosystem to support and maintain ecological processes and a diverse community of organisms. It is measured as the degree to which a diverse community of native organisms is maintained, and is used as a proxy for ecological resilience, intended as the capacity of an ecosystem to adapt in the face of stressors, while maintaining the functions of interest (IPBES 2019a).

Ecosystem services - The benefits people obtain from ecosystems. According to the original formulation of the Millennium Ecosystem Assessment (MEA), ecosystem services were divided into supporting, regulating, provisioning and cultural. After the MEA, the Common International Classification for Ecosystem Services (CICES) distinguishes three main categories of ecosystem services: regulating, provisioning and cultural. The "ecosystem services" classification, however, is superseded in IPBES assessments by the system used under "nature's contributions to people". This is because IPBES recognises that many services fit into more than one of the four categories. For example, food is both a provisioning service and, emphatically, a cultural service, in many cultures. See the equivalence of this concept to the concept of nature's contribution to people predominantly used in this assessment (Hassan *et al*. 2005b; IPBES 2019a).

Equity - Fairness of rights, distribution, and access. Depending on context, this can refer to resources, services, or power (Hassan *et al*. 2005b).

Extensification [of agricultural production] - increasing production by extending the area under cultivation while maintaining or reducing aggregate input levels per unit area (Erenstein 2006).

F

Feedback loop – see Climate feedback

Fen - A type of peatland which is additionally to rain water also fed by water that has been in contact with the mineral soil/bedrock and thus generally less acidic and more nutrient-rich than bogs. (Ramsar Convention on Wetlands 2018a).

Floriculture – is a subdiscipline of horticultural sciences, concerning with growing, handling, maintaining and marketing of ornamentals. for gardens and floristry. It includes cut flowers, cut greens, bedding plant, houseplants, flowering garden and potted plants etc (Erenstein 2006; Wani *et al*. 2018).

Forested peatlands – wetland type Xp, which includes peat swamp forests, according with the globally accepted classification system for wetland type established by the Ramsar Convention on Wetlands (Resolution XI.8 Annex 2, Appendix B). Please see also "Ramsar Classification System for Wetland Type" (Ramsar 2014).

G

Global Ecological Zones (GEZ) Classification System - A classification system developed by the Food and Agriculture Organization of the United Nations (FAO) for vegetation formations. These classes with ecological meaning were firstly developed to enable the presentation of some of the FAO forest statistics and maps. The Classification System has been updated for the whole globe (FAO 2012).

Governance -A comprehensive and inclusive concept of the full range of means for deciding, managing, implementing, and monitoring actions and measures, including policies (IPCC 2018; IPBES 2019a). Broadly speaking, 'governance' can be understood as involving those who have the power to make decisions on appropriate actions or rules, how these decisions are made (through specific interactions such as negotiation and deliberation between participating actors), and who is accountable for these actions (Kirschke and Newig, 2017).

Green bonds - A mode of private financing that tap the debt capital market through fixed income instruments (i.e., bonds) to raise capital to finance climate-friendly projects in key sectors of, but not limited to, transport, energy, building and industry, water, agriculture and forestry and waste (OECD 2017; IPBES 2019a).

Greenhouse gases (GHGs) - Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary GHGs in the Earth's atmosphere. Moreover, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol deals with the GHGs sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (IPCC 2018).

Groundwater dependent ecosystems (GDEs) - ecosystems which require access to/ input of groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services (Richardson *et al*. 2011).

H

Habitat fragmentation - The set of processes by which habitat loss results in the division of continuous habitats into a greater number of smaller patches of lesser total and isolated from each other by a matrix of dissimilar habitats. Habitat fragmentation may occur through natural processes (e.g., forest and grassland fires, flooding) and through human activities (forestry, agriculture, urbanization) (IPBES 2019a).

Heat Map – a two-dimensional graphical representations of data where the values of a variable are shown as colors (Jacko 2009).

Hotspot – A general term used across disciplines to describe a region or value that is higher relative to its surroundings (Harris *et al*. 2017).

I

Indigenous and local knowledge (ILK) - The knowledge, practices and innovations embedded in the relationships of Indigenous Peoples and Local Communities to nature. ILK is situated in a place and social context, but at the same time open and hybrid, continuously evolving through the combination of written, oral, tacit, practical, and scientific knowledge attained from various sources, and validated by experimentation and in practice of direct interaction with nature (IPBES 2019a).

Indigenous and local knowledge (ILK) systems - Social and ecological knowledge practices and beliefs pertaining to the relationship of living beings, including people, with one another and with their environments. Such knowledge can provide information, methods, theory and practice for sustainable ecosystem management (IPBES 2019a).

Indigenous Peoples and Local Communities (IPLCs) - The Convention on Biological Diversity does not define the terms indigenous and local communities or Indigenous Peoples and Local Communities. The United Nations Declaration on the Rights of Indigenous Peoples does not adopt or recommend a universal definition for Indigenous Peoples (Decision CBD/COP/DEC/14/13).

As used in the global assessment, Indigenous Peoples and Local Communities (IPLCs) is a term used internationally by representatives, organizations, and conventions to refer to individuals and communities who are, on the one hand, self-identified as indigenous and, on the other hand, are members of local communities that maintain inter- generational connection to place and nature through livelihood, cultural identity and worldviews, institutions and ecological knowledge. The term is not intended to ignore differences and diversity within and among Indigenous Peoples and between them and local communities; Indigenous Peoples have recognized and distinct rights, which are not extendable to the broader and encompassing concept of local communities (IPBES 2019a).

Insetting - Interventions by a company in or along their value chain that are designed to generate GHG emissions reductions or carbon removals, and at the same time create positive impacts for communities, landscapes and ecosystems (International Platform for Insetting 2022).

Institutions - Institutions encompass formal and informal rules and norms that structure individual and collective behaviour, including interactions among stakeholders and social structures that help to define how decisions are taken and implemented, how power is exercised, and how responsibilities are distributed (IPBES 2019a).

Intensification [of agricultural production] - increasing production per unit area through more intensive production practices. It thereby encompasses two distinct forms – land-use intensification (i.e., increasing the frequency of cropping per unit area) and technological intensification (i.e., increasing capital and/or labour input use per crop per unit area) (Erenstein 2006).

Invasive alien species - are plants, animals, pathogens and other organisms that are non-native to an ecosystem, and which may cause economic or environmental harm or adversely affect human health. In particular, they impact adversely upon biodiversity, including decline or elimination of native species - through competition, predation, or transmission of pathogens - and the disruption of local ecosystems and ecosystem functions (Convention on Biological Diversity n.d.).

K

Kernel Density - Calculates a magnitude-per-unit area from point or polyline features using a kernel function to fit a smoothly tapered surface to each point or polyline (Silverman 1998).

L

Land - terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system (UNCCD 2011; FAO and ITPS 2015).

Land cover - The physical coverage of land, usually expressed in terms of vegetation cover or lack of it. Related to, but not synonymous with, land use (Hassan *et al*. 2005b).

Land use - The human use of a piece of land for a certain purpose (such as irrigated agriculture or recreation). Influenced by, but not synonymous with, land cover (Hassan *et al*. 2005b).

Land Use, Land Use Change and Forestry (LULUCF) - In the context of national greenhouse gas (GHG) inventories under the UNFCCC, LULUCF is a GHG inventory sector that covers anthropogenic emissions and removals of GHG from carbon pools in managed lands, excluding non-CO_2 agricultural emissions. Following the 2006 IPCC Guidelines for National GHG Inventories, 'anthropogenic' land-related GHG fluxes are defined as all those occurring on 'managed land', i.e., 'where human interventions and practices have been applied to perform production, ecological or social functions'. Since managed land may include CO_2 removals not considered as direct human-induced in some of the scientific literature assessed in this report (e.g., removals associated with CO_2 fertilization and N deposition), the land-related net GHG emission estimates included in IPCC reports are not necessarily directly comparable with LULUCF estimates in National GHG Inventories (IPCC 2018).

Lifeway - term used to suggest the close interaction of worldview and economy in small-scale societies (Oxford English Dictionary [OED] Online 2022).

Living things - animals, plants, society etc. in the vision of the Aboriginal people (Aikenhead and Ogawa, 2007).

M

Material Nature's Contributions to People [correspondence with the provisioning ecosystem services] - Material contributions are substances, objects, or other material elements from nature that directly sustain people's physical existence and material assets. They are typically physically consumed in the process of being experienced—for example, when organisms are transformed into food, energy, or materials for ornamental purposes (Díaz *et al*. 2018; IPBES n.d.).

Megaherbs – Herbaceous perennial forbs with large growth forms (often more than 1 metre high or wide), with large leaves and very colourful floral displays. The megaherb species belong to the genera *Pleurophyllum* (Asteraceae), *Anisotome* (Apiaceae), *Bulbinella* (Liliaceae) and *Stilbocarpa* (Araliaceae) (Hooker 1984; Nicholls and Rapson 1999).

Mire - A peatland with active peat accumulation (Ramsar Convention on Wetlands 2018a).

Mitigation (to climate change) - A human intervention to reduce emissions or enhance the sinks of greenhouse gases (IPCC 2018).

Monoculture - The agricultural practice of cultivating a single crop over a whole farm or area (Zaid 2001; IPBES 2019a).

Moorland - is a unique vegetation type dominated by a hummock forming, tussock Cyperaceous sedge, *Gymnoschoenus sphaerocephalus*. The presence of this species, or the *Restionaceous* species with which it typically associates, defines this vegetation. It is highly variable in structure, ranging from low closed sedgeland, through heathland, and low open scrub to open woodland (Jarman *et al*. 1998).

Moss peat banks – characteristic banks of peat in the Antarctic formed by two species of moss, namely ved, *Polytrichum alpestre* Hoppe and *Chorisodontium aciphyllum* (Hook. f. et Wils.) Brot. Besides being formed by only two moss species, other characteristics are: i) no vascular plants are present, ii) *Polytrichum alpestre* produces clearly demarcated annual growth segments and productivity is easily measured, iii) visible structure is retained at all depths in the peat, and so compressive processes can be observed and measured, iv) the effect of animals in or above the peat is negligible, v) the peat is not waterlogged and there is no anaerobic layer, vi) 20-30 cm below the surface the peat becomes permanently (Fenton 1980).

N

Natural capital - A concept referring to the stock of renewable and non-renewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people (UNDP 2016; IPBES 2019a). It also includes ecosystems, which contribute to the generation of goods and services of value for people (Guerry *et al*. 2015). Within the IPBES conceptual framework, it is part of the "nature" category, representing an economic-utilitarian perspective on nature, specifically those aspects of nature that people use (or anticipate to use) as source of NCP.

Natural capital accounts - A set of objective data on the stocks of natural resources (including ecosystems), how they contribute to the economy (e.g., via the supply of ecosystem services) and how the economy affects natural resources compiled on a regular and consistent basis (Vardon *et al*. 2017).

Nature-based solutions - actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits (United Nations Environment Programme 2022).

Nature's contributions to people (NCP) - The contributions, both positive and negative, of living nature (i.e., all organisms, ecosystems, and their associated ecological and evolutionary processes) to people's quality of life. Beneficial contributions include e.g., food provision, water purification, flood control, and artistic inspiration, whereas detrimental contributions include e.g., disease transmission and predation that damages people or their assets (Díaz *et al*. 2018; IPBES n.d.).

Net zero - Cutting greenhouse gas emissions to as close to zero as possible, with any remaining emissions reabsorbed from the atmosphere, by oceans and forests for instance (United Nations n.d.).

Net zero emissions - Net zero emissions are achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period. Where multiple greenhouse gases are involved, the quantification of net zero emissions depends on the climate metric chosen to compare emissions of different gases (such as global warming potential, global temperature change potential, and others, as well as the chosen time horizon). See also Net zero CO_2 emissions, Negative emissions and Net negative emissions. (IPCC 2018).

Non-forested peatlands – wetland type U, which includes shrub or open bogs, swamps and fens, according with the globally accepted classification system for wetland type established by the Ramsar Convention on Wetlands (Resolution XI.8 Annex 2, Appendix B). Please see also "Ramsar Classification System for Wetland Type" (Ramsar 2014).

Non-Material Nature's Contributions to People [correspondence with the cultural ecosystem services] - Nonmaterial contributions are nature's effects on subjective or psychological aspects underpinning people's quality of life, both individually and collectively. Examples include forests and coral reefs providing opportunities for recreation and inspiration, or particular animals and plants being the basis of spiritual or social-cohesion experiences (Díaz *et al*. 2018; IPBES n.d.).

Non-timber forest products (NTFPs) - Any biological resources found in forests other than timber, including fruits, fuel wood and small wood, nuts, seeds, oils, foliage, game animals, berries, medicinal plants, fish, spices, barks, and mushrooms, among others (Prasad 1993; IPBES 2019a).

O

Ombrogenous peatland – Peatland that receives nutrients and water only from the atmosphere. Also called ombrotrophic (Parish *et al*. 2008).

P

Paludiculture - The cultivation of biomass on wet and rewetted peatlands, so that subsidence is stopped and greenhouse gas emisisons minimized [definition informed by the one appearing in the *Ramsar COP13 Resolution XIII.12. (2018) Guidance on identifying peatlands as Wetlands of International Importance (Ramsar Sites) for global climate change regulation as an additional argument to existing Ramsar criteria]* (Ramsar Convention on Wetlands 2018b).

Participatory methods - Participatory research methods are a variety of qualitative and quantitative methods geared towards planning and conducting the research process with those people whose life-world and meaningful actions are under study (Bergold and Thomas 2012; IPBES 2019a).

Participatory process - Specific methods employed to achieve active participation by all members of a group in a decision-making process (Chatty *et al*. 2003; IPBES 2019a).

Palsas - peaty permafrost mounds containing a core of alternating layers of segregated ice and peat or mineral soil material (French 1996).

Peat - consists of dead, partly decomposed plant remains (but still macroscopically recognizable) that have accumulated and have been conserved on the spot where they have been produced (in-situ). Peat forms in waterlogged areas where microbial decomposition of the dead organic matter is slowed by anoxic conditions or very low temperatures *[definition informed by the one appearing in the Ramsar COP13 Resolution XIII.12. (2018) Guidance on identifying peatlands as Wetlands of International Importance (Ramsar Sites) for global climate change regulation as an additional argument to existing Ramsar criteria]* (Ramsar Convention on Wetlands 2018b).

Peat banks (also described as moss peat banks) – specific form of peat accumulation in the maritime Antarctic and South Georgia (Collins 1976a; Collins 1976b; Lewis-Smith 1981; Fenton and Lewis-Smith 1982; Birkenmajer *et al*. 1985; Fabiszewski and Wojtun 1993; Fabiszewski and Wojtun 1997). In the maritime Antarctic region these peat "banks" formed by one or both of the tall turf-forming mosses *Chorisodontium aciphyllum* (Hook. f. et Wils.) Broth. and Polytrichum alpestre Hoppe are a unique feature of the vegetation (Smith 1972; Fenton 1982).

Peat sequences – peat samples that can provide evidence of high-resolution paleoclimatic fluctuations as well as paleobotanical evolution through periods of peat-formation. They are investigated in sedimentological, sequence stratigraphic and petrographic analyses to understand the evolution of their peat forming environments (Guo *et al*. 2018).

Peatland - Land with a naturally accumulated layer of peat at the surface. Peatlands include both ecosystems that are actively accumulating peat and degraded peatlands that are losing peat (convention on wetlands 2018b). The threshold for the depth of peat that constitutes peat soil varies by country (Intergovernmental Panel on Climate Change 2014).

Permafrost - Ground (soil or rock and included ice and organic material) that remains at or below 0°C for at least two consecutive years (Pachauri and Mayer 2015; IPBES 2019a).

Poldering – the activity of creating polders (please see polders).

Polder - a low-lying tract of land that forms an artificial hydrological entity, enclosed by embankments known as dikes (Natural Water Retention Measures [NWRM] Project 2013).

Polygonal tundra - a primary landscape type in Arctic systems consisting of ice-wedge polygons that form when freeze-thaw cycles physically move the soil (Walker 2000; Farquharson *et al*. 2016; Lara *et al*. 2018).

Protected area - A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated values to people. There are multiple categories of protected areas, including and excluding people from within its boundaries (IPBES 2019a).

Q

Quaking bog – Mire in which the peat layer and plant cover are only partially attached to the basin bottom or floating like a raft. Also called quagmire, quaking mat, floating mat, Schwingmoor (Parish *et al*. 2008).

R

Ramsar Classification System for Wetland Type - A globally accepted classification system for wetland type established by the Ramsar Convention on Wetlands (Resolution XI.8 Annex 2, Appendix B). This classification system proposes four Inland Wetland categories encompassing peatlands: U – Non-forested peatlands; includes shrub or open bogs, swamps and fens; Va – Alpine wetlands; includes peat-forming alpine meadows waterlogged soils; Vt – Tundra wetlands; includes peat-forming tundra meadows with waterlogged soils; and Xp – Forested peatlands; includes peat swamp forests (Ramsar 2014).

Rare – a species is considered rare when it has small populations that are not at present "endangered" or "vulnerable" but are at risk. Usually, a rare species is located within restricted geographical areas or habitats or are thinly scattered over a more extensive range (IUCN 1990).

REDD+ (Reducing emissions from deforestation and forest degradation and conservation, sustainable management of forests and enhancement of forest carbon stocks) - Mechanism developed by Parties to the United Nations Framework Convention on Climate Change (UNFCCC), which creates a financial value for the carbon stored in forests by offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. Developing countries would receive results-based payments for results-based actions. REDD+ goes beyond simply deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (IPBES 2019a).

Reforestation - Planting of forests on lands that have previously contained forests but that have been converted to some other use (IPCC 2018).

Regulating Nature's Contributions to People [correspondence with the regulating ecosystem services] - Regulating contributions are functional and structural aspects of organisms and ecosystems that modify environmental conditions experienced by people and/or regulate the generation of material and nonmaterial contributions. Regulating contributions frequently affect quality of life in indirect ways. For example, people directly enjoy useful or beautiful plants but only indirectly benefit from the soil organisms that are essential for the supply of nutrients to such plants (Díaz *et al*. 2018; IPBES n.d.).

Reprofiling – a term applied in the context of restoration. Reprofile the topography is usually needed in peripheral remnant peatlands to make them more amenable to restoration: by cutting the steep slopes along the edges of remnant peatlands and using this peat to backfill the edges of extracted surfaces and create a uniform gradual slope *(Line Rocheford, personal communication)*.

Restoration (Ecosystem restoration) - the process of halting and reversing degradation, resulting in improved ecosystem services and recovered biodiversity. Ecosystem restoration encompasses a wide continuum of practices, depending on local conditions and societal choice (UNEP 2021).

S

Seismic lines - narrow linear clearings created during hydrocarbon exploration which are a common feature in the hydrocarbon-rich boreal and tundra ecosystems (Dabros *et al*. 2018).

Social norms - a social norm is what people in a group generally agree as shared expectations guiding individual and collective behaviour and action, that is, believed to be a typical action, an appropriate action, or both, and without necessarily representing a formal rule (Mackie *et al*. 2015; IPBES 2019a).

Soil - the upper layer of the Earth's crust transformed by weathering and physical/chemical and biological processes. It is composed of mineral particles, organic matter, water, air and living organisms organized in genetic soil horizons (International Organization for Standardization 2013; FAO and ITPS 2015).

Soil organic carbon (SOC) - a summarizing parameter including all of the carbon forms for dissolved (DOC: Dissolved Organic Carbon) and total organic compounds (TOC: Total Organic Carbon) in soils (International Organization for Standardization 2013; FAO and ITPS 2015).

Soil organic matter (SOM) - matter consisting of plant and/or animal organic materials, and the conversion products of those materials in soils (ISO< 2013) (International Organization for Standardization [IOS] 2013; FAO and ITPS 2015).

***Sphagnum* farming** – is the cultivation of *Sphagnum* mosses to produce biomass of non-decomposed *Sphagnum* fibers on a cyclic and renewable basis (Pouliot *et al*. 2015).

Sustainability - a characteristic or state whereby the needs of the present and local human population can be met without compromising the ability of future generations or populations in other locations to meet their needs (Chopra *et al*. 2005; IPBES 2019a).

Sustainable intensification - to produce more products from the same region while saving resources, reducing negative impacts on the environment, enhancing natural capital and ecosystem services flows (FAO, 2011).

Sustainable use (of biodiversity and its components) - the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations (Convention on Biological Diversity 1992; IPBES 2019a).

T

Tepuis – table-top type mountains in South America (Rieley and Page 2016).

Thermokarst - distinctive depressions in the landscape formed by the thawing of ice-rich permafrost or the melting of ground ice leads when temperatures rise (UNEP, 2019).

Treed peatland – under Canadian classification, there are three tree cover types for wetlands. Open peatlands are dominated by shrub or sedge and can have up to 10% tree cover. Treed peatlands are dominated by small trees with 10-25% cover, and forested peatlands are sites with large trees with over 25% cover (Bona *et al*. 2020).

W

Watershed - the land area that drains into a particular watercourse or body of water. Sometimes used to describe the dividing line of high ground between two catchment basins (Hassan *et al*. 2005b).

Well-being (Human) - a perspective on a good life that comprises access to basic resources, freedom and choice, health and physical, including psychological, well-being, good social relationships, security, equity, peace of mind and spiritual experience. Well-being is achieved when individuals and communities can act meaningfully to pursue their goals and can enjoy a good quality of life. The concept of human well-being is used by many countries and societies. In the context of IPBES' conceptual framework, it is used complementary and together with living in harmony with nature, and living well in balance and harmony with Mother Earth. All these are different perspectives on a good quality of life (IPBES 2019a).

Wet Heathland (Wet Heath) - a type of lowland heathland, usually waterlogged. In Europe wet heaths are a habitat of Atlantic and sub-Atlantic lowlands and foothills, with typical nutrient-poor peats and peaty mineral soils (European Environment Agency n.d.). In Australia the term is used to describe coastal and sub-coastal swamps with low-nutrient soils (Barry 2010).

Wetland - area of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres (Ramsar 2014).

Wetlands of International Importance (also referred to as Ramsar Sites) – wetlands that have been designated under the criteria of the Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Convention on Wetlands, also referred to as the Ramsar Convention on Wetlands) as sites important for the conservation of global biological diversity and for sustaining human life through the maintenance of their ecosystem components, processes and benefits/services. Once designated, these sites are added to the Convention's List of Wetlands of International Importance (Ramsar 2014; Ramsar Convention on Wetlands, 2012).

Acronyms

LIST OF ACRONYMS

C	Carbon
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CH_4	Methane
CO_2	carbon dioxide
COP	Conference of Parties
CSPMA	Canadian Sphagnum Peat Moss Association
DEM	Digital Elevation Models
DRC	Democratic Republic of the Congo
ENTC	Eswatini National Trust Commission
EO	Earth Observation
ES	Ecosystem Services
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GBR	United Kingdom of Great Britain and Northern Ireland
GEC	Global Environment Centre
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GMC	Greifswald Mire Centre
GPA	Global Peatlands Assessment
GPD	Global Peatlands Database
GPI	Global Peatlands Initiative
HBL	Hudson Bay Lowland (Canada)
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCA	Indigenous Protected and Conserved Areas
IPCC	Intergovernmental Panel on Climate change
IPLC	Indigenous Peoples and Local Communities
IUCN	International Union for Conservation of Nature
LAC	Latin America and Caribbean
LULUCF	Land Use, Land Use Change and Forestry
MINAM	Ministry of Environment (Peru) [From the Spanish *Ministerio del Ambiente – Gobierno del Perú*]
MLTT	Moss Layer Transfer Technique
MSF	Michael Succow Foundation
MW	Megawatt
N_2O	Nitrous oxide
NBI	Nile Basin Initiative
NbS	Nature-based Solutions
NCP	Nature's Contributions to People
NDC	Nationally Determined Contribution
NRI	Natural Resources Institute
PHU	Peatland Hydrological Unit
PICTs	Pacific Island Countries and Territories
PNG	Papua New Guinea
REDD+	Reducing Emissions from Deforestation and Degradation (the "+" signifies the role of conservation, sustainable management of forests and enhancement of forest carbon stocks)
SAGD	Steam-Assisted Gravity Drainage
SEA	Southeast Asian
SIDA	Swedish International Development Cooperation Agency
SOC	Soil Organic Carbon
SPM	Summary for Policy Makers
SRUC	Scotland's Rural College
TDF	Tierra del Fuego
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
UNEP-WCMC	United Nations Environment Programme World Conservation Monitoring Centre
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
VCM	Voluntary Carbon Market
WCS	Wildlife Conservation Society
WI	Wetlands International
WRI	World Resources Institute

Annexes

Annexes

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Annex I. Procedural and Conceptual Aspects of this Assessment

This assessment followed where possible the conceptual and procedural aspects developed by the IPBES to guide the production of both global and regional assessments (IPBES 2018).

I.1. Procedural Aspects

At the first stage (i.e., Preparatory stage) the scope for the assessment was defined, partnerships for its coordination and support identified, a GPA Development Team was structured (Box 1– *Who is Who in the GPA*) and a concept note was approved by the GPI's Steering Committee in February 2021 and presented to the public at the Global Peatland Pavilion[1] during the UNFCCC COP26 (November 2021).

The second stage (i.e., Assessment stage) involved the author nomination process throughout 2021 and the development of the assessment throughout the last quarter of 2021 and the first three quarters of 2022. An open call for researchers was issued and all GPI partners were invited to nominate experts, describing how their knowledge was relevant to the assessment. A group of thirty Coordinating Lead Authors were selected by the GPA Development Team with oversight by UNEP and the GPI Steering Committee by considering several criteria (gender balance, appropriate representation of experts from the different United Nations regions, and extensive coverage of different peatlands' expertise areas). After Coordinating Lead Authors were formally invited to join the GPA, the assessment work by experts was guided by three author meetings and involved different review periods. It involved an iterative and collective expert evaluation of the peatlands' state of knowledge, which has entailed the preparation and review of the successive draft chapters of the report. A call for experts and parties' focal points to provide an update on both spatial data and policy progress related to peatlands was issued by UNEP to the GPI partners and through the GPA Development Team as well as by the Ramsar Secretariat directly to their parties.

In the first author meeting, held in September 2021 in an online format, Coordinating Lead Authors have worked to agree on the assessment process, sources of information, overall outline, and collaborative work procedures. The selection of Contributing Authors was through the last quarter of 2021 and the first quarter of 2022. A first-order draft of the main report has been produced throughout the second quarter of 2022 and a group of external reviewers selected by the GPA Development Team proceeded to review the chapters. The Second Authors' Meeting to plan the development of the report's second-order draft took place in June 2022 in hybrid format. The second-order draft of the main report was produced by August. The selected external reviewers worked at the same time that the GPA Development Team was reviewing. In parallel there was an open peer review process available (in August) for external contributions to the full second-order draft. The Third Authors' Meeting took place end of August 2022 to prepare the third-order draft delivered in September 2022. The report's final draft was then reviewed and edited by a selected team of expert overall review editors, a professional senior editor, and by some members of the GPA Development Team. The Summary for Policy Makers was developed by a working group. This working group included some review editors and a professional senior editor.

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[1] The Global Peatland Map version 2.0 was launched during the same session, improving the base knowledge on the extent of peatlands.

Box I.1. Who is Who in the GPA

A total of 226 experts (44% women; 56% men) coming from 51 different countries were involved in the development of the GPA, including the ones responsible for developing the assessment (authors), those who were part of the GPA's coordination, support and overseeing structures and all the other experts involved in the assessment either as external reviewers, overall review editors, a professional editor or information providers.

Structure's name	Responsible(s)	Role
Scientific Advisory Group (GPI-SAG)	Global Experts	Oversees and reviews with respect to the scientific and technical aspects
GPI Steering Committee (GPI-SC)	UNEP, FAO, GMC, IPS, Indonesian Government	Approves the process and nominees involved in the assessment ensuring the production of a high-quality assessment that is policy relevant
GPA Development Team	UNEP, FAO, GMC, Ramsar Sec, UNEP-WCMC	Gives direction for the GPA development process ensuring the production of a high-quality assessment
GPA Coordination Team	UNEP-WCMC & UNEP	Coordinates the assessment on behalf of the GPI to ensure inclusion and timely delivery
GPI Research Working Group Secretariat	Researchers & UNEP	Provides scientific support (when requested) to the authors for developing the assessment
GPI Coordinator	UNEP	Provides overall leadership, direction, reviews and approves the GPA ensuring high-quality
Authors, reviewers, review editors and information providers		

The different chapter drafts were developed by Coordinating Lead Authors and their teams of Contributing Authors. Selected External Reviewers were involved in the revision of drafts 1 and 2 whereas overall Review Editors were involved in the revision of draft 3, alongside with the Scientific Advisory Group members and UNEP. A selected team of Review Editors worked together to write the SPM which was reviewed by some GPA Development Team members, interested Coordinating Lead Authors, Scientific Advisory Group members and UNEP. A professional senior editor edited all chapters of the GPA and the SPM. Several researchers, government representatives and other stakeholders were involved in the GPA as information providers.

Production of maps under the assessment

The GMC was responsible for the production of maps for the assessment. Annex III details the methods used.

The third stage (i.e., Approval stage) involved the submission of a full draft of the report for review and approval by GPI Scientific Advisory Group members and following UNEP's publishing review process. The final draft has reflected all the comments made during both the internal and external peer review processes.

The fourth stage – Outreach stage – involves the communication of the key findings and messages to the different stakeholders.

The selected group of experts has critically evaluated the knowledge available on peatlands (including peer-reviewed scientific literature, grey literature, and knowledge coming from other knowledge systems) and synthesized the best knowledge in this assessment, as well as its gaps. This assessment, per definition, did not undertake new primary research but has involved a re-analysis of existing spatial data to bring the best information for peatlands' extent, state, values, threats, and policy options at both regional and global levels (more details on the production of maps for this assessment can be found in Annex III).

I.2. Conceptual Aspects

I.2.1. The Conceptual Framework

The conceptual framework that has guided this assessment is the one from IPBES outlining the interaction between people and nature. Six interconnected elements operating at various scales in time and space are considered (Fig. I.1):

- Nature (biodiversity and ecosystems) *(other knowledge systems include "living in harmony with nature" and "Mother Earth", among others).*
- Nature's contributions to people (refers to all the contributions that humanity obtains from nature; ecosystem services are included in this category, but also aspects of nature that can be negative to people, such as pests, pathogens or predators) *(other knowledge systems include "nature's gifts" and similar concepts).*
- Anthropogenic assets;
- Institutions and governance systems and other indirect drivers of change;
- Direct drivers of change; and
- Good quality of life (human well-being) *(other knowledge systems include "living in harmony with nature" and "living well in balance with Mother Earth").*

The concept of nature's contributions to people (NCP) is central in this conceptual framework, recognizing the inescapable role that culture plays in defining all links between people and nature, emphasizing the role of indigenous and local knowledge and fully recognizing that a diversity of views on the way humans and nature relationships are perceived exist (Díaz *et al.* 2018; IPBES n.d.). In the description of peatlands' contributions to people, the authors have followed the three main groups of NCP: regulating (corresponding to the regulating ecosystem services), material (corresponding to the provisioning ecosystem services), and non-material (corresponding to the cultural ecosystem services) (Díaz *et al.* 2018; IPBES n.d.).

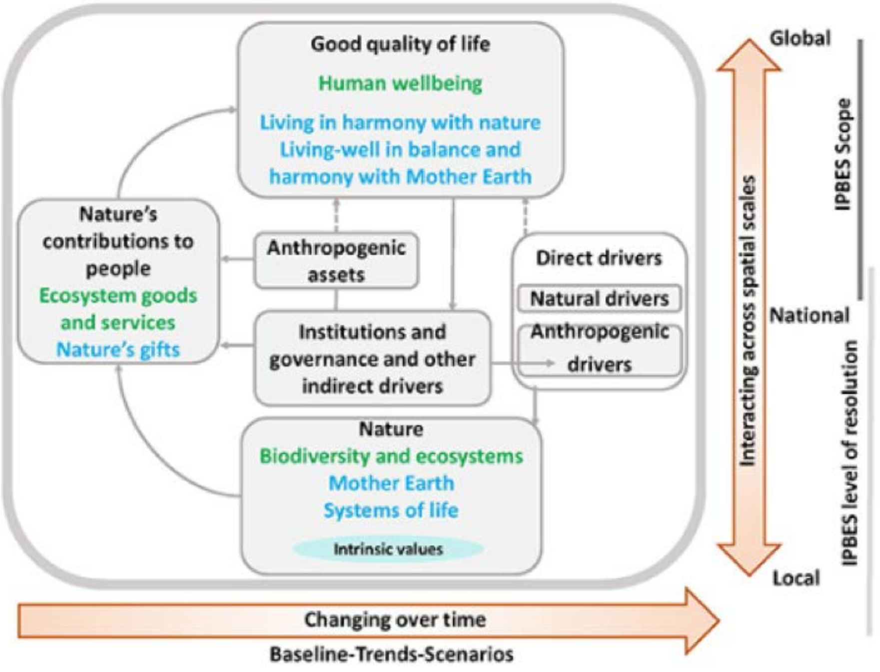

Figure I.1. Analytical conceptual framework considered in the IPBES assessments (adapted for the GPA) considering the main elements and relationships for the conservation and sustainable use of biodiversity and NCP, human well-being and sustainable development ("nature", "nature's contributions to people" and "good quality of life" - indicated as black headlines - are inclusive of all world views; text in ***green*** *denotes the concepts of science; and text in* ***blue*** *denotes those of other knowledge systems).*
Sources: Díaz et al. 2018; IPBES n.d.

Understanding the Concepts of Governance and Management

When discussing governance and management it is helpful to clarify these terms and how they relate to each other. Broadly speaking, 'governance' can be understood as involving those who have the power to make decisions on appropriate actions or rules, how these decisions are made (through specific interactions such as negotiation and deliberation between participating actors), and who is accountable for these actions (Kirschke and Newig 2017). Governance therefore serves as an 'organising framework' that can include different forms of coordination (Kirschke and Newig 2017). Governance thinking is widely understood to encapsulate transition from 'government' – or state as the center of all decision-making processes, to the process of interactions between state and other actors, and on mechanisms and solutions outside government (Kooiman 1993; Young 2005; Armitage *et al.* 2012).

Some features which are common to the varied definitions of governance are involvement of different actors, processes, structures and institutions in political decision-making and implementation (Treib *et al.* 2007; Driessen *et al.* 2012) and as social function centred on steering human groups towards desirable outcomes and away from undesirable outcomes (Young 2013). The notion of governance also to some extent has a normative dimension, especially given the assumption that good governance is important for quality of life of citizens, and important for the success of states, civil society, corporates and other entities in their functioning (Fennell *et al.* 2008; Peters 2012). In contrast, 'management' involves actions taken to complete objectives decided by those setting the agenda – which may or may not include all relevant stakeholders (Rights and Resources Initiative Norway 2022). Certain governance approaches can therefore facilitate or undermine effective environmental management (Bennett 2015).

Several categorizations of governance modes have been suggested, differentiated in terms of idealized forms (hierarchies, markets and networks (Thompson 2003), locus on state intervention to societal autonomy continuum (Treib *et al.* 2007), or on the role of governmental and non-governmental actors occurring in combinations of hierarchical, self and co-governance modes (Kooiman 2000). The interactive governance perspective focuses on interactions between governance actors (social agencies possessing agency or power of action) and structures (frameworks within which actors operate), as key determinants of governability (overall capacity of governance) of the social entity or system (Kooiman *et al.* 2008). Values, together with images and principles form the deep-ingrained 'meta-level' governance elements of those involved in governing, and explain much of differences in governance outcomes, especially their capability to deal with 'wicked problems' (Kooiman and Jentoft 2009; Meuleman 2019) while navigating towards just and sustainable futures. Value choices regarding the nature of society we live in and want to leave for posterity are the linchpins of societal steering decisions, navigating within the realm of fragmented power across many actors and societal subsystems (Meadowcroft 2007).

Annex II. Delineation of Regions and Cross-boundary Issues

The geographic division followed by the GPA is the United Nations M49 standard, available at: https://unstats.un.org/unsd/methodology/m49/

Table II.1 presents the division of countries per region according to the standard. The Antarctica region was the exception, being described in the Oceania chapter.

The biogeographical characteristics of peatlands were considered in both the global and regional maps.

Region	Sub-region	Countries		
Africa	Northern Africa	Algeria Egypt Libya	Morocco Sudan Tunisia	Western Sahara
Africa	Eastern Africa	British Indian Ocean Territory Burundi Comoros Djibouti Eritrea Ethiopia French Southern Territories	Kenya Madagascar Malawi Mauritius Mayotte Mozambique Réunion Rwanda Seychelles	Somalia South Sudan Uganda United Republic of Tanzania Zambia Zimbabwe
Africa	Middle Africa	Angola Cameroon Central African Rep. Chad	Democratic Rep. of the Congo Equatorial Guinea Gabon	Rep. of the Congo Sao Tome and Principe
Africa	Southern Africa	Botswana Eswatini	Lesotho Namibia	South Africa
Africa	Western Africa	Benin Burkina Faso Cabo Verde Côte d'Ivoire Gambia Ghana	Guinea Guinea-Bissau Liberia Mali Mauritania Niger	Nigeria Saint Helena Senegal Sierra Leone Togo
Americas: Latin America and the Caribbean	Caribbean	Anguilla Antigua and Barbuda Aruba Bahamas Barbados Bonaire, Sint Eustatius and Saba British Virgin Islands Cayman Islands Cuba Curaçao Dominica	Dominican Republic Grenada Guadeloupe Haiti Jamaica Martinique Montserrat Puerto Rico Saint Barthélemy Saint Kitts and Nevis Saint Lucia	Saint Martin (French Part) Saint Vincent and the Grenadines Sint Maarten (Dutch part) Trinidad and Tobago Turks and Caicos Islands United States Virgin Islands
Americas: Latin America and the Caribbean	Central America	Belize Costa Rica El Salvador Guatemala Honduras	Mexico Nicaragua Panama	20
Americas: Latin America and the Caribbean	South America	Argentina Bolivia (Plurinational State of) Bouvet Island Brazil Chile Colombia	Ecuador Falkland Islands (Malvinas) French Guiana Guyana Paraguay Peru	South Georgia and the South Sandwich Islands Suriname Uruguay Venezuela (Bolivarian Republic of)

Region	Sub-region	Countries		
Americas	Northern America	United States of America Canada	Greenland Bermuda	Saint Pierre and Miquelon
Americas		Antarctica (*)		
Asia	Central Asia	Kazakhstan Kyrgyzstan	Tajikistan Turkmenistan	Uzbekistan
Asia	Eastern Asia	China China, Hong Kong Spec. Admin. Region China, Macao Spec. Admin. Region	Dem. People's Rep. of Korea Japan Mongolia Republic of Korea	
Asia	Southeast Asia	Brunei Darussalam Cambodia Indonesia Lao People's	Democratic Republic Malaysia Myanmar Philippines	Singapore Thailand Timor-Leste Viet Nam
Asia	Southern Asia	Afghanistan Bangladesh Bhutan India	Iran (Islamic Republic of) Maldives Nepal	Pakistan Sri Lanka
Asia	Western Asia	Armenia Azerbaijan Bahrain Cyprus Georgia Iraq Israel	Jordan Kuwait Lebanon Oman Qatar Saudi Arabia State of Palestine	Syrian Arab Republic Türkiye United Arab Emirates Yemen
Europe	Eastern Europe	Belarus Bulgaria Czechia Hungary	Poland Republic of Moldova Romania Russian Federation	Slovakia Ukraine
Europe	Northern Europe	Åland Islands Channel Islands (Guernsey, Jersey, Sark) Denmark Estonia Faroe Islands	Finland Iceland Ireland Isle of Man Latvia Lithuania Norway	Svalbard and Jan Mayen Islands Sweden United Kingdom of Great Britain and Northern Ireland
Europe	Southern Europe	Albania Andorra Bosnia and Herzegovina Croatia Gibraltar	Greece Holy See Italy Malta Montenegro North Macedonia	Portugal San Marino Serbia Slovenia Spain
Europe	Western Europe	Austria Belgium France	Germany Liechtenstein Luxembourg	Germany Liechtenstein Luxembourg
Oceania	Australia and New Zealand	Australia Christmas Island Cocos (Keeling) Islands	Australia Christmas Island Cocos (Keeling) Islands	
Oceania	Melanesia	Fiji New Caledonia Papua New Guinea	(Federated States of) Nauru Northern Mariana Islands	Palau United States Minor Outlying Islands
Oceania	Micronesia	Guam Kiribati Marshall Islands Micronesia	20	20
Oceania	Polynesia	American Samoa Cook Islands French Polynesia Niue	Pitcairn Samoa Tokelau Tonga	Tuvalu Wallis and Futuna Islands

(*) described in the Oceania chapter

Ecological Zones

For describing the ecological zones, the GPA has used FAO's Global Ecological Zones (GEZ)[2] as a reference.

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[2] https://data.apps.fao.org/map/catalog/srv/api/records/2fb209d0-fd34-4e5e-a3d8a13c241eb61b/attachments/ecozones2010_1.jpg

Annex III. Production of the Global Peatland Map 2.0

Procedures of assessing and integrating external peatland GIS data in the GPM2.0, and the development of additional GIS-data at Greifswald Mire Centre to fill coverage gaps are outlined in the work flow below (Fig. III.1). First step has always been a comprehensive assessment of regionally/ nationally available peat and proxy data to scope for location and distribution of peatlands in a specific region.

Data that have not be produced at the Greifswald Mire Centre, but accessed from a variety of sources (Table III.2. below) we refer to as ‘external data’. For industrial countries with longer history of land and soil assessment, external data with regular national coverage in GIS format could often be requested from administrative bodies. In many other countries, external data have been gathered in digital and analogue form from peatland and soil research, or from research related to peatland proxies like wetlands, vegetation, or land systems.

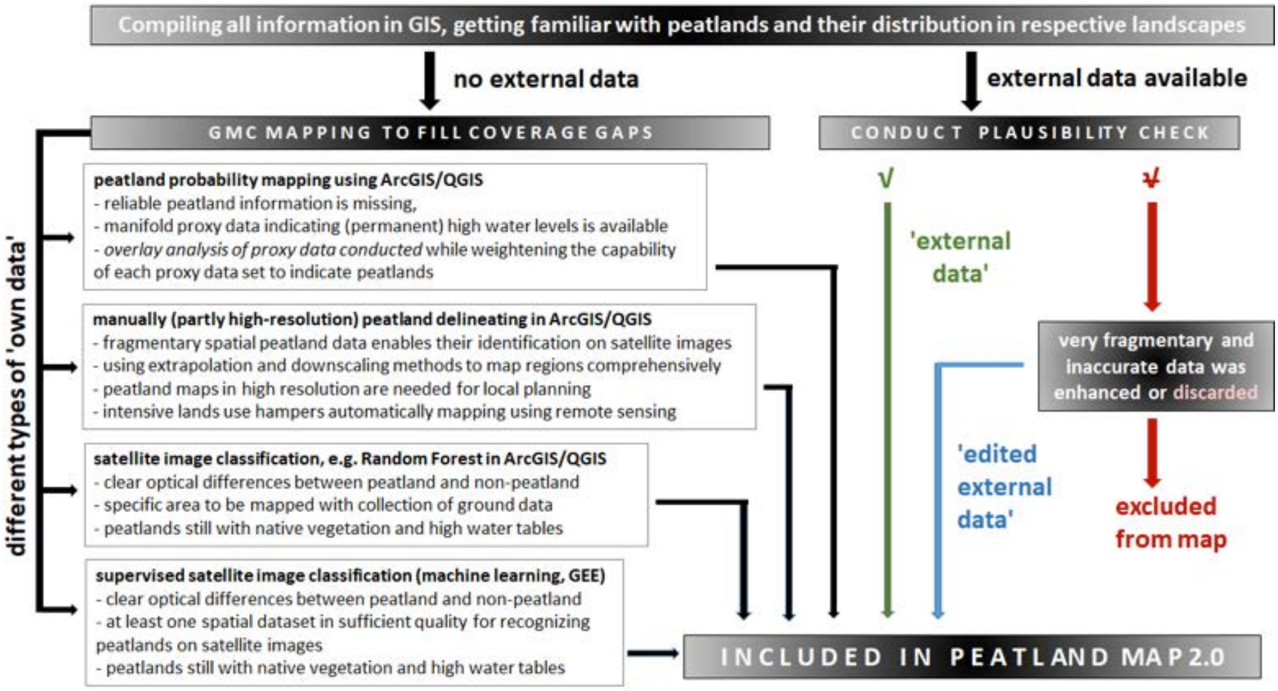


Figure III.1 Workflow for generating the Global Peatland Map 2.0 (GPM 2.0). First step: comprehensive assessment of regionally/ nationally available peat and proxy data; afterwards the procedures have been followed depending if 1) no ’external data’ were available or 2) ’external data' were available. More details are given in the text below; cf. Barthelmes et al. 2015; cf. Malpica et al. 2021.

Where external data were insufficient to confirm the location and distribution of peatlands, multiple ‘own’ GIS data sets have been developed at Greifswald Mire Centre under the Global Peatland Database. Methods for generating ‘own data’ on peatlands included:

1. probability mapping by comparing and ranking multiple proxy data in a GIS (developed at Greifswald Mire Centre; cf. Villegas Mejia 2018; Malpica 2019; Malpica *et al.* 2021);
2. supervised satellite image classification using Random Forest (partly in Google Earth Engine); and
3. manual delineation using a combination of legacy soil maps, peat point data, suitable Earth Observation (EO) data and landscape- and peatland-ecological expert judgement (cf. Barthelmes *et al.* 2015a, 2015b).

Manual downscaling and information extrapolation partly allowed for distinguishing different peatland types, several drainage intensities and multiple land use types. We also combined downscaling with extrapolation from regions with higher or medium resolution maps to areas with a similar geomorphological setting and the same appearance in satellite imagery.

Where thousands of small potential peatlands were identified in the initial meta-study and on aerial/ satellite imagery (e.g., in north-eastern Kazakhstan, south and west of the large Esteros del Iberá peatland in Argentina, or along the east coast of Madagascar), some of these potential peatlands were mapped manually ("indicatively") to highlight them for awareness-raising, or in large polygons as "peat in the soil mosaic". A "comprehensive" mapping of peatlands in a given region, landscape unit or country was carried out when its maximum number potentially did not exceed 1000 polygons. This mapping aimed to delineate all potential peatlands that could be identified with available data and on satellite or aerial imagery (often with a resolution between 1:20,000 and 1:50,000), using various EO based methods, cf. Figure III.1 workflow).

III.1. Key Sources of Information for Compiling the GPM2.0

Especially for screening specific regions for peatlands during the preparatory phase of own mapping and to conduct the ‘plausibility check’ for external data as well as informing their improvement (see Fig. III.1 above), plenty digital/digitized maps containing peat or proxy information (e.g., soil, vegetation, land systems) of various spatial resolution have been accessed from open access online archives (Table III.1).

Table III.1 Open access online archives from which maps have been downloaded and used to sustain the GPM2.0.

Source	Website
International Soil Reference and Information Centre (ISRIC World Soil Information)	http://www.isric.org/.
European Union Joint Research Centre	https://ec.europa.eu/jrc/en.
FAO Corporate Document Repository	http://www.fao.org/documents/search/en/.
Institute de Recherche pour le Développent: Base de données Sphaera du service Cartographie	http://www.cartographie.ird.fr/sphaera.
World Soil Survey Archive and Catalogue (WOSSAC)	http://www.wossac.com.
Perry-Castañeda Library Map Collection, University of Texas at Austin	http://www.lib.utexas.edu/maps/topo/.
Ghent University Laboratory of Soil Science	http://www.labsoilscience.ugent.be/Congo.
Commonwealth Scientific and Industrial Research Organization: Land Research Surveys	http://www.publish.csiro.au/nid/289/aid/16088.
International Mire Conservation Group: Publications	www.imcg.net/pages/publications/papers.php.

We are grateful for the compilation of these maps and data in these archives and for their unrestricted availability.

Ancillary (often non-spatially explicit) data have been obtained from a wide range of sources, including publications and grey literature on wetland, peatland and organic soil research and protection, palaeo-ecological, pedological, geological and botanical studies, as well as expedition reports, technical reports from private companies and environmental organisations, and incidental descriptions.

To locate meaningful peat or proxy data, relevant research institutes, government ministries or agencies of several countries have been contacted. Relevant national authorities included those dealing with agriculture, forestry, resource extraction, geology or environment. We became familiar with local terminology and concepts used for peatlands and organic soils before contacting local authorities and researchers.

If direct data on the distribution of peatlands and organic soils were lacking, indirect information has been analysed and integrated that indicate the presence of long-term wet conditions and thus, possibly peat. This includes data on particular soil conditions (e.g., 'hydromorphic soil' or 'wetland soil'), bedrock (for example, 'young alluvium', 'lacustrine sediments'), relief (e.g., 'inundated depression'), vegetation (e.g., 'Peat Swamp Forest', '*Raphia* palms', '*Papyrus* reeds'), or land use and land cover ('poorly drained', 'inundation'; cf. Barthelmes *et al.* 2015).

The references for key external data integrated into the GMP2.0 are given in Table III.2 below.

Table III.2 List of main sources for 'external data' and main inputs for peatland mapping ('own data'; mapping in the GMC) for compiling the GPM2.0. [AF – Africa, AS – Asia, EU – Europe, NA – North America, OC – Oceania, LAC – Latin America and the Caribbean]

Region	Reference
AF	Willaime P. & B. Volkoff (1967). Carte pédologique du Dahomey à l'échelle de 1:1000 000, Paris (France) ORSTOM, Office de la recherche scientifique et technique outre mer, Paris, France.
AF	Lamouroux, R (1966). Carte pédologique du Togo: à l'échelle de 1:1000000, Paris (France), ORSTOM, Office de la recherche scientifique et technique outre mer,.
AF	Dargie, G.C., Lewis, S.L., Lawson, I.T., Mitchard, E.T.A., Page, S.E., Bocko, Y.E. & S.A. Ifo (2017). Age, extent and carbon storage of the central Congo Basin peatland complex. Nature, doi:10.1038/nature21048
AF	Grundling, P., Grundling, A.T., Pretorius, L., Mulders, J. & S. Mitchell (2017). South African Peatlands: Ecohydrological Characteristics and Socio-Economic Value, WRC report No. 2346/1/17, Water Research Commission, Pretoria, South Africa.
AF	Gumbricht *et al.* (2017). An expert system model for mapping tropical wetlands and peatlands reveals South America as the largest contributor. Global Change Biology. DOI: 10.1111/gcb.13688
AF	Harry Oppemheimer. Okavango Research Centre. Preliminary Vegetation Map Okavango Delta. University of Botswana, Botswana.
AF	Moat J. & P. Smith (eds.) (2007). Madagascar Vegetation mapping Project. Madagascar Vegetation Atlas, Royal Botanic Gardens, Kew, UK.
AF	Mauro, L. Fitchett, F.M. & S. Woodborne (2022). Angolan highlands peatlands: Extent, age and growth dynamics. Science of the Total Environment: 810; 152315.
AF	Grundling, P-L., Grundling, AA.T., Deventer, van H. & J.P. Le Roux (2021). Current state, pressures and protection of South African peatlands. Mires and Peat: 27, Article 26, 25 pp., DOI: 10.19189/MaP.2020.OMB.StA.2125
AF	Rebelo *et al.* (2012): Flood Pulsing in the Sudd Wetland: analysis of Seasonal Variations in Inundation and Evaporation in South Sudan. Earth Interactions, 16 Paper No. 1 DOI: 10.1175/2011EI382.1
AF	Castanheira, D.A. & F.Q. De Barros Aguiar (1973). Soils around the Okavango basin in Angola Recursos em terras com Aptid'o para o regadio na Bacia do Cubango. Instituto de Investigação Agronomica de Angola. No 33. Origin: RAISON.

Region	Reference
AF	SWAMP (2016). "Tropical and Subtropical Histosol Distribution", v3, https://doi.org/10.17528/CIFOR/DATA.00029, Center for International Forestry Research (CIFOR), Bogor, Indonesia (http://www.cifor.org/library/4014/mapping-global-tropical-wetlands-from-earth-observing-satellite-imagery/)
AS	Khurshid Alam, M., Shahidu Hasan, A.K.M., Rahman Kha, M. & J.W. Whitney (1990). Geological Map of Bangladesh, 1:1,000,000, Geological Survey of Bangladesh.
AS	Carter R.W. *et al.* (2016). Strategic Guidelines for Heritage Tourism in Battambang Provine, Cambodia, Biochar Assessment and Soil Mapping Study. Technical Report, ICEM (International Centre for Environmental Management, Hanoi, Melbourne, Yangon, Hong Kong, Singapore, Vientiane, Phnom Penh.
AS	Davies J. (2012). Priorities for Research in the Wetland Forests of Brunei. Presentation for the international Conference on wetland forests "Forests for sustainable living" Brunei Darussalam.
AS	Saxon, E. & S. Sheppard (2010). Land Systems of Indonesia and New Guinea.
AS	GIS Unit, SRDI (1997): General Soil Map of Bangladesh, 1:1000000. Soil Resource Development Institute.
AS	Global Environment Centre (GEC) (2002 – 2021). Overview Map of Peatlands in Southeast Asia (SEA).
AS	Gumbricht *et al.* (2017). An expert system model for mapping tropical wetlands and peatlands reveals South America as the largest contributor. Global Change Biology. DOI: 10.1111/gcb.13688
AS	Leifeld, J. & L. Menichetti (2018). The underappreciated potential of peatlands in global climate change mitigation strategies. Nat Commun 9, 1071. https://doi.org/10.1038/s41467-018-03406-6
AS	Hebermehl, L. (2021). A first assessment of the potential distribution of peatlands in Uzbekistan (2021). MSc-thesis in Landscape Ecology and Nature Conservation, Institute of Botany and Landscape Ecology, University of Greifswald
AS	Aljes, M., Fell, F., Heinicke, T., Bärisch, S., Haberl, A., Peters, J. & J. Zeitz (2014). Moorökosysteme in Kirgistan: Verbreitung, Charakteristika und Bedeutung für den Klimaschutz. Project Report. Berlin, Bishkek and Greifswald.
AS	Osaki, M. & Tsuji, N. (eds.) (2016). Tropical peatland ecosystems. Springer, Japan.
AS	Panagos, P., Jones, A., Bosco, C. & P.S. Senthil Kumar (2011). European digital archive on soil maps (EuDASM): preserving important soil data for public free access. International Journal of Digital Earth 4 (5): 434-443.
AS	Parish, F. (2015). New Peatland Areas Confirmed in Myanmar. Peatlands International 2015 (1) p. 18-21.
AS	Subasinghe, S.A.P. (1988). Final Project Report - 1987/1988. Department of Cartography ITC, Land use Division, Irrigation Department, Colombo, Sri Lanka and ITC, Enschede, The Netherlands.
AS	Selvaradjou, S.-K., Montanarella, L., Spaargaren, O. & D. Dent (2005). European Digital Archive of Soil Maps (EuDASM) – Soil Maps of Asia DVD-ROM version. Office of the Official Publications of the European Communities, Luxembourg.
AS	Nguyên B.V. (1981). Soil map of the Trans Bassac area. 1:25,0000. Soil Department, University of Can Tho, Vietnam, Winwand Staring Centre, Wageningen, The Netherlands.
AS	Department of Agriculture, Sarawak (1968). Soil Map of Sarawak, Malaysia, Timor. Sheet A, B, staff of the Soil Survey Division and the Directorate of National Mapping, Malaysia.
AS	Director of National Mapping, Malaysia (1968). Reconnaissance soil map of Peninsular Malaysia. 1:500, 000. Staff of the Soil Survey Division, Soils and Analytical Services Branch. Division of Agriculture. Ministry of Agriculture and Fisheries, Malaysia, under the Supervision of Law, W.M.
AS	Tarnocai, C., Kimble, J., Swanson, D., Goryachkin, S., Naumov, Y.M., Stolbovoi, V., Jakobsen, B., Broll, G., Montanarella, L., Arnoldussen, A., Arnalds O. & M. Yli-Halla (2002). Northern Circumpolar Soils Map, Version 1. Research Branch, Agriculture and Agri-Food Canada, Ottawa, Canada.
AS	Vompersky, S.E., Sirin, A.A., Salnikov, A.A., Tsyganova, O.P. & Valyaeva, N.A. (2011). Estimation of forest cover extent over peatland and paludified shallow peatlands in Russia. Contemporary Problems of Ecology 4-7: 734-741.
AS	Xu, J., Morris, P.J., Junguo L. & J. Holden (2017). PEATMAP: Refining estimates of global peatland distribution based on a meta-analysis. Incl. dataset, CATENA: 160: 134-140. https://doi.org/10.5518/252

Region	Reference
AS	Yang, G., Peng, C., Chen, H., Dong, F., Ning, W., Yang, Y., Zhang, Y, Zhu, D., He, Y., Shi, S. Zeng, X., Xi, T., Meng, Q. & Q. Zhu (2017). Qinghai–Tibetan Plateau peatland sustainable utilization under anthropogenic disturbances and climate change. Ecosystem Health and Sustainability 3(3), https://doi.org/10.1002/ehs2.1263
EU	Tanneberger *et al.* (2017). The peatland Map of Europe. Mires and Peat 19: article 22: 1-7.
NA	Bermuda National Trust, UNEP-WCMC (2022). Protected Area Profile for Bermuda from the World Database on Protected Areas, September 2021. Available at: www.protectedplanet.net
NA	Bourgeau-Chavez, L.L., Endres, S., Battaglia, M., Miller, M.E., Banda, E., Laubach, Z., Higman, P., Chow-Fraser, P. & J. Marcaccio (2015). Development of a Bi-National Great Lakes coastal wetland and land use map using three season PALSAR and Landsat imagery. Remote Sens 7(7): 8655-8682. doi:10.3390/rs70708655
NA	Bourgeau-Chavez, L.L., Endres, S., Powell, R., Battaglia, M.J., Benscoter, B., Turetsky, M.R., Kasischke, E.S. & E. Banda (2017). Mapping Boreal peatland ecosystem types from multi-temporal Radar and Optical satellite imagery. Canadian Journal of Forest Research 47(4): 545-559. 10.1139/cjfr-2016-0192
NA	Bourgeau-Chavez, L.L., J.A. Graham, S. Endres, N.H.F. French, M. Battaglia, D. Hansen & D. Tanzer (2019). ABoVE: ecosystem map, Great Slave Lake Area, Northwest Territories, Canada, 1997-2011. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1695
NA	French, N.H.F., Graham, J.A., Vander Bilt, D.J.L., Jenkins, L.K., Battaglia M.J. & L.L. Bourgeau-Chavez (2022). ABoVE: wetland types, Slave River and Peace-Athabasca Deltas, Canada, 2007 and 2017. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1947
NA	Hawaii Soil Atlas. https://gis.ctahr.hawaii.edu/SoilAtlas
NA	Hitt, K.J. (2007). Vulnerability of shallow ground water and drinking-water wells to nitrate in the United States: model of predicted nitrate concentration in shallow, recently recharged ground water -- Input data set for histosols (gwava-s_hist), edition 1, raster digital data, Geological Survey, Reston, Virginia, USA.
NA	Tarnocai, C., Kettles I.M. & B. Lacelle (2011). Peatlands of Canada. Geological Survey of Canada, Open File 6561, 1 CD-ROM. https://doi.org/10.4095/288786
OC	Bryan J.E. & P. L. Shearman (2008). Papua New Guinea Resource Information Handbook (PNGRIS Publication, 7) University of Papua New Guinea, Department of Agriculture and Livestock. Land Utilisation Section.
OC	Ausseil, A.-G. E., Jamali H., Clarkson B. R. & N. E. Golubiewski (2015). Soil carbon stocks in wetlands of New Zealand and impact of land conversion since European settlement. Wetlands Ecology and Management 23(5):947-961.
OC	Minasny, B., Berglund, Ö., Connolly, J., Hedley, C., de Vries, F., Gimona, A., Kempen, B., Kidd, D., Lilja, H., Malone, B., McBratney, A., Roudier, P., O'Rourke, S., Padarian, R.J., Poggio, L., ten Caten, A., Thompson, D., Tuve, C. & W. Widyatmanti (2019). Digital mapping of peatlands – a critical review, Earth-Science Reviews 196, 102870.https://doi.org/10.1016/j.earscirev.2019.05.014.
OC	Department of Primary Industries, Parks, Water and Environment (2021). Digital soil maps of TASMANIA. dataset inventory, Tasmanian Government. https://nrmdatalibrary.dpipwe.tas.gov.au/FactSheets/WfW/ListMapUserNotes/Inventory_DSM_Tas.pdf
OC	Leathwick, J.R., West, D., Chadderton, L., Gerbeaux, P., Kelly, D., Robertson H. & D. Brown (2010). Freshwater Ecosystems of New Zealand. 'FENZ' Geodatabase, version One, Department of Conservation, government of New Zealand.
OC	Hodgson, DD.A. *et al.* (2014). Terrestrial and submarine evidence for the extent and timing of the Last Glacial Maximum and the onset of deglaciation on the maritime-Antarctic and sub-Antarctic islands. Quaternary Science Reviews 100: 137-158.
OC	Hope, G.S. & Nanson, R.A. (2015). Peatland carbon stores and fluxes in the Snowy Mountains, New South Wales, Australia. Mires and Peat 15: Art. 11. (Online: http://www.mires-and-peat.net/pages/volumes/map15/map1511.php)
OC	I.G. Barber *et al.* (2016). A radiocarbon investigation of Moriori forest use on Rēkohu (Chatham Island), southwestern Polynesia. Journal of Archaeological Science: Reports 10: 96–109.
OC	Kidd, D., Moreton, R. & G. Brown (2021). Tasmanian Organic Soil Mapping Project. Methods Report, Department of Primary Industries, Parks, Water and Environment, Tasmania, Australia.

Region	Reference
OC	Rainsley, E., Turney, C. S. M., Golledge, N. R., Wilmshurst, J. M., McGlone, M. S., Hogg, A. G., Li, B., Thomas, Z. A., Roberts, R., Jones, R. T., Palmer, J. G., Flett, V., de Wet, G., Hutchinson, D. K., Lipson, M. J., Fenwick, P., Hines, B. R., Binetti, U. & C. J. Fogwill (2019). Pleistocene glacial history of the New Zealand subantarctic islands, Clim. Past 15: 423–448. https://doi.org/10.5194/cp-15-423-2019, 2019.
OC	Smith, L. (1981). Types of peat and peat forming vegetation on South Georgia. British Antarctic Survey Bulletin 53: 119-139.
LAC	ANAM/CBMAP (2000). Mapa de vegetación de Panamá. In: Atlas Ambiental de la República Panamá, Biblioteca Virtual, 2020-12-14.
LAC	Hoyos-Santillan, J., Dominguez, E., Miranda, A., Martínez, M.P. & D Villarroel (2020). Monitoreo de cambios, corrección cartográfica y actualización del catastro de los recursos vegetacionales nativos de la Región de Magallanes y de la Antártica Chilena. Resumen Ejecutivo, CONAF (Corporación Nacional Forestal), Santiago, Chile 52 p.
LAC	Corporación Nacional Forestal and Universidad Austral de Chile (2014). Monitoreo de cambios, corrección cartográfica y actualización del catastro de recursos vegetacionales nativos de la Región de Los Lagos. Resumen Ejecutivo Santiago, Chile, 54 p.
LAC	Domínguez, E. & D: Vega-Valdés (2015). Análisis espacial de la distribución geográfica de las Turberas de Sphagnum de la Región de Magallanes y Antártica Chilena. In: Funciones y servicios ecosistémicos de las turberas en Magallanes, (eds. Domínguez, E. & D. Vega-Valdés), Colección de libros INIA No 33 334, Instituto de Investigaciones Agropecuarias.
LAC	Villarroel, D. *et al.* (2021). Distribución geográfica de turberas de *Sphagnum* en la región de Aysén. In: Funciones y servicios ecosistémicos de las turberas de *Sphagnum* en la región de Aysén (eds. Domínguez, E. & Martínez, M. P.) Colección Libros INEA No. 41: 21–47, Instituto de Investigaciones Agropecuarias, Centro Regional de Investigación Tamel Aike.
LAC	AFE-COHDEFOR (2007). Mapa de suelos, Honduras. Accessed at: http://calidadsuelos2010-estefania.blogspot.com/
LAC	Bourgeau-Chavez, L.L., Grelik, S.L., Battaglia, M.J. Leisman, D. J., Chimner, R. A., Hribljan, J. A., Lilleskov, E. A., Draper, F. C., Zutta, B. R., Hergoualc’h, K., Bhomia, R. K. & O. Lähteenoja (2021). Advances in Amazonian Peatland Discrimination with Multi-Temporal PALSAR Refines Estimates of Peatland Distribution, C Stocks and Deforestation. Front. Earth Sci. 9: 676748. DOI: 10.3389/feart.2021.676748
LAC	Brinkman, R. & L.J. Pons (1968): A pedo-geomorphological classification and map of the Holocene sediments in the coastal plain of the three Guianas. In Soil Survey Papers 4, Netherlands Soil Survey Institute, Wageningen, 40 p.
LAC	Cardoso, M., Polizel, S.P., Matos, R.O., Bufacchi, P., Filho, G.C.K. & L. Borma (2018). Hydrological Characteristics Related to Peatland Fire in the Paraíba Do Sul River Basin, in the State of São Paulo, Brazil. Latin American Conference on Sustainable Development of Energy, Water and Environment Systems, 28-31 January, Rio de Janeiro, Brazil.
LAC	Chimner R.A., Bourgeau-Chavez, L.L., Grelik, S., Hribljan, J.A., Planas-Clarke, A.M., Polk, M.H., Lilleskov, E.A. & B. Fuentealba (2019). Mapping extent and types of wetlands in the Cordillera Blanca, Peru. Wetlands. DOI: 10.1007/s13157-019-01134-1.
LAC	Bourgeau-Chavez, L.; Grelik, S., Chimner, R.A., Lilleskov, E.A., Hribljan, J.A., Planas-Clarke, A.M. Polk, M.H. & B. Fuentealba (2019). Maps of mountain peatlands and wetlands in central Peru. Dataset, Center for International Forestry Research (CIFOR), https://doi.org/10.17528/CIFOR/DATA.00190..
LAC	Cubizolle, H., Mouandza, M.M. & F. Muller (2013). Mires and Histosols in French Guiana (South America): new data relating to location and area. Mires and Peat: 12 Article 03, 1–10.
LAC	Cunha Lima, A.L.d., Costa, I.V.G.d., Silva, J.F.d. & A.J.D. Rocha (1982). Turfa na faixa costeira Bahia-Sergipe. In: Anais do 32 Congresso, Vol. 5, Simposios - Geoquimica/Uranio/Turfa/Petrolea, Sociedade Brasileira de Geologia, Salvador - Bahia, Brazil.
LAC	Dijkshoorn, J.A., van Engelen, V.W.P. & J.R.M. Huting (2008). Soil and landform properties for LADA partner countries (Argentina, China, Cuba, Senegal and The Gambia, South Africa and Tunisia). ISRIC report 2008/06 and GLADA report 2008/03, ISRIC – World Soil Information and FAO, Wageningen (23 pp. with data set).
LAC	Wright, A.C.S (1958). British Honduras Provisional soil map Sheet 1 and 2. 1:250,000, Directorate of Overseas Surveys, (ISRIC_24282,24285).

Region	Reference
LAC	Larach, J.O.I., Cardoso A., Carvalho, A.P.de, Hochmüller, D.P., Martins J.S., Rauen, M.deJ., Fasolo P.J. & R.O. Pötter (1984). Levantamento de reconhecimento dos solos do estado do Parana. Governo do Estado do Parana, Iapar, Emrbapa, Sudesul, Brazil.
LAC	Hastie, A., Honorio Coronado, E., Reyna, J., Mitchard, E.T.A., Åkesson, C.M., Baker, T.R., Cole, L.E.S., Córdova Oroche, C.J., Dargie, G., Dávila, N., De Grandi, E.C., Del Águila, J., Del Castillo Torres, D., de la Cruz Paiva, R., Draper, F.C., Flores, G., Grández, J., Hergoualc'h, K., Householder, J.E., Janovec, J.P., Lähteenoja, O., Reyna, D., Rodríguez-Veiga, P., Roucoux, K.H., Tobler, M., Wheeler, C.E., Williams, M & I.T Lawson (2022). Risks to carbon storage from land-use change revealed by peat thickness maps of Peru. Nat. Geosci. 15: 369-374. https://doi.org/10.7488/ds/3408
LAC	Hernandez, A., Perez Jimenez, J.M.& O. Ascanio (1971). Mapa genetico de suelos. Instiduto Cubano de Geodesia y Cartografia, Academia de Ciencias de Cuba, Intituto de suelos, 19 maps.
LAC	Hribljan, J.A., Suarez, E., Bourgeau Chavez, L., Endres, S., Lilleskov, E.A., Chimbolema, S., Wayson, C., Serocki, E. & R.A. Chimner (2017). Multidate, multi-sensor remote sensing reveals high density of carbonrich mountain peatlands in the Páramo of Ecuador. Global Change Biology 23(12): 5412-25. doi: 10.1111/gcb.13807.
LAC	Bourgeau-Chavez, L., Grelik, S., Chimner, R.A., Lilleskov, E.A., Hribljan, J.A., Wayson, C., Serocki, E. & E. Suarez (2019). Map of mountain peatlands in Ecuador, Center for International Forestry Research (CIFOR), V1, dataset. https://doi.org/10.17528/CIFOR/DATA.00191
LAC	IBGE (2017). Mapas por municipio do Censo Agro, Brazil, https://censoagro2017.ibge.gov.br/
LAC	Korsch K. (2019). Locating peatlands on the Caribbean Islands. MSc-thesis in Biodiversity and Ecology, Institute of Botany and Landscape Ecology, University of Greifswald.
LAC	Lévéque A. (1962). Guyane Francaise_Carte des sols des terres basses: Guisbour_Ouanary. 1:100,000, Office de la recherche scientifique et technique outre-mer(ORSTOM), Paris, France.
LAC	Lévéque A. (1962). Guyane Francaise_Carte des sols des terres basses: Cayenne_Regina. 1:100,000, Office de la recherche scientifique et technique outre-mer (ORSTOM), Paris, France.
LAC	Llavallol, C.I. & C.J.M. (2007). Mapa de vegetación de la isla de los estados Multequina, núm. 16, pp. 139-155, Instituto Argentino de Investigaciones de las Zonas Áridas Mendoza, Argentina.
LAC	IGAC - Instituto Geográfico Agustín Codazzi (2019). Mapas de Suelos del Territorio Colombiano a escala 1:100000. https://data.amerigeoss.org/id/dataset/mapas-de-suelos-del-territorio-colombiano-a-escala-1-100-000-departamento-boyaca
LAC	Marius, C., Levêque, A., Sourdat, M., Arthur, E. & J.-J. Rostan (1968). Carte pédologique de la Guyane Francaise, Cayenne (N.O.). 1:50,000, ORSTOM, Office de la recherche scientifique et technique outre mer, Paris, France.
LAC	Ministerio del Medio Ambiente (2020). Programa Inventario Nacional de Humedales, Chile. https://humedaleschile.mma.gob.cl/inventario-humadales/
LAC	Custode, E. (1983). Mapa morfo edafologico - Provincia del napo. Ministerio de Agricultura y Granaderia Programa National de Regionalizacion agraria Pronareg-Ecuador. ORSTOM, Office de la recherche scientifique et technique outre mer, Paris, France.
LAC	Delhumeau, M., Rostan, J.J. & M. Lance (1974). Carte pédologique de la Guyane francaise: Régina (N.E.). 1:50,000, ORSTOM, Office de la recherce scientifique et technique de outre mer, Paris, France.
LAC	NatureServe (2017). International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Databases, Arlington, VA. U.S.A. Data current as of 13 November 2017.
LAC	Pereira, L.H.M.P. & N.A. Tesch (1982). Avaliacao dos depositos de turfa no municipio de conde-bahia. In: Anais do 32 Congresso, Vol. 5, Simposios - Geoquimica, Uranio, Turfa, Petrolea, Sociedade Brasileira de Geologia, Salvador - Bahia, Brazil.
LAC	Villegas Mejía, L. (2018). Mapping of coastal peatlands in the Caribbean region: Columbia and Costa Rica. MSc-thesis in Landscape Ecology and Nature Conservation, Institute of Botany and Landscape Ecology, University of Greifswald.
LAC	Republica de Nicaragua Mapa de suelos WRB (2010) 1:1,000,000, https://es.slideshare.net/FAOoftheUN/estado-prioridades-y-necesidades-para-el-manejo-sostenible-del-suelo-en-nicaragua-luis-manuel-urbina-instituto-nicaragense-de-tecnologia-agropecuaria

Region	Reference
LAC	Peacock, H.L. (1962). Mapa parcial de Honduras. Clasificación de Tierras, Organizacion de los Estados Americanos, Whashington D.C., USA
LAC	Ramos-Reyes, R., Zavala-Cruz, J., Gama-Campillo, L.M., Pech-Pool, D. & M.A. Ortiz-Pérez (2016). Indicadores geomorfológicos para evaluar la vulnerabilidad por inundación ante el ascenso del nivel del mar debido al cambio climático en la costa de Tabasco y Campeche, México. Boletín de la Sociedad Geológica Mexicana 68(3): 581-598.
LAC	Rossi, M. (2017). Mapa pedológico do Estado de São Paulo: revisado e ampliado. V.1. São Paulo: Instituto Florestal, 118p. (inclui Mapas).
LAC	SAERI, Falkland Islands Government's Department of Agriculture, James Hutton Institute, UK Falkland Islands Trust, UK Centre for Ecology and Hydrology, the Natural History Museum, University of Magallanes. Falkland Islands Soil Mapping. Contact Stefanie Crater <scarter (at) saeri.ac.fk> (https://data.saeri.org/saeri_webgis/lizmap/www/index.php/view/map/?repository=o5f072020&project=soil_mapping_webremote_wu)
LAC	SECAD (Servicio de Cartografia Digital e IDE) & Universidad de Extremadura (2015): Mapa de vegetación/usos del suelo de Cuba. 1:500,000.
LAC	Secretaria Comunal de Planificación (1999). Honduras - Mapa de Capacidad de Uso de Suelos. 1:1,000,000.
LAC	Iturraspe, R., Urciuolo, A. & R. Iturraspe (2012). Spatial analysis and description of eastern peatlands of Tierra del Fuego, Argentina. In: Mires from Pole to Pole (Lindholm T. & R. Heikkilä). The Finnish Environment 38:385-399,
LAC	Peters, J. & Tegetmeyer, C. (2019) Inventory of peatlands in the Caribbean and first description of priority areas. Proceedings of the Greifswald Mire Centre 05/2019 (selfpublished, ISSN 2627910X), 76 p.
LAC	Turenne, J.F. (1972). Carte pédologique de la Guyane Francaise - Mana St Laurent (S.O.) ORSTOM, Office de la recherce scientifique et technique de outre mer, Paris, Frace.
LAC	Wong, T.E., Kramer, R. de, Boer, P. L.,de, Langereis, C. & J. Sew-A-Tjon (2009). The influence of sea-level changes on tropical coastal lowlands; the Pleistocene Coropina Formation, Suriname. Sedimentary Geology 216: 125-137. DOI: 10.1016/j.sedgeo.2009.02.003

III.2. The GPM2.0 Compared to Other Global Peatland, Histosol or Soil Organic Carbon Maps

Yu *et al.* (2010) published a widely cited global peatland map. To overcome the scarcity of peat/organic soil data for Africa and South America, they adopted beside the Histosol also the Gleysoil layer from the Harmonized World Soil Database (HWSD) (Fischer *et al.* 2008) as proxy for peatland distribution, which led to considerable areal overestimation in e.g., western Sub-Sahara Africa, the Mekong River and delta and South America. The same resulted from transferring the 'Inland marshes feature' from Niu *et al.* (2009) as 'peatlands' to China (incl. Tibet).

Leifeld and Menichetti (2018) re-used the Yu *et al*. (2010) map and updated it with new data from e.g., Sweden, Estonia, Indonesia, Malaysia, Kyrgyzstan and Tasmania. The PEATMAP from Xu *et al.* (2018) avoided many of the overestimations of the peat extent in the previous mentioned maps in Asia and Africa, but added a huge overestimation of peatlands in the Amazon Basin due to adopting an early version of the Global Wetlands dataset (Gumbricht *et al.* 2017), but left Sub-Sahara Africa and South America beside the Congo Basin and Amazonas widely empty. The Gumbricht (2017) 'Global Wetlands' for the Tropics data possess a higher resolution than GPM2.0, but have hardly coverage on (sub-)tropical mountain peatlands, and widely overestimate the peat extent in Bangladesh and the Mekong Delta. However, GlobalWetlands_v3 seems to be the best Remote Sensing-based approximation of peatlands in the Tropics. For tropical regions, where no better data were available, we used this map as unchanged regional extract, for other regions we edited and improved this map using ancillary data like legacy soil maps, fragmentary GIS data on local peatland occurrences and satellite imagery (e.g., for the Amazon Basin).

While comparing the coverage of Soil Organic Carbon (SOC) >180 g/kg from the 'Global Soil Organic Carbon Map' with the available peatland maps, the SOC map is almost empty in Africa and South America, where it focuses on high-altitude peatlands, e.g., in Ethiopia and the Andes, but does not show the peatlands in the Congo Basin and the Peruvian lowland (nor those in South Kalimantan, Borneo). Also, the coverage of Histosols in the SoilGrids dataset (Poggio *et al*. 2021) (while having a high resolution of 250 m) is globally almost reduced to Siberia, Scandinavia, Canada, Indonesia, Malaysia and parts of Peru, if a threshold of 20% probability of Histosol occurrence per grid cell is applied.

Although the GPM2.0 can be seen as an important update to global peatland maps, peatland mapping and assessment remain a huge task for many countries around the world (see Table III.3). This needs to be done in a relatively short timeframe to get sufficient information stop or prevent peatland drainage and degradation and thus, to mitigate climate change).

Table III.3 Selection of countries with considerable uncertainty of available GIS peatland data or substantial gaps in knowledge of peatland coverage in available scientific and ancillary data: 1) country barely covered in GPM2.0 so far; 2) country in GPM2.0 mainly covered by proxy data or low resolution global/regional data on peatlands (e.g., Wetlands_v3, CIFOR); 3) peatland data incomplete on the national scale, and 4) high resolution mapping necessary because of a) many small peatlands, b) peatlands intertwined with mineral wetlands, or c) peatlands possibly lost through intensive land use.

Africa	North America	Latin America	Asia	Oceania	Europe	Antarctica and Sub-Antarctic Islands
Angola [3, 4]	Greenland [1]	Argentina [3, 4]	Bangladesh [3, 4]	New Caledonia[1]	Austria [3, 4]	Antarctica [1]
Cameroon [3]	United States of America [3, 4]	Belize [3, 4]	Cambodia [1, 4]	Papua New Guinea [3, 4]	Belgium [3, 4]	Amsterdam and St-Paul Islands [1]
Central African Republic [1]	St. Pierre et Miquelon [3, 4]	Bolivia [1]	China [3, 4]	*many Pacific Islands* [1]	Bulgaria [1]	Îles Crozet [1]
Dem. Rep. of the Congo [3, 4]		Brazil [3, 4]	India [3, 4]		Croatia [1]	Macquarie Island [1]
Gabon [1]		Chile [3, 4]	Iran [3, 4]		Czech Republic[3, 4]	Prince Edward Islands [1]
Guinea-Bissau[2, 4]		Colombia [3, 4]	Iraq [3, 4]		France [3, 4]	South Georgia [1]
Lesotho 1		Ecuador [3]	Kazakhstan [3, 4]		Hungary [3, 4]	St. Helena [1]
Liberia [2, 4]		French Guiana [3]	Kyrgyzstan [3, 4]		Italy [1, 4]	Tristan da Cunha [1]
Madagascar [3, 4]		Guyana [3]	Laos [1]		Norway [3]	
Malawi [1, 4]		Paraguay [1]	Mongolia [3, 4]		Portugal [1, 4]	
Mozambique [2, 3, 4]		Suriname [3]	Myanmar [3, 4]		Romania [3, 4]	
Nigeria [2, 4]		Uruguay [1]	Nepal [1]		Spain [1, 4]	
Rep. of the Congo [3, 4]		Venezuela [3, 4]	North Korea [1]			
Sierra Leone [2, 4]		Costa Rica [3]	Philippines [2, 3]			
South Sudan [2, 3]		Honduras [2, 3]	Sri Lanka [3]			
		Mexico [2, 3, 4]	Thailand [1, 4]			
		Nicaragua [3, 4]	Vietnam [1, 4]			
		Panama [2, 3]				
		Puerto Rico [3]				

III.3. Production of Thematic Maps

The peatland distribution map served as a basis for the development of regional peatland distribution maps, and maps highlighting e.g., multiple land use types and land use changes, peatland protection, human pressure, or biodiversity values. To make these thematic maps on a global (Chapter 2) or regional scale (Chapters 3-8), the worldwide peatland occurrence (i.e., both classes 'peat dominated' + 'peat in soil mosaic' of the GPM2.0 (cf. Fig. 2.1) was overlain with relevant global thematic data ('thematic GIS-layers'). Many of the created maps were prepared as 'Hotspot Maps' (or 'Heat Maps'), which show the density distribution of point clouds with a colour gradient, produced with Kernel Density Estimation. Kernel Density calculates the density of features (here mainly points) in a specified neighbourhood around those features (Bailey and Gatrell 1995; Silverman 2017). The radius and cell size of the result depends largely on the input data. In this study, radiuses of 10-25 geographical degrees were used.

Calculations and analyses were carried out with ArcGIS Pro 2.9.0, ArcMap 10.8.1 and QGIS 3.16.16-Hannover. Layouts were essentially created with ArcMap 10.8.1 and ArcGIS Pro 2.9.0.

Table III.4 gives background information on the thematic geo-spatial input layers used to derive hotspot and other maps.

Table III.4. Thematic geo-spatial input layers used to derive hotspot and other maps for this Global Peatland Assessment.

Map	Map type	Method	Thematic layer	Reference
Continental peat extent maps			Peatland distribution GPD	Based on Data of the Global Peatland Database / Greifswald Mire Centre (2022)
Cropland	heat map	Calculation of Kernel Density of raster cells indicating cropland on the GPM2.0	HILDA+, state layer (2019)	Winkler, K., Fuchs, R., Rounsevell, M.D.A. and H. Martin (2020). HILDA+ Global Land Use Change between 1960 and 2019. PANGAEA, https://doi.org/10.1594/PANGAEA.921847
Forest Integrity Map	heat map	Calculation of Kernel Density of raster cells indicating low or high forest integrity on the GPM2.0	Forest Landscape Integrity Index	Grantham, H.S., Duncan, A., Evans, T.D., Jones, K.R., Beyer, H.L., Schuster, R., *et al.* (2020). Anthropogenic modification of forests means only 40% of remaining forests have high ecosystem integrity. Nat. Commun. 11: 5978. https://doi.org/10.1038/s41467-020-19493-3
Distribution of peatlands in permafrost: polar and high altitudes	thematic overlay, visualization only	Overlay of the permafrost dataset on the GPM2.0	Northern Hemisphere permafrost map	Obu, J., Westermann, S., Kääb, A. and A. Bartsch (2018). Ground Temperature Map, 2000-2016, Northern Hemisphere Permafrost. Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, PANGAEA, https://doi.org/10.1594/PANGAEA.888600
Peatlands related to biodiversity hotspots/ species richness	thematic overlay heat map	Calculation of Kernel Density of raster cells indicating medium or high species richness on the GPM2.0	UNEP-WCMC (2022) Rarity-weighted species richness	UNEP-WCMC (2022). Rarity-weighted species richness created from species range polygons extracted from the IUCN Red List (IUCN Red List of Threatened Species (2021) Version 2021.3. http://www.iucnredlist.org). For amphibians, birds, mammals and a few comprehensively assessed fresh water groups (shrimps, crabs and

Map	Map type	Method	Thematic layer	Reference
Peatlands in protected areas	thematic overlay, additional statistics: bar chart	Analysis of peatland distribution within and outside protected area, area calculation based on the peatland extent of the GPM2.0	WDPA	UNEP-WCMC and IUCN (2022), Protected Planet: The World Database on Protected Areas (WDPA) [Online], February 2022, Cambridge, UK: UNEP-WCMC and IUCN. Available at: www.protectedplanet.net.
Peatlands in high mountains	thematic overlay, visualization only	Extraction of peatlands within altitudes above 1,000 and 2,000 m.a.s.l., visualization	SRTM World	Jarvis, A., Reuter, H.I., Nelson, A. and Guevara, E. (2008). Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90m Database (http://srtm.csi.cgiar.org).
Peatlands in arid and sub-arid climates	heat map	Extraction of peatlands within arid and sub-arid climate zones, calculation of Kernel Density of extracted raster cells	Climate Zones - Koppen-Geiger	Peel, M.C., Finlayson, B. L. and McMahon, T.A. (2007). Updated world map of the Köppen-Geiger climate classification. Hydrol. Earth Syst. Sci. 11: 1633-1644. doi:10.5194/hess-11-1633-2007
Peatlands in FAO Ecoregions	heat map	Extraction of peatlands within the different ecological zones, calculation of Kernel Density of extracted raster cells	FAO Global Ecological Zones (adapted for GPA)	FAO (2012). Global ecological zones for FAO forest reporting: 2010 Update. Forest resources Assessment Working Paper 179, Rome, 2012.
Peat fires (2015/2020 El Nino/La Nina)	heat map	Calculation of Kernel Density of raster cells indicating fire on peat distribution of the GPM2.0 area for 2015 and 2020	MODIS Active Fire Products	MODIS Collection 61 NRT Hotspot / Active Fire Detections MCD14DL distributed from NASA FIRMS.Available on-line https://earthdata.nasa.gov/firms. doi: 10.5067/FIRMS/MODIS/MCD14DL.NRT.0061

Map	Map type	Method	Thematic layer	Reference
Peatland extent per country	country based colour gradient, visualization of gradients		Stats of the GMC Global Peatland Database (GPD)	Based on Data of the Global Peatland Database / Greifswald Mire Centre (2022)
Emissions from degrading peatlands per country	country based colour gradient, visualization of gradients		Stats of the GMC Global Peatland emission Database	Based on Data of the Global Peatland Emission Database / Greifswald Mire Centre (2022)
Peatlands in anthropogenic biomes	heat map and thematic overlay, additional statistics: pie chart	Calculation of Kernel Density of raster cells indicating lowand high Human Footprint on peat distribution area	The Last of the Wild Project V2: Global Human Footprint Dataset	Wildlife Conservation Society - WCS, and Center for International Earth Science Information Network - CIESIN - Columbia University (2015). Last of the Wild Project, Version 2, 2005 (LWP-2): Last of the Wild Dataset (Geographic). NASA Socioeconomic Data and Applications Center (SEDAC), https://doi.org/10.7927/H4348H83.

Note that none of the thematic levels used were developed specifically for peatlands and that some global thematic levels may introduce specific or point biases. We carefully selected thematic levels from recent scientific research and widely accepted sources of spatial data (Table III.4). We have already recognized that the HILDA+, State Layer (2019; Table III.4), in particular, regularly generates much too high area figures for rangeland and pasture, especially in peatlands dominated by grassy plant species (Africa, Latin America and the Caribbean, and to some extent Asia). We have therefore assigned very low impacts to these area estimates or omitted them.

III.3.1. Detailed Methods for the Development of Selected Maps

Peatlands related to biodiversity:

To map biodiversity hot spots on peatlands, the ‘Global map of rarity-weighted richness’ - an index that combines metrics of endemism and species richness – with a resolution of 10 km was used (UNEP-WCMC 2022). This raster is based on the raw IUCN ranges for amphibians, birds, mammals, reptiles, shrimps, crabs and crayfish. As the species ranges have not been refined (for example, by altitude and landcover), there may be a fair amount of unsuitable habitat in the raw ranges.

The data set provides data as floating points. High values of the index describe a high importance of an area for the species groups regarded. For a reasonable grouping of the continuous values, we used the mean (0.01578) and standard deviation (0.07515). Values below the mean were considered as “low” species richness and values above the sum of the mean and the standard deviation (0.0993) were considered as "high” species richness in a specific area. All other values have been summarized as “medium” species richness.

Using this classification, the thematic grid was intersected with the peatland distribution, and heat maps for high and medium species richness on peatland were created.

Peatlands in anthropogenic biomes

To map ‘Hot spots of human impact on peatlands’, the ‘Global map of anthropogenic impacts on the environment’ from the Last of the Wild, v2. Dataset was used. The Last of the Wild Dataset provides a layer of Global Human Footprint - the index values range from 1 to 100 (Wildlife Conservation Society - WCS, and Center for International Earth Science Information Network - CIESIN - Columbia University (2015). Last of the Wild Project, Version 2, 2005 (LWP-2): Last of the Wild Dataset (Geographic). NASA Socioeconomic Data and Applications Center (SEDAC), https://doi.org/10.7927/H4348H83). The Human Influence Index and Human Footprint are produced through an overlay of a number of global data layers that represent the location of various factors presumed to exert an influence on ecosystems: human population distribution, urban areas, roads, navigable rivers, and various agricultural land uses. The combined influence of these factors yields the Human Influence Index. The Human Influence Index (HII), in turn, is normalized by global biomes to create the Human Footprint (HF) data set. HF values range from 1 to 100. A score of 1 in moist tropical forests indicates that that grid cell is part of the 1% least influenced or “wildest” area in its biome, the same as a score of 1 in temperate broadleaf forests (although the absolute amount of influence in those two places may be quite different). The areas that have the least influence (Human Footprint grid values less than or equal to 10) are included in The Last of the Wild data set. Areas with values less than or equal to 10 are considered as least influenced. Areas with values higher than 30 are considered as heavily influenced, all other areas are classified as medium influenced.

Using this classification, the thematic grid was intersected with the peatland distribution and heat maps for high, medium and low human influence on peatland were created.

Peat fires (2015/2020 El Nino/La Nina)

The mapping of fire events on peatlands has been done with MODIS data from NASA Fire Information for Resource Management System (cf. Table III.4). Data for all global fire events in the years 2015 (El Niño) and 2020 (La Niña) were chosen to compare recent fire events connected to peatland area under different climatic conditions. All fire pixels with a confidential value below 30 were removed from the datasets before intersection with peatland distribution area to create the heat maps in a further step.

Peatlands in arid and sub-arid climates

The indication of peatland in arid and sub arid areas has been done by an intersection of the global peatland dataset with the climate zones of Koppen- Geiger (2007; cf. Table III.4).). All peatland areas within the arid-desert or arid-steppe climate zone (BSh, BSk, BWh and BWk) were extracted from the global layer. Using this selection heat maps of their occurrence have been generated.

Forest Integrity on peatlands

To map the state of forest integrity on peatlands the Forest Landscape Integrity Index map (https://www.forestintegrity.com) for 2019 was intersected with the global peatland dataset. The scores of the integrity index range from 0 (lowest integrity) to 10 (highest). Following the benchmarking of the developers we classified the dataset into 3 classes: low (≤6.0); medium (>6.0 and <9.6); and high forest integrity (≥9.6).

Using this classification, the thematic grid was intersected with the peatland distribution and heat maps for high, medium and low forest integrity on peatland sites were produced.

III.4. Deriving 'best estimates' for the country-wise total peatland area, peatland area per land use type and the calculation of related GHG emissions

The shortcomings of GPM2.0 (despite the progress made; cf. Table III.2) did not permit to overlay the GPM2.0 data with the HILDA+ land use layer in all cases. We cross-checked the area data from the GPM2.0 with available data spatial and non-spatial products to derive 'best estimates' of the total peatland area in each country using:

- direct peatland area extracted from the GPM2.0;
- other spatial products as e.g., GlobalWetlands_v3 and peatland ecological indicators (e.g., of permanent wet areas, soil moisture, topography),
- peatland and soil science-based, or national area data from the Global Peatland Database where detailed descriptions and references for individual countries and regions can be found (cf. Joosten 2009), - ancillary information found in the WWW (e.g., legacy soil maps; Table III.1 above), and
- expert judgement based on available peat data, peatland and landscape ecological knowledge, and satellite or aerial imagery.

The derivation of these 'best estimates' was an iterative process in which conflicting information from multiple data sources had to be balanced. However, single best estimates may still deviate substantially from 'reality' on the ground.

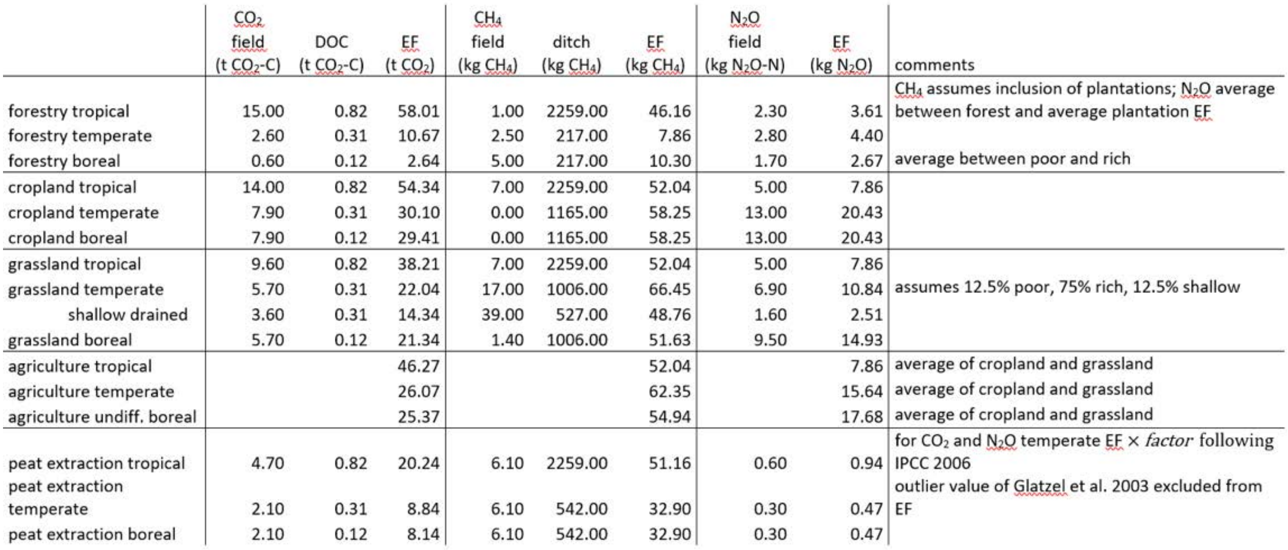
Important information on land use on peatlands (for GPA: drained forestry, drained agriculture and drained peat extraction) was gathered from:

- National Inventory Submissions of ANNEX 1 parties to the UNFCCC;
- (partly) National Communications of Non-ANNEX 1 parties to the UNFCCC;
- spatial data on cropland extent derived from the overlay of the GPM2.0 with the HILDA+ land use database (Winkler *et al.* 2022);
- related scientific data and ancillary information from the WWW and from the IMCG/GMC Global Peatland Database (https://greifswaldmoor.de/global-peatland-database-en.html) where detailed descriptions and references for individual countries and areas are collected and stored since many years (cf. Joosten 2009);
- expert judgement while comparing the peatland areas in the GPM2.0 in a specific region with satellite and aerial imagery searching for evidence for logging, agriculture, and drainage; and
- feedback from the Coordinating Lead Authors of this assessment.

The data ranges presented from these variable sources are often no real reliability ranges but compilations of different estimates. In the assessment we do not present all these (sometimes extremely dissimilar) estimates but present the most probable figure. Especially, we must recognize that the HILDA+ rangeland/pasture layer fails to clearly distinguish natural grasslands from grazed land in Latin America and Africa. Overall, the land use data for forestry, agriculture and peat extraction have more reliability in the northern hemisphere/industrial countries than in the southern hemisphere. Especially for Africa and Latin America the inventory holds many uncertainties. We hope that this assessment on peatland area and land use is received as a challenge and invitation for countries to improve their peatland inventory.

Table III.5 below gives the emission factors for the land use types a) forestry, b) cropland, c) grassland, d) undifferentiated agriculture (if a discrimination between cropland and grassland was impossible), and e) peat extraction. The country-wise areas assigned to these land use types have been multiplied with this emission factors to derive the national land use related GHG emissions.

Table III.5 Emission factors per ha and year used in the assessment; all values taken from or based on IPCC (2014).



	CO_2 field (t CO_2-C)	DOC (t CO_2-C)	EF (t CO_2)	CH_4 field (kg CH_4)	ditch (kg CH_4)	EF (kg CH_4)	N_2O field (kg N_2O-N)	EF (kg N_2O)	comments
forestry tropical	15.00	0.82	58.01	1.00	2259.00	46.16	2.30	3.61	CH_4 assumes inclusion of plantations; N_2O average between forest and average plantation EF
forestry temperate	2.60	0.31	10.67	2.50	217.00	7.86	2.80	4.40	
forestry boreal	0.60	0.12	2.64	5.00	217.00	10.30	1.70	2.67	average between poor and rich
cropland tropical	14.00	0.82	54.34	7.00	2259.00	52.04	5.00	7.86	
cropland temperate	7.90	0.31	30.10	0.00	1165.00	58.25	13.00	20.43	
cropland boreal	7.90	0.12	29.41	0.00	1165.00	58.25	13.00	20.43	
grassland tropical	9.60	0.82	38.21	7.00	2259.00	52.04	5.00	7.86	
grassland temperate	5.70	0.31	22.04	17.00	1006.00	66.45	6.90	10.84	assumes 12.5% poor, 75% rich, 12.5% shallow
shallow drained	3.60	0.31	14.34	39.00	527.00	48.76	1.60	2.51	
grassland boreal	5.70	0.12	21.34	1.40	1006.00	51.63	9.50	14.93	
agriculture tropical			46.27			52.04		7.86	average of cropland and grassland
agriculture temperate			26.07			62.35		15.64	average of cropland and grassland
agriculture undiff. boreal			25.37			54.94		17.68	average of cropland and grassland
peat extraction tropical	4.70	0.82	20.24	6.10	2259.00	51.16	0.60	0.94	for CO_2 and N_2O temperate EF × *factor* following IPCC 2006
peat extraction temperate	2.10	0.31	8.84	6.10	542.00	32.90	0.30	0.47	outlier value of Glatzel et al. 2003 excluded from EF
peat extraction boreal	2.10	0.12	8.14	6.10	542.00	32.90	0.30	0.47	

Annex IV.1. Additional Figures

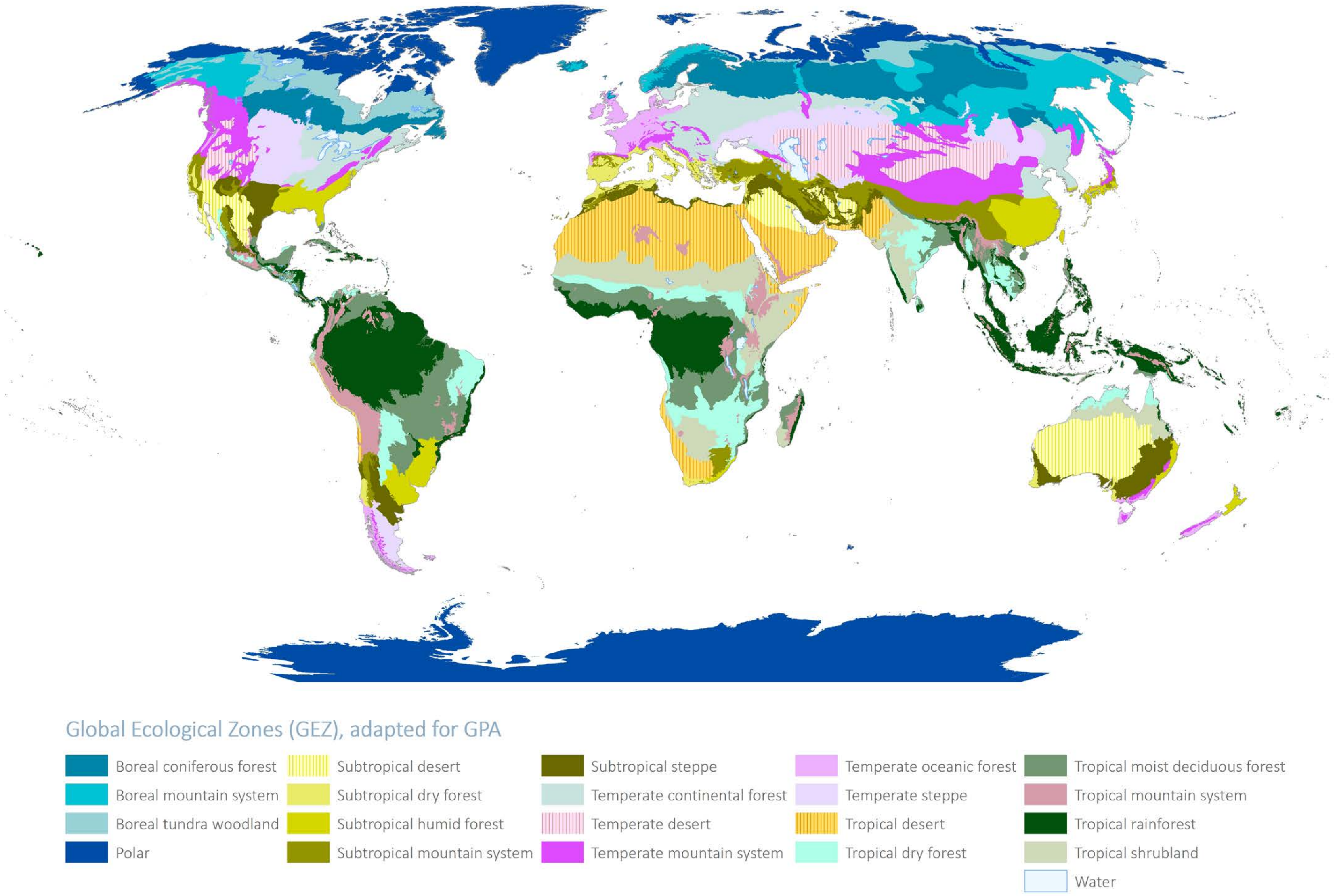


Figure. IV.1 Global Ecological Zones (GEZ) developed by FAO, adapted for the GPA.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre

Boreal coniferous forest

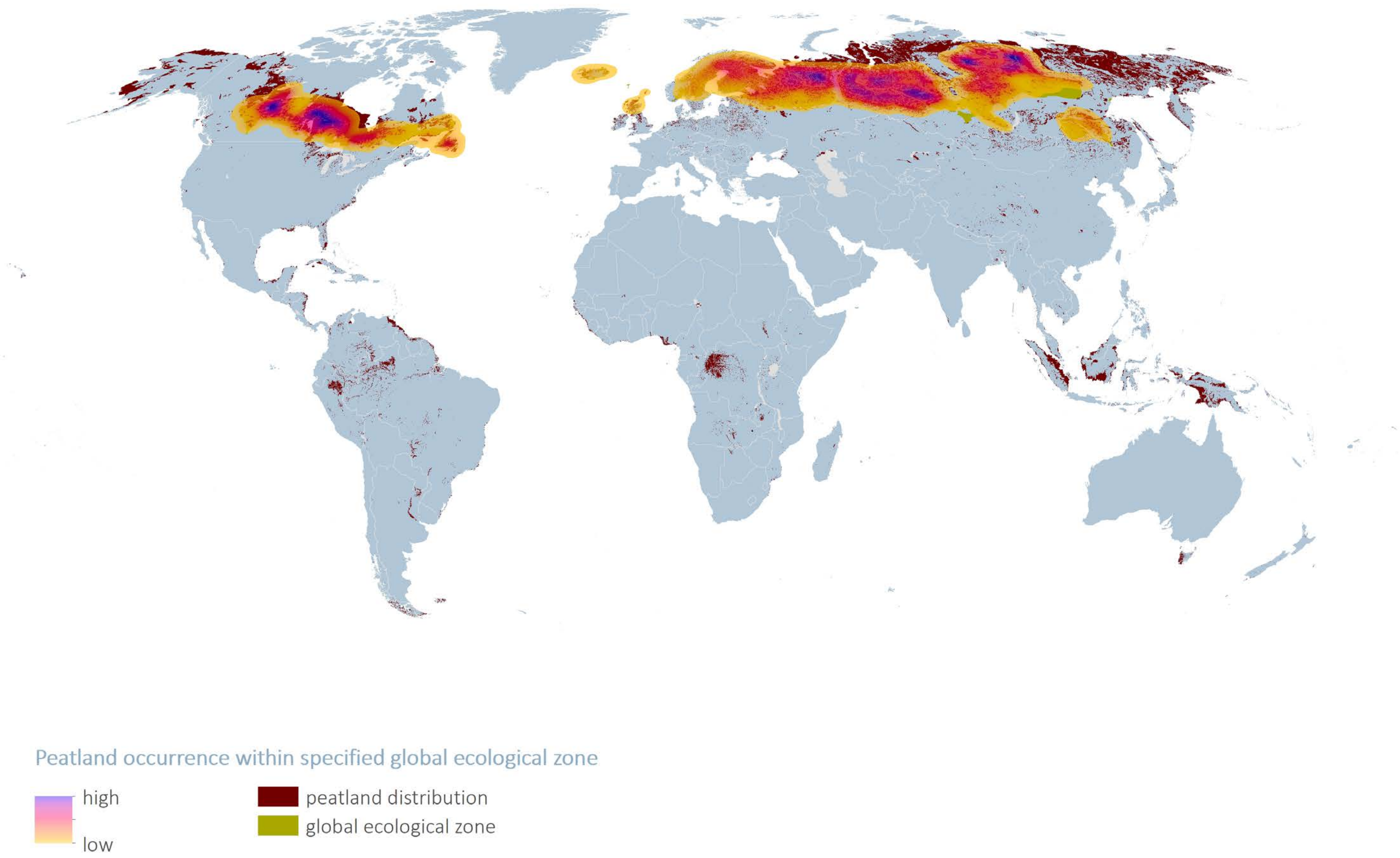


Figure. IV.2 Peatland occurrence within Boreal Coniferous Forests.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Boreal mountain system

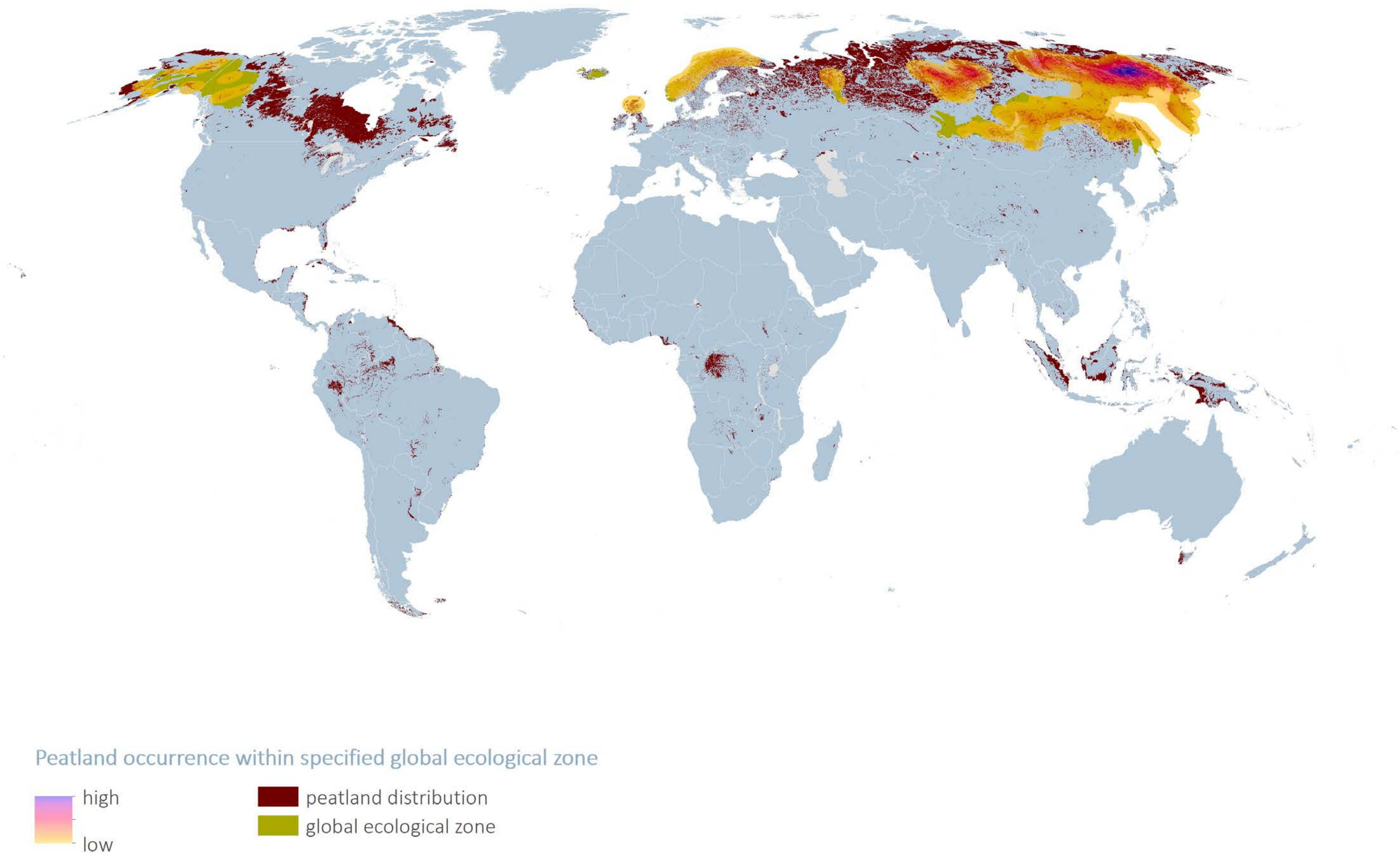


Figure. IV.3 Peatland occurrence within Boreal Mountain Systems.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Boreal tundra woodland

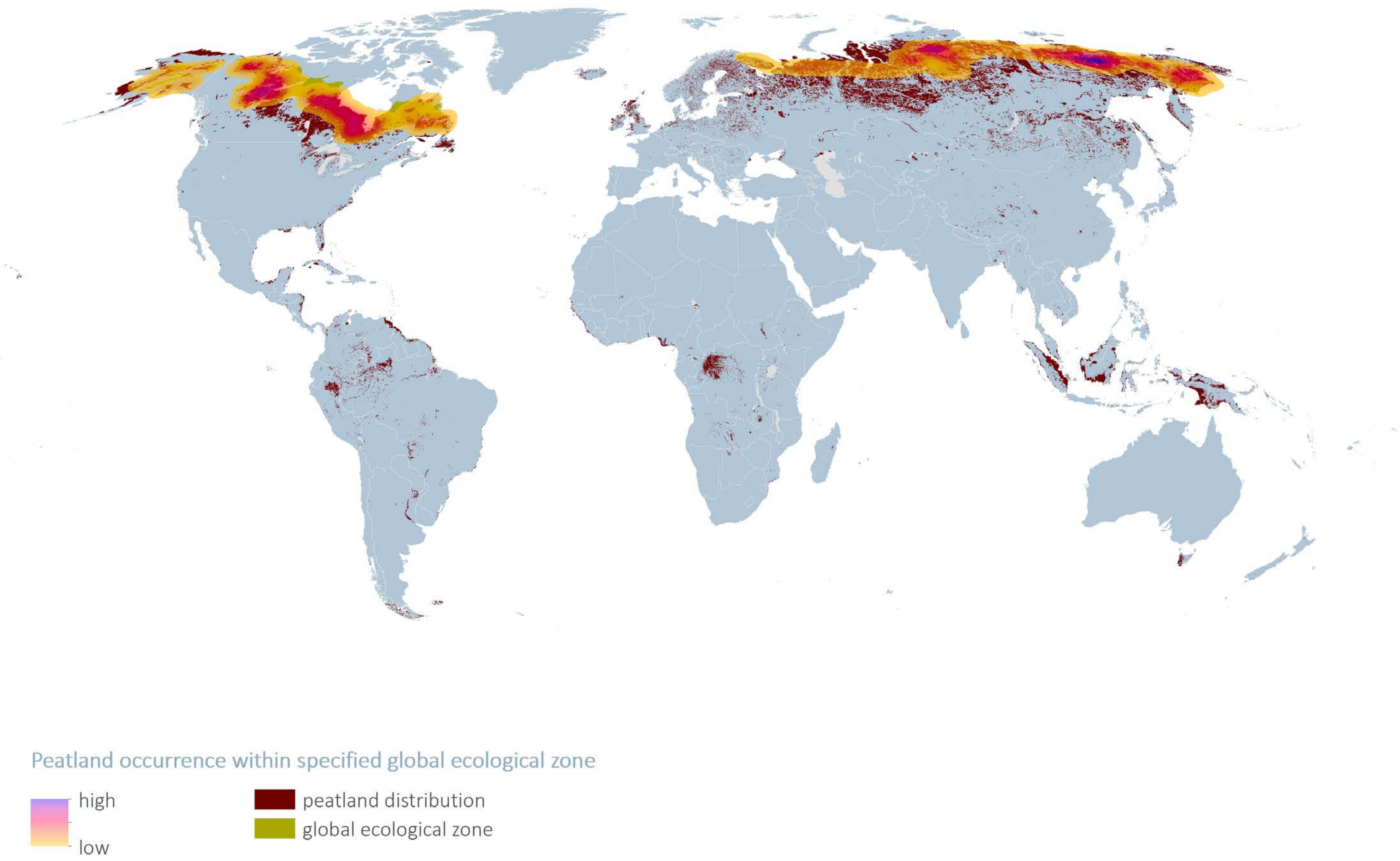


Figure. IV.4 Peatland occurrence within Boreal Tundra Woodlands.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

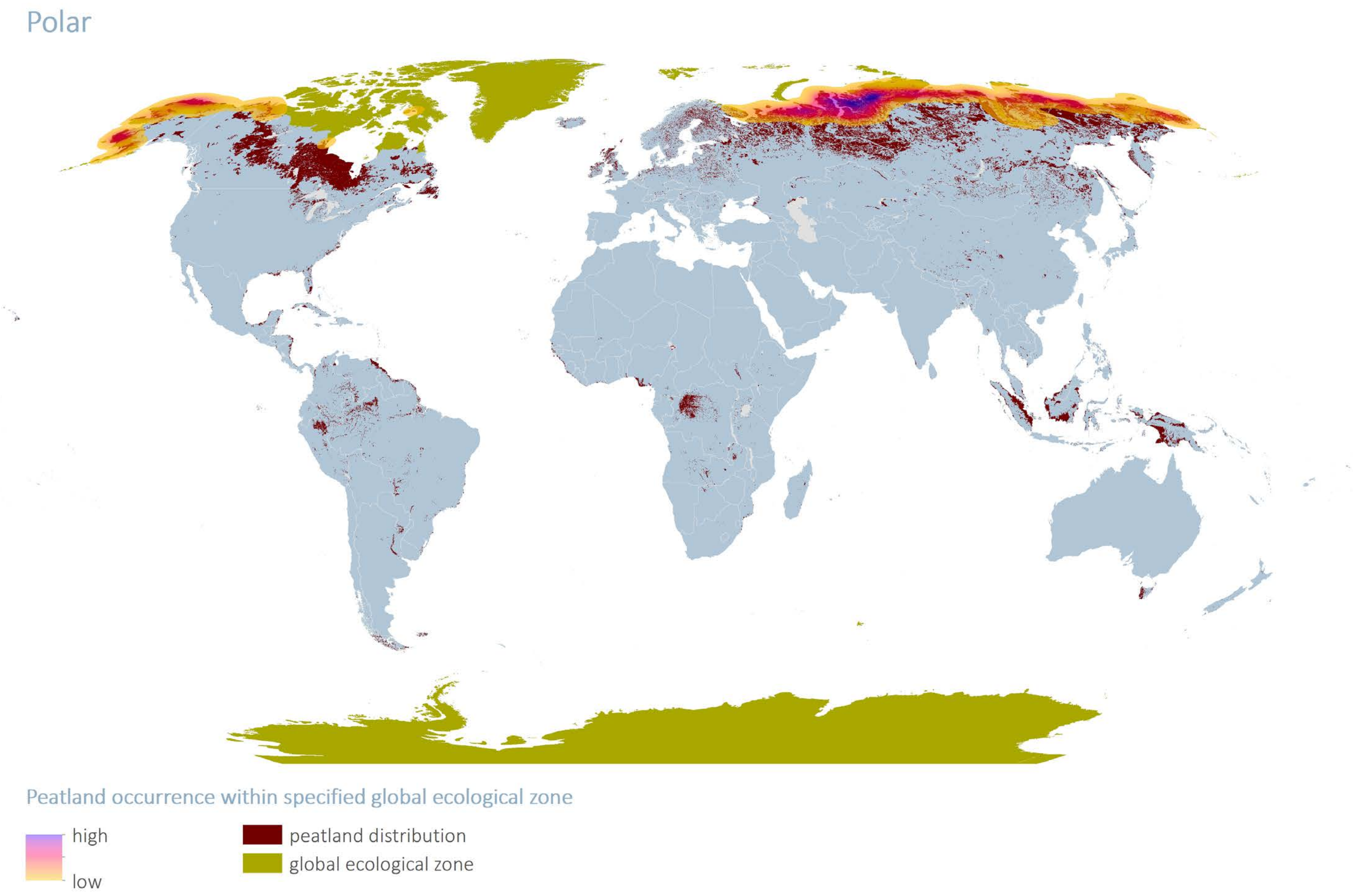


Figure. IV.5 Peatland occurrence within Polar Zones.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Subtropical desert

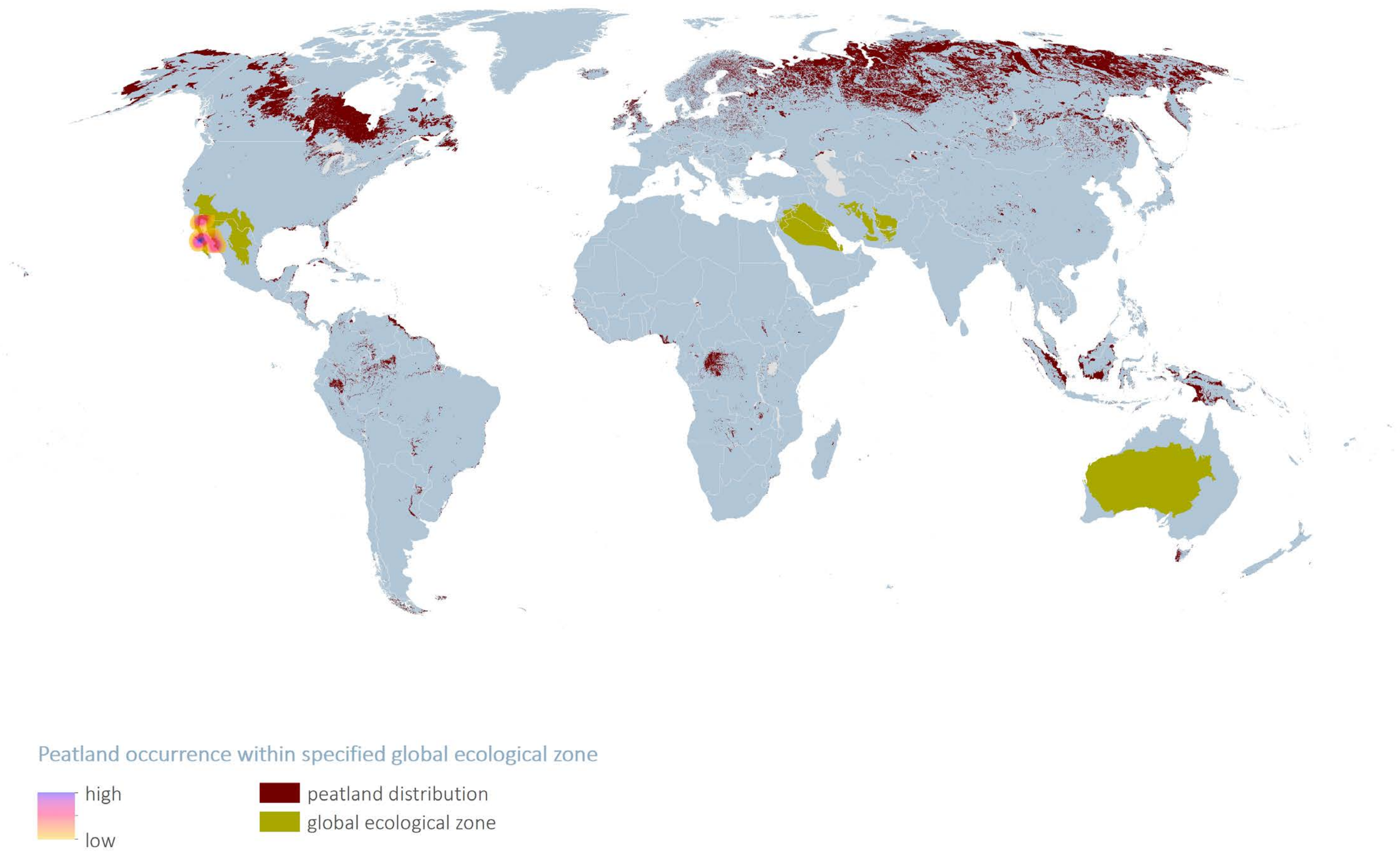


Figure. IV.6 Peatland occurrence within Subtropical Deserts.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre

Subtropical dry forest

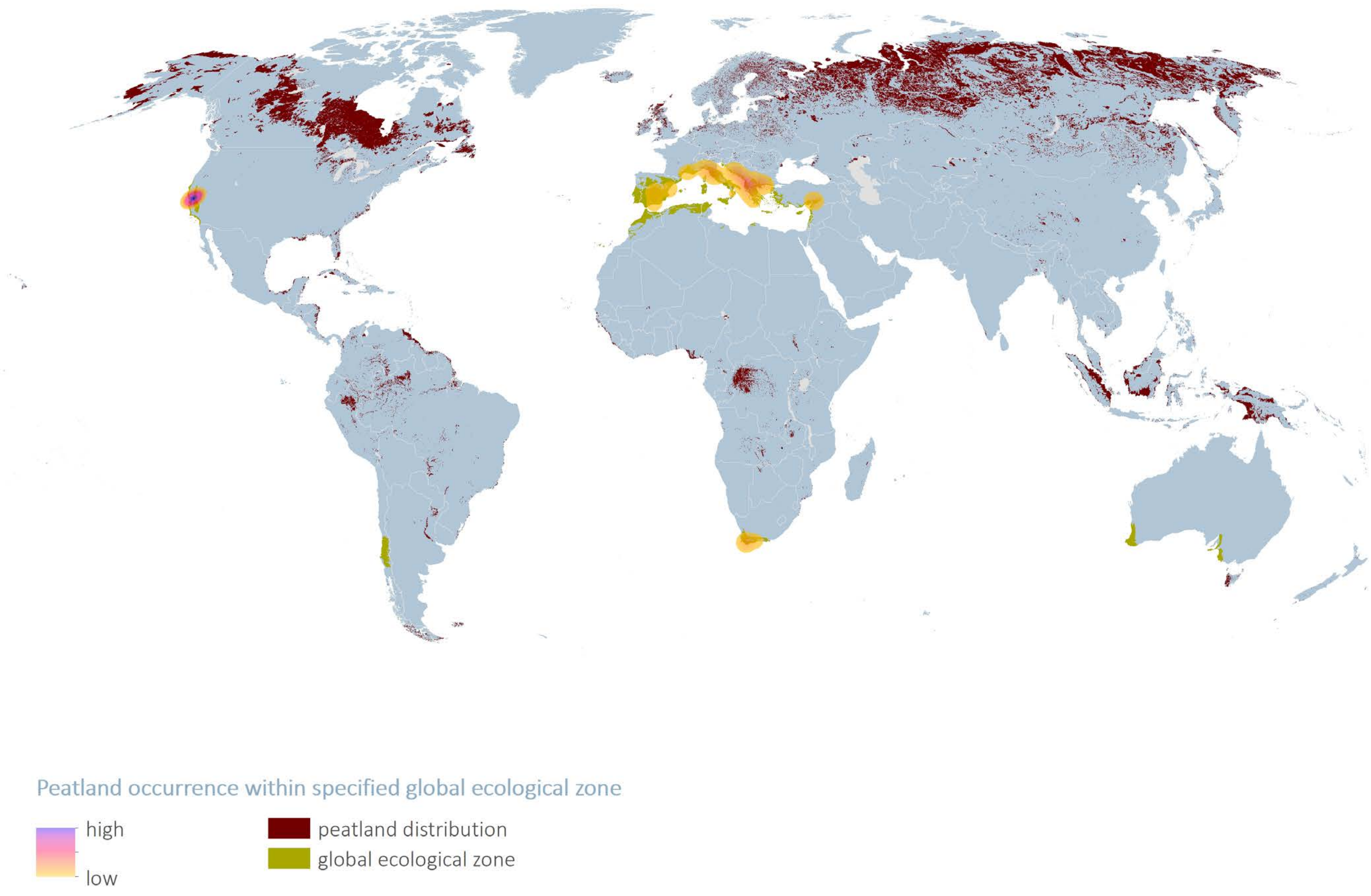
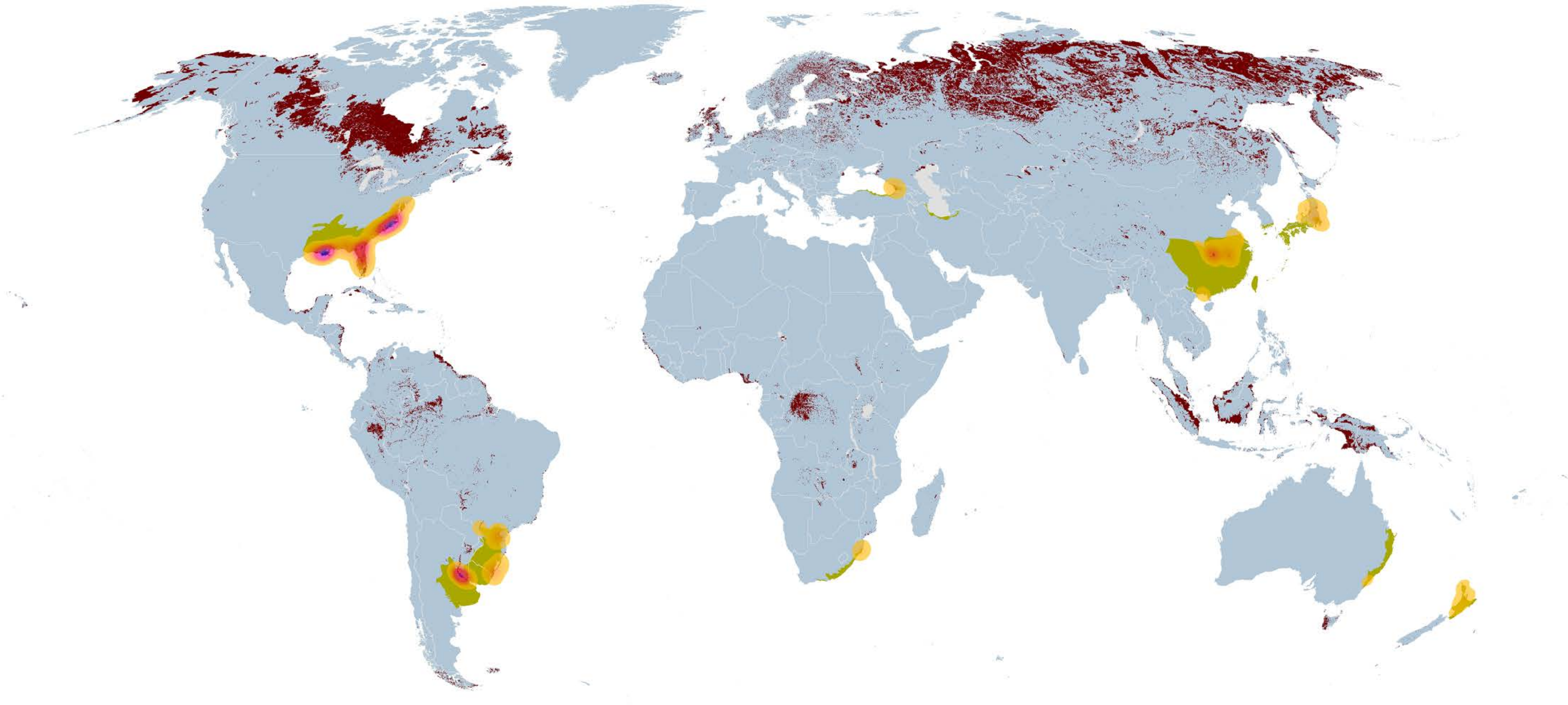


Figure. IV.7 Peatland occurrence within Subtropical Dry Forests.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Subtropical humid forest



Peatland occurrence within specified global ecological zone

high

low

🟥 peatland distribution

🟩 global ecological zone

Figure. IV.8 Peatland occurrence within Subtropical Humid Forests.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

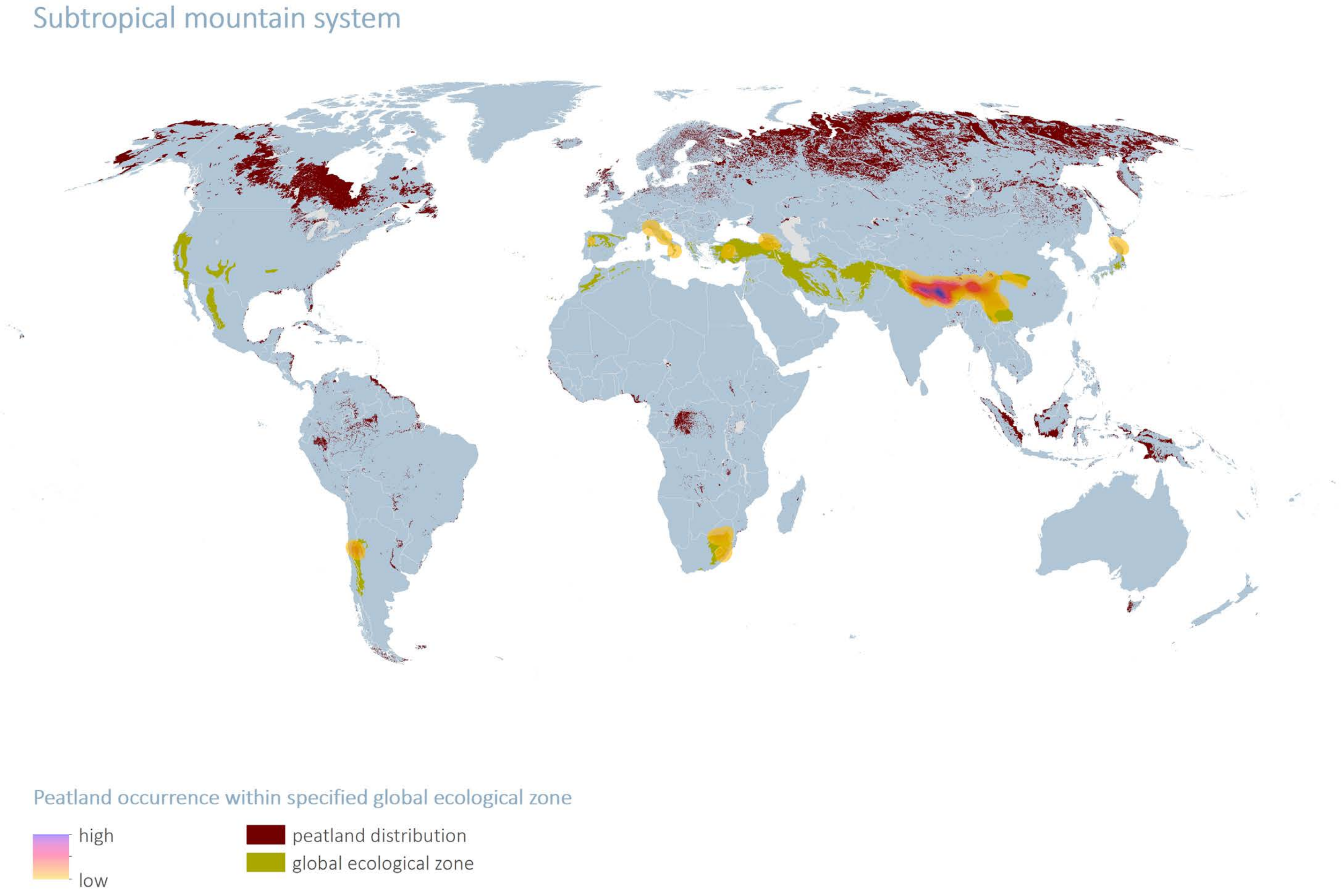


Figure. IV.9 Peatland occurrence within Subtropical Mountain Systems.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Subtropical steppe

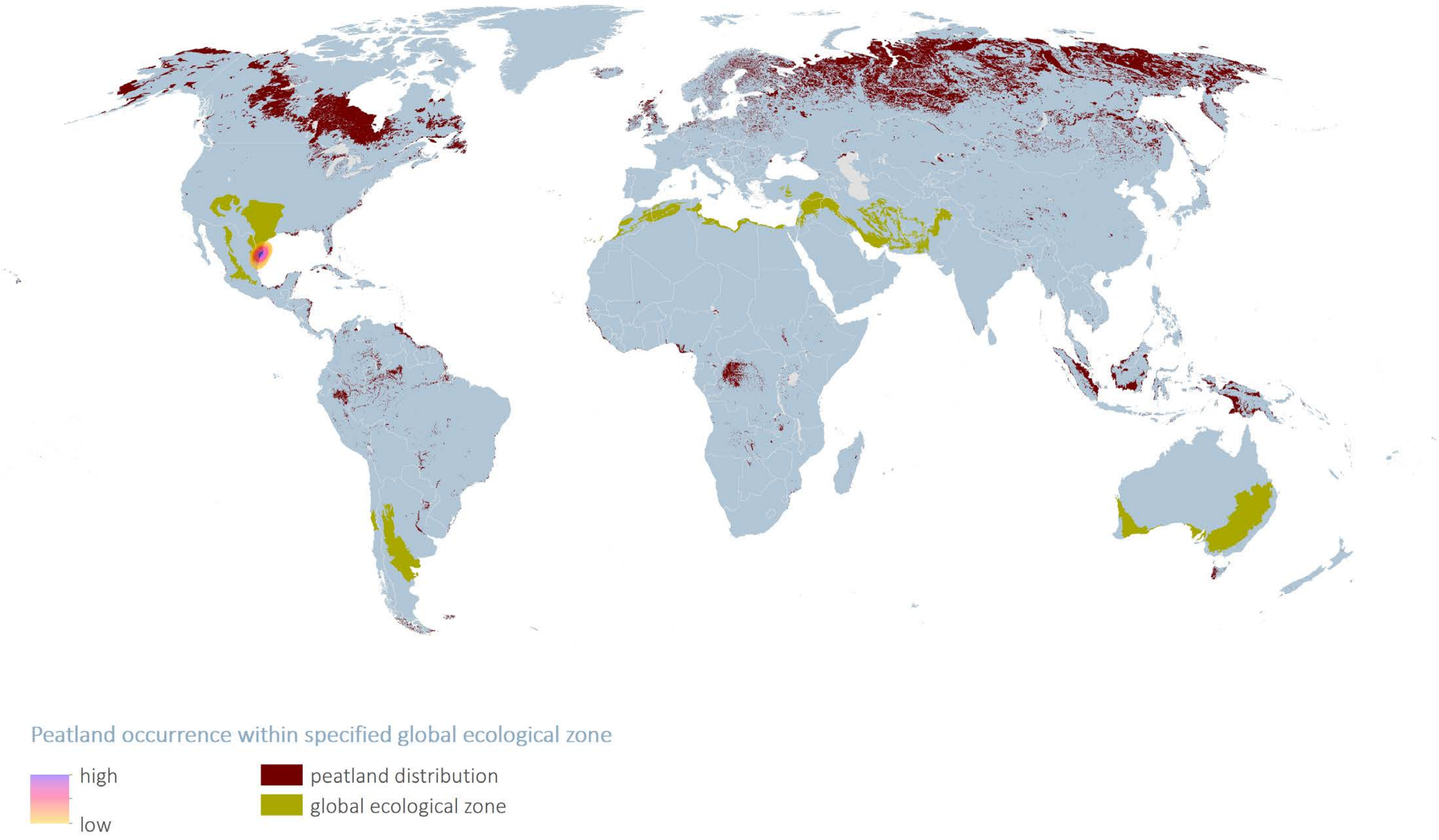


Figure. IV.10 Peatland occurrence within Subtropical Steppes.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Temperate continental forest

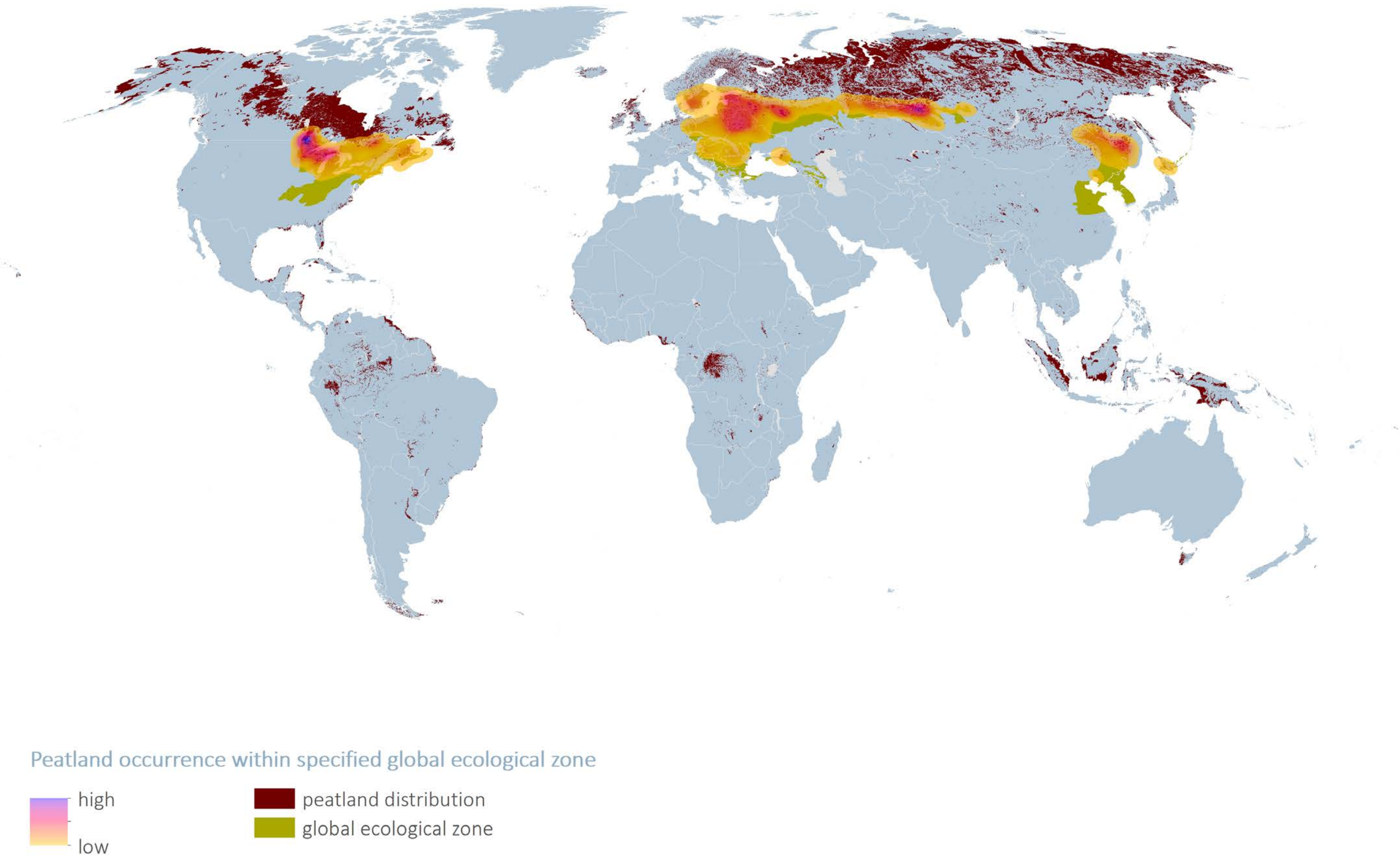


Figure. IV.11 Peatland occurrence within Temperate Continental Forests.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Temperate desert

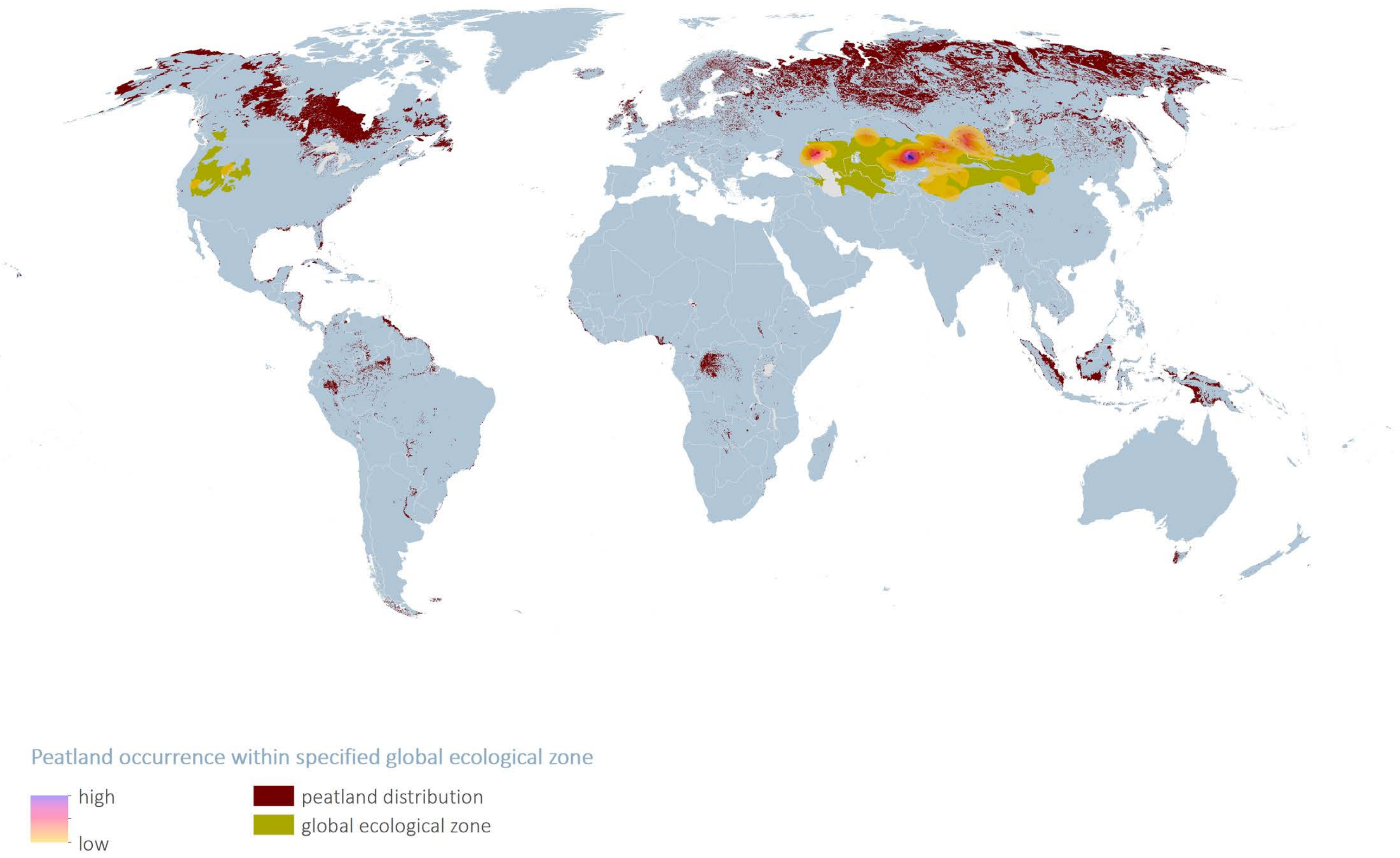


Figure. IV.12 Peatland occurrence within Temperate Deserts.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Temperate mountain system

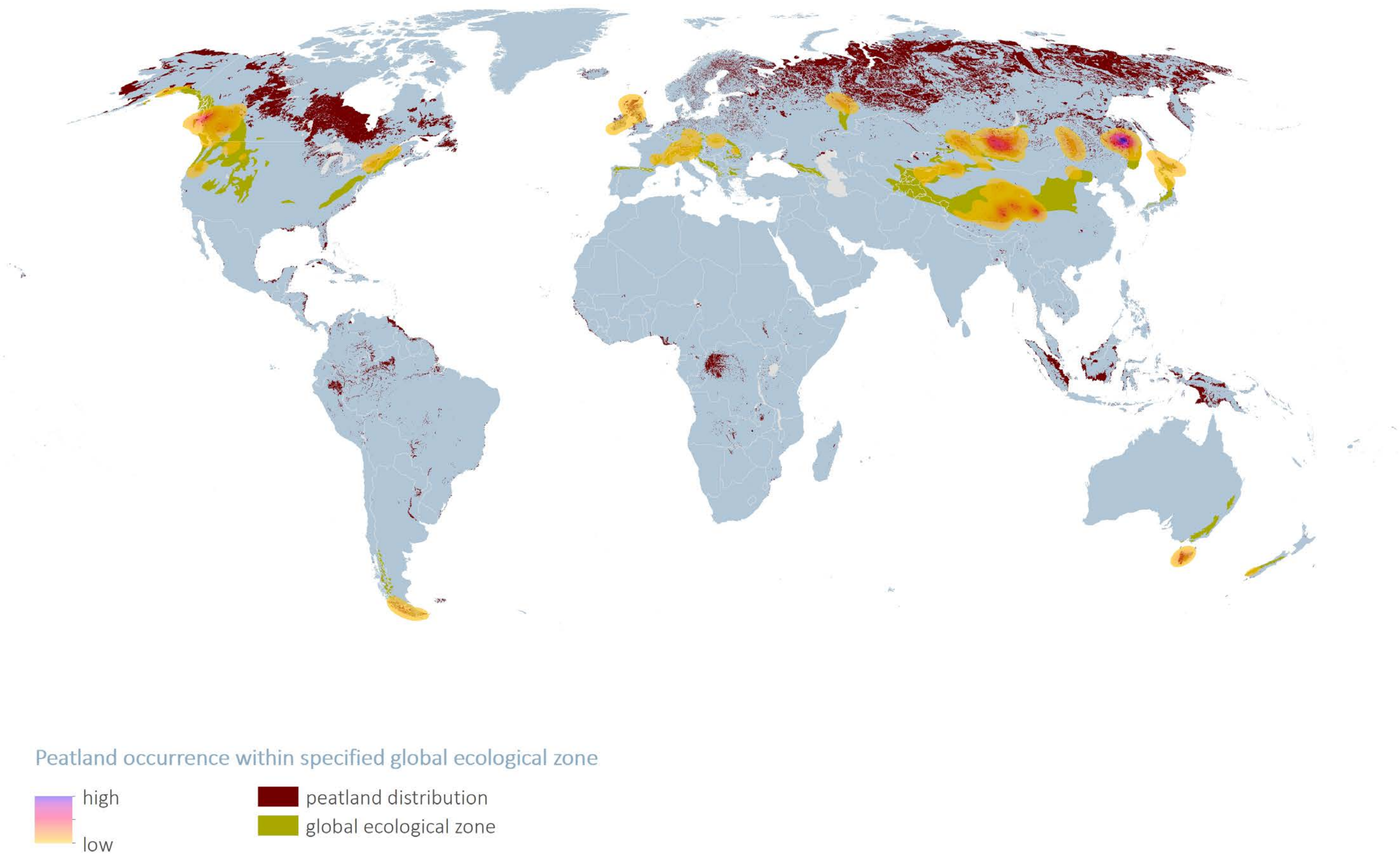
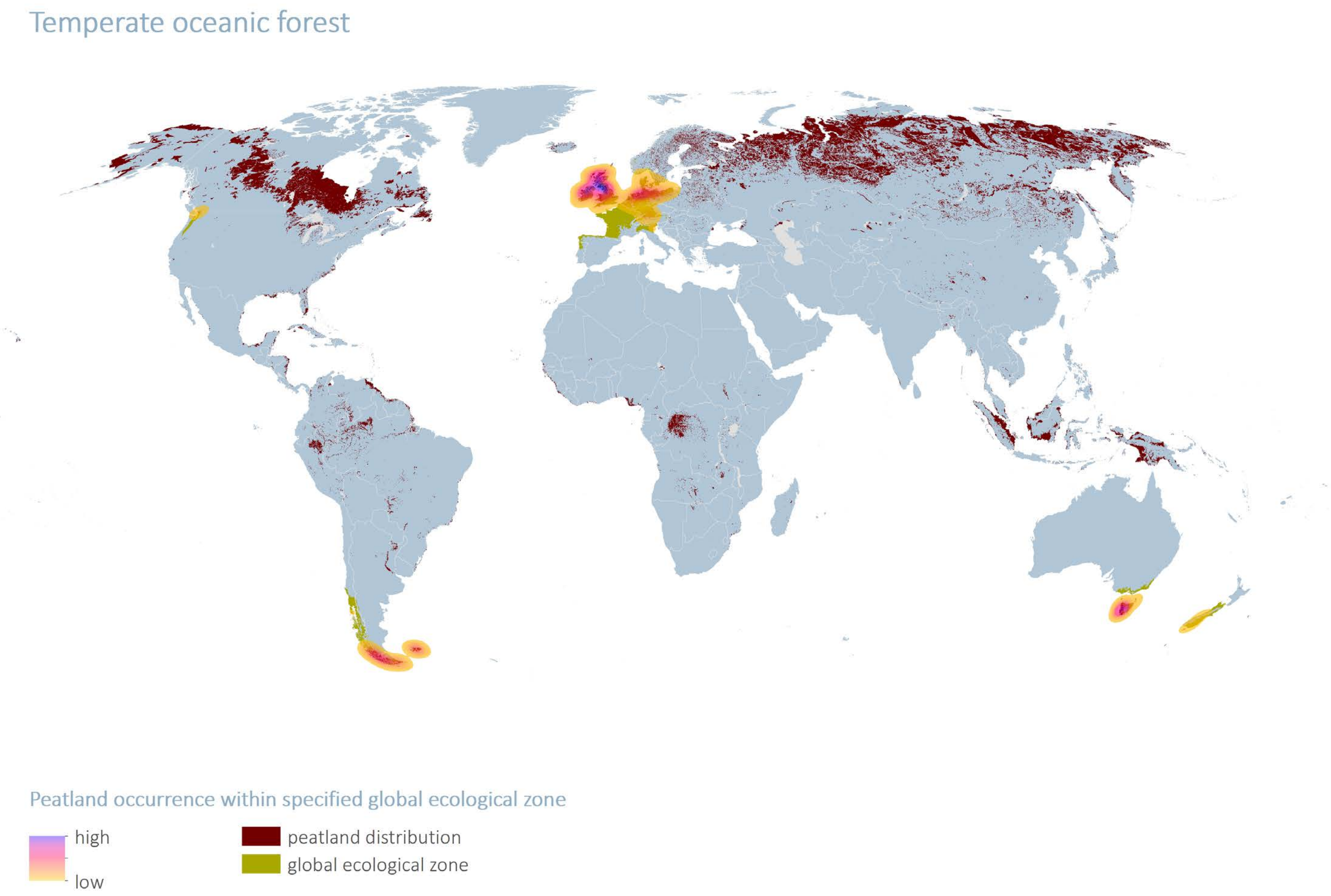


Figure. IV.13 Peatland occurrence within Temperate Mountain Systems.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.



Temperate oceanic forest

Figure IV.14 Peatland occurrence within Temperate Oceanic Forests.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Temperate steppe

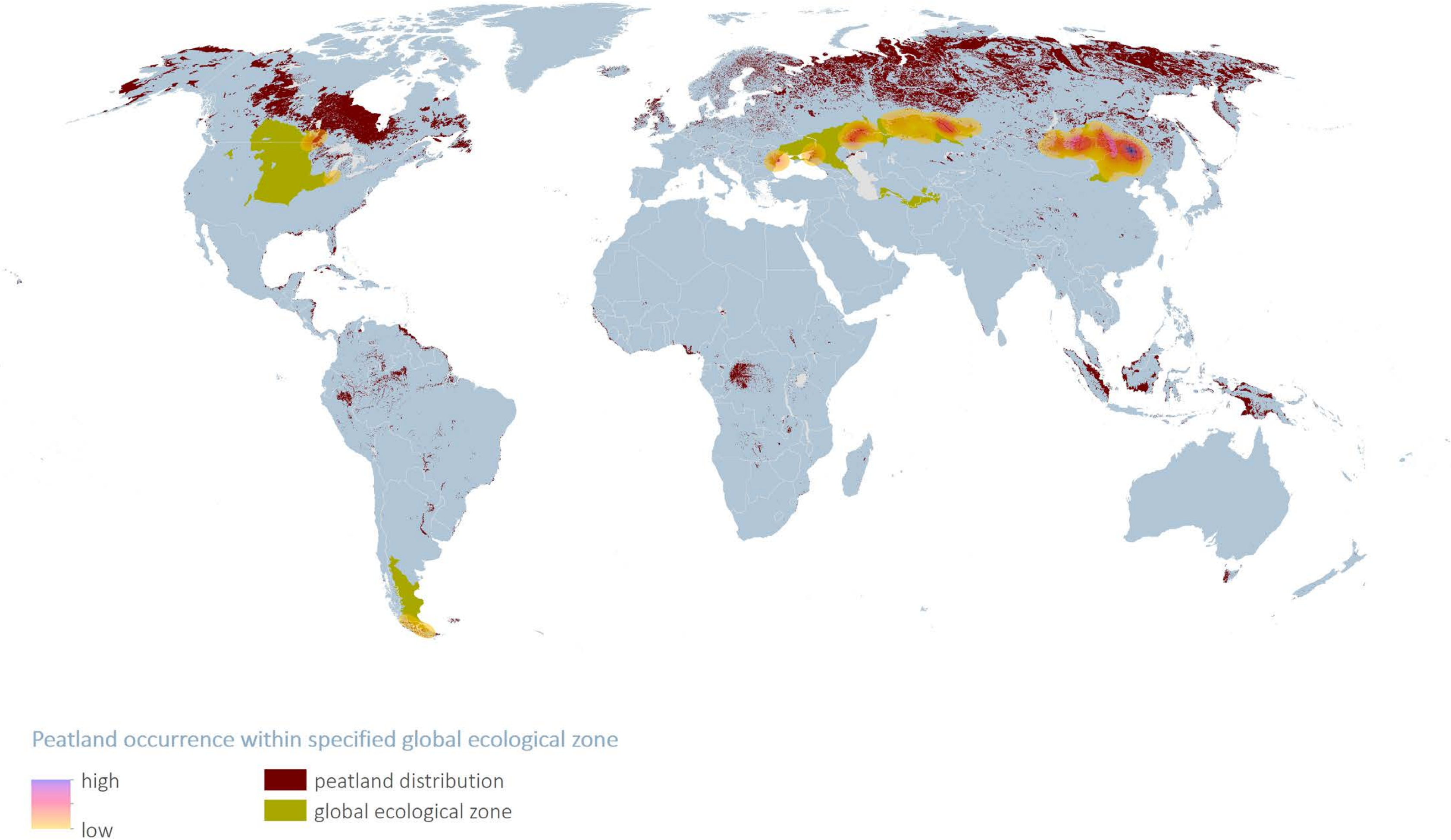


Figure IV.15 Peatland occurrence within Temperate Steppes.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Tropical desert

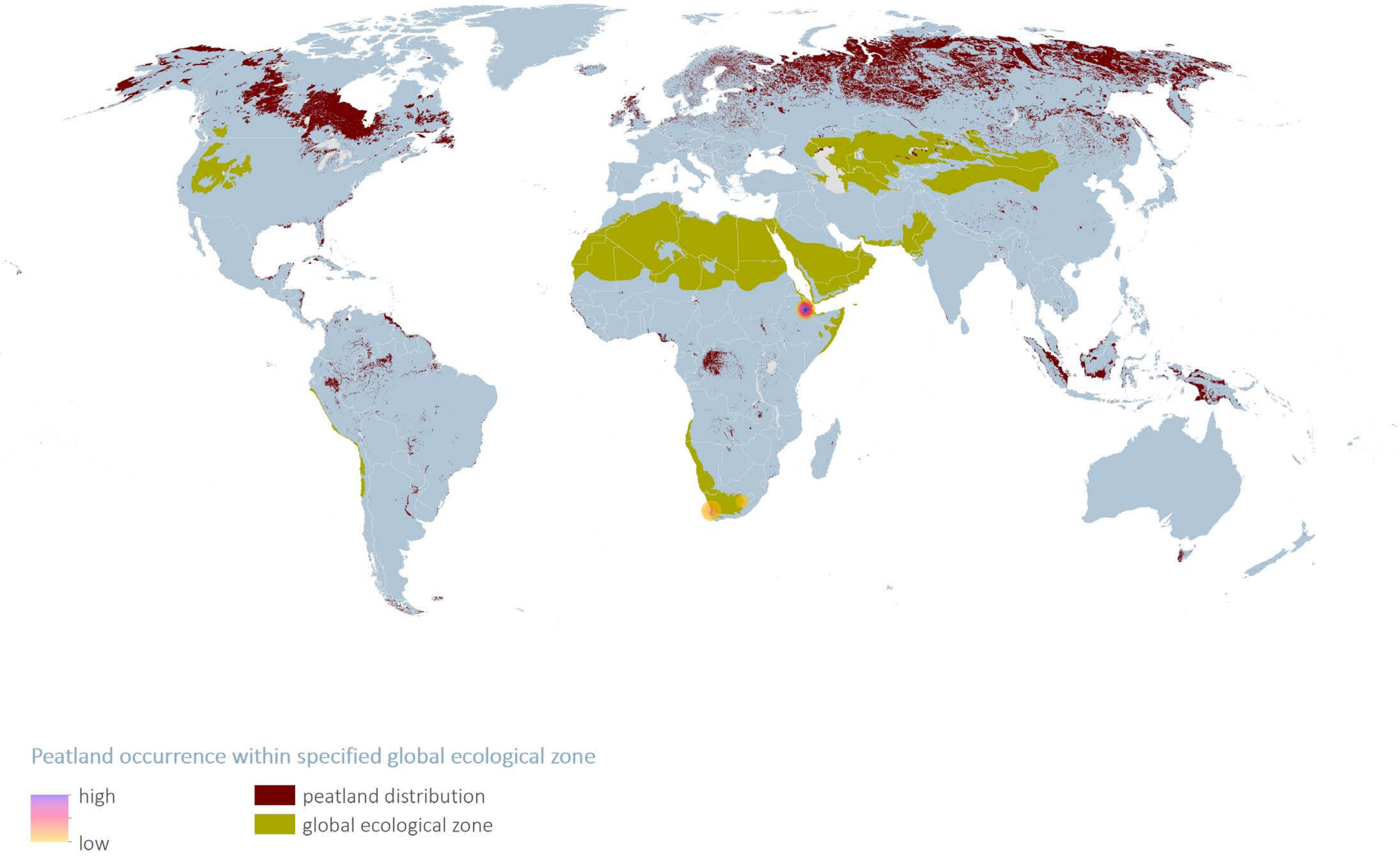


Figure IV.16 Peatland occurrence within Tropical Deserts.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Tropical dry forest

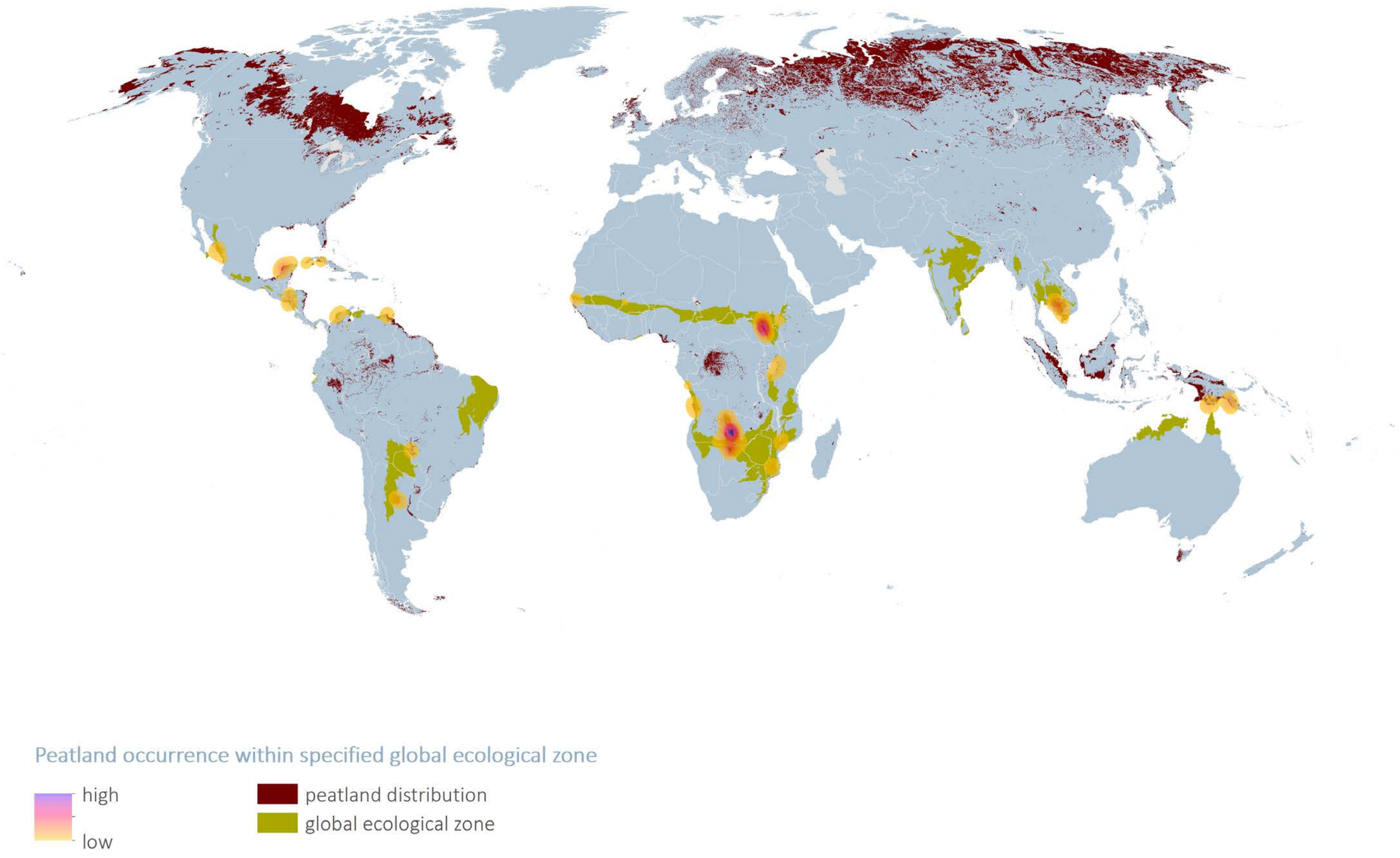


Figure IV.17 Peatland occurrence within Tropical Dry Forests.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Tropical moist deciduous forest

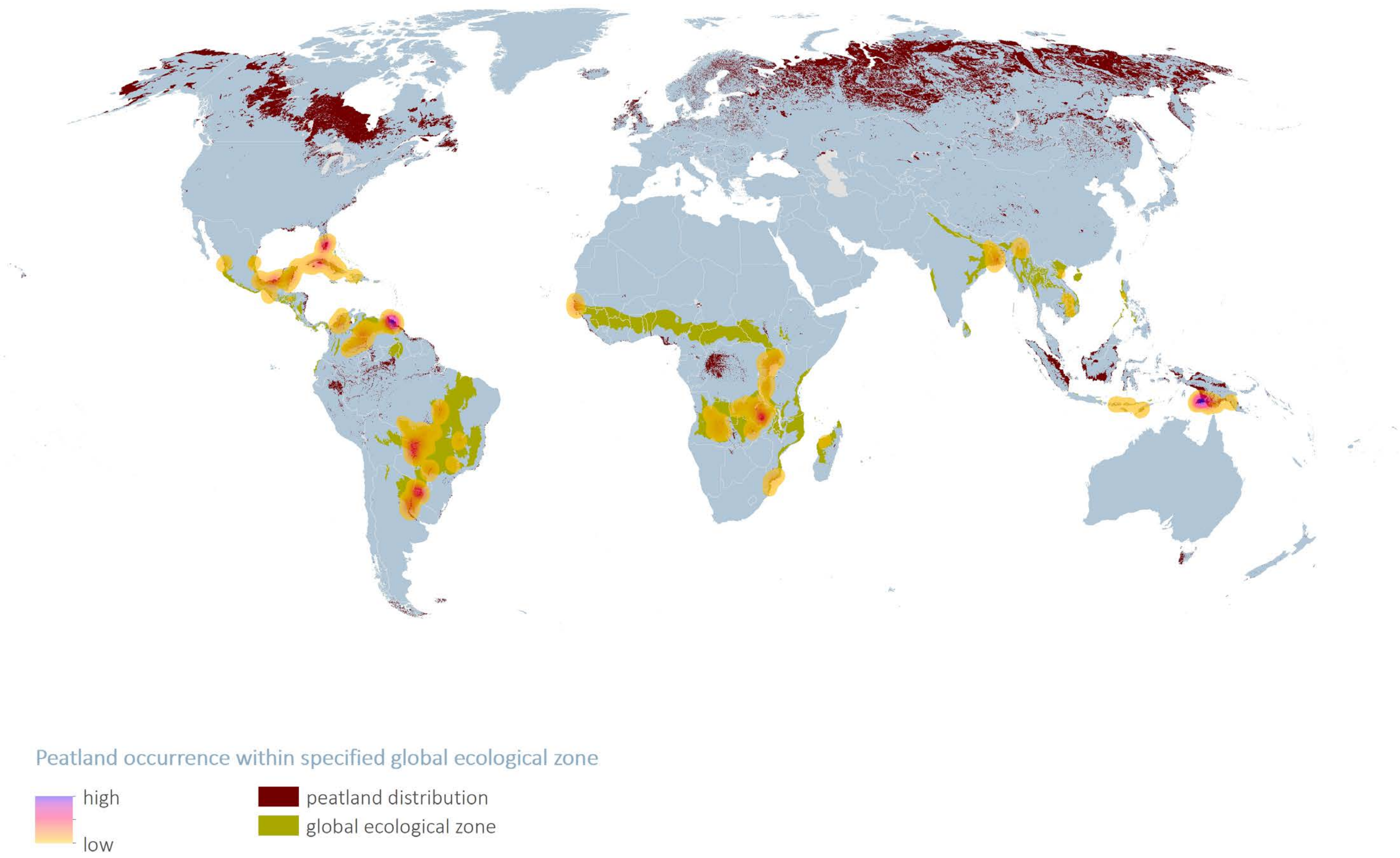


Figure IV.18 Peatland occurrence within Tropical Moist Deciduous Forests.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Tropical mountain system

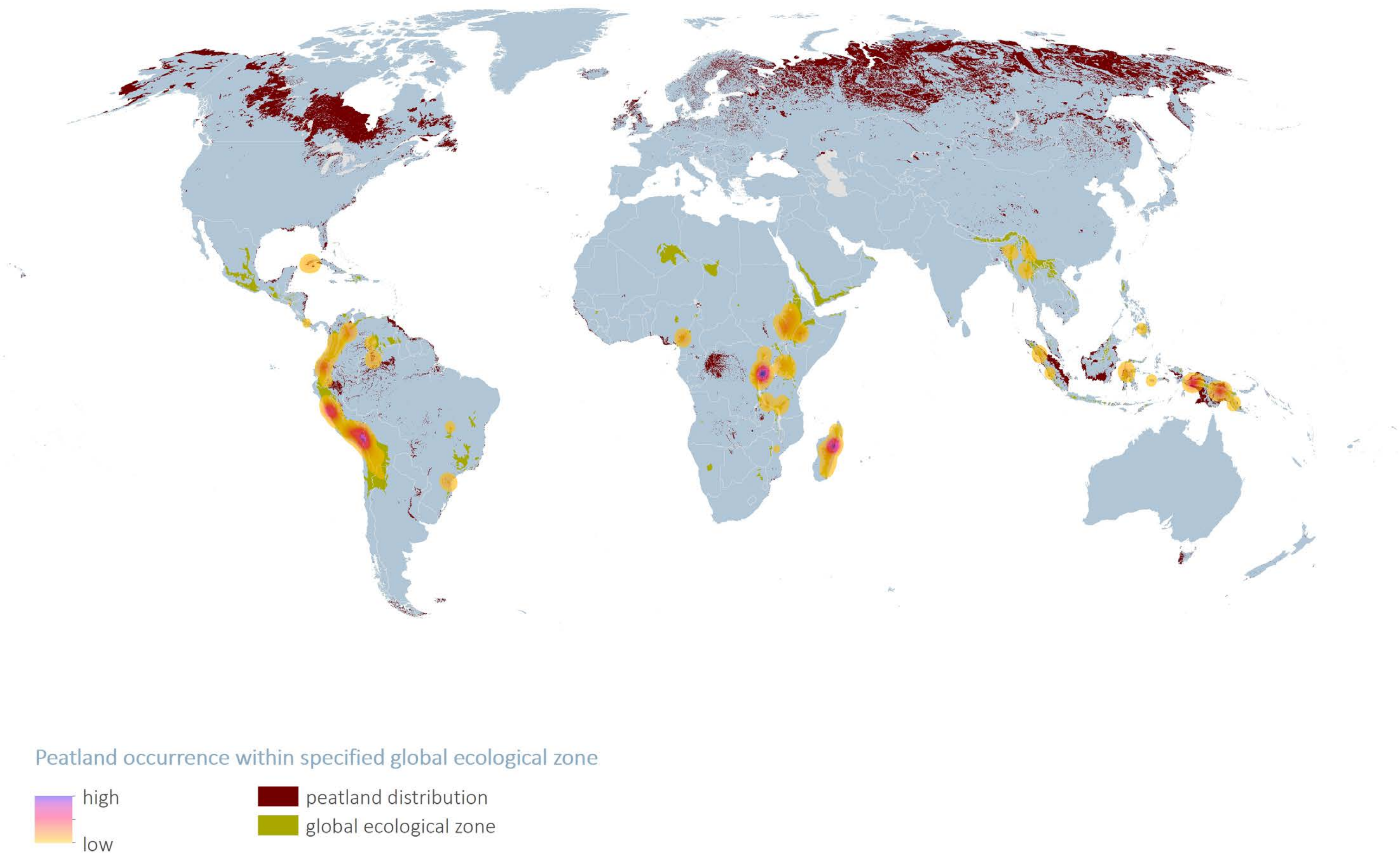


Figure IV.19 Peatland occurrence within Tropical Mountain Systems.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Tropical rainforest

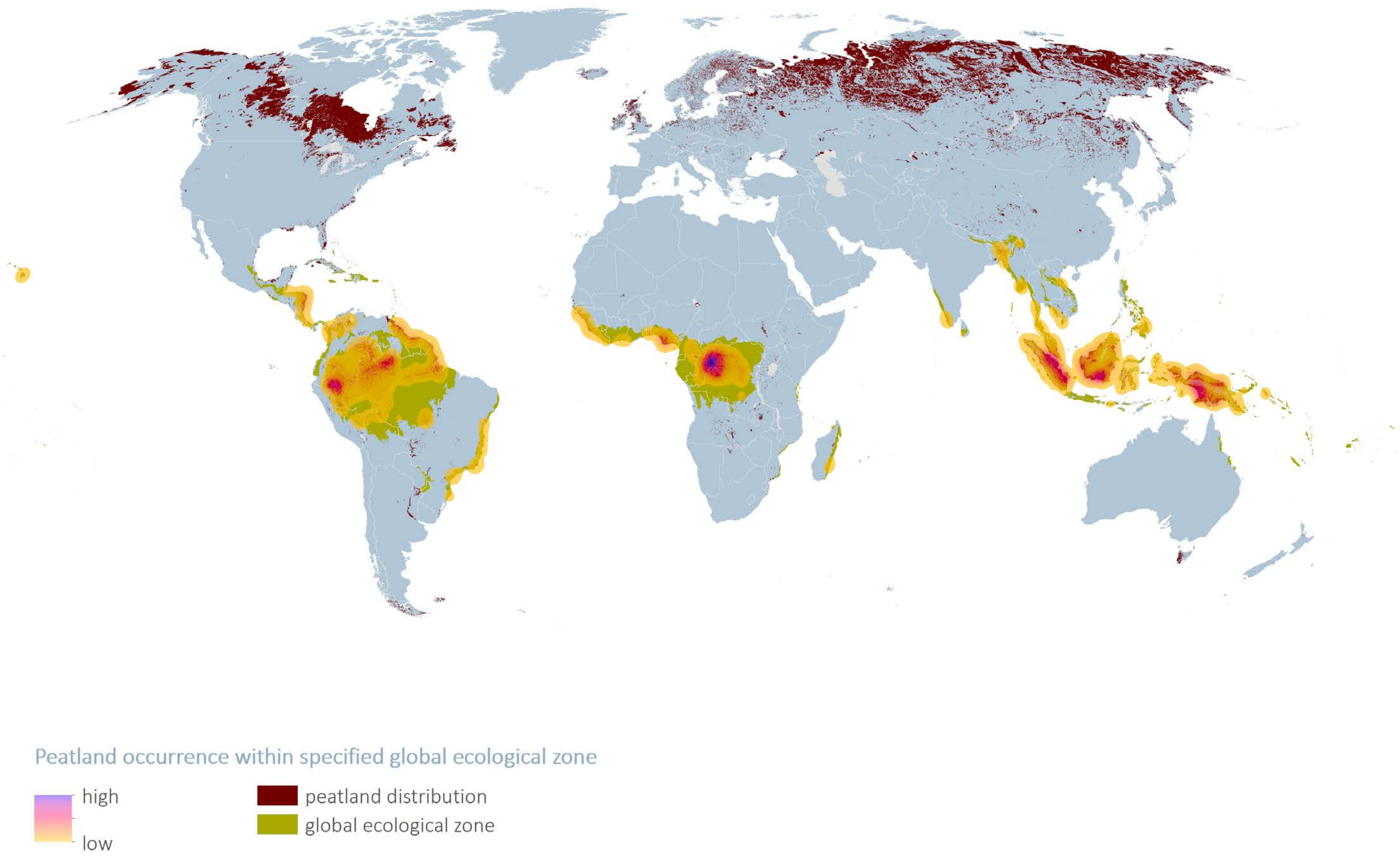


Figure IV.20 Peatland occurrence within Tropical Rainforests.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Tropical shrubland

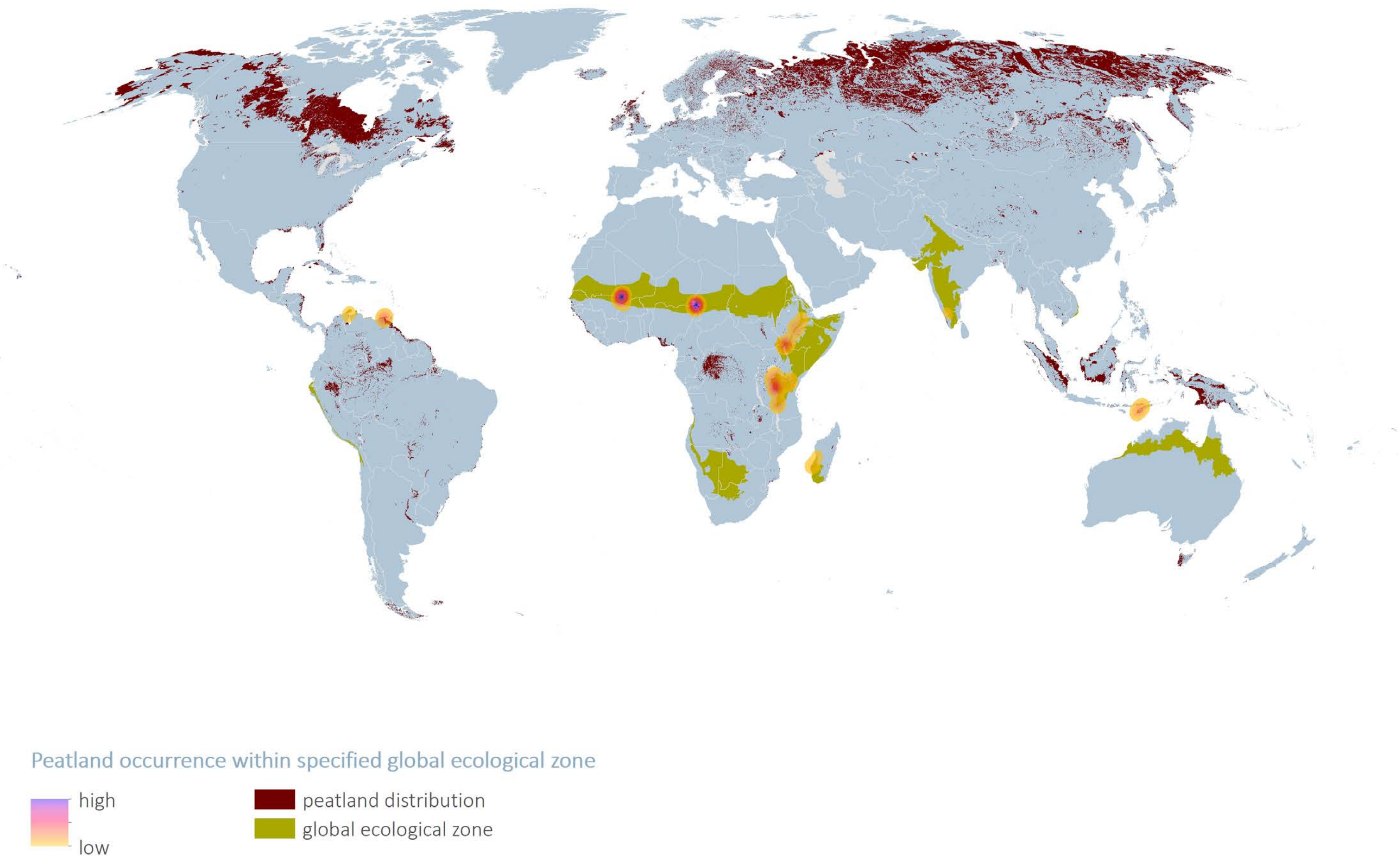


Figure IV.21 Peatland occurrence within Tropical Shrublands.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

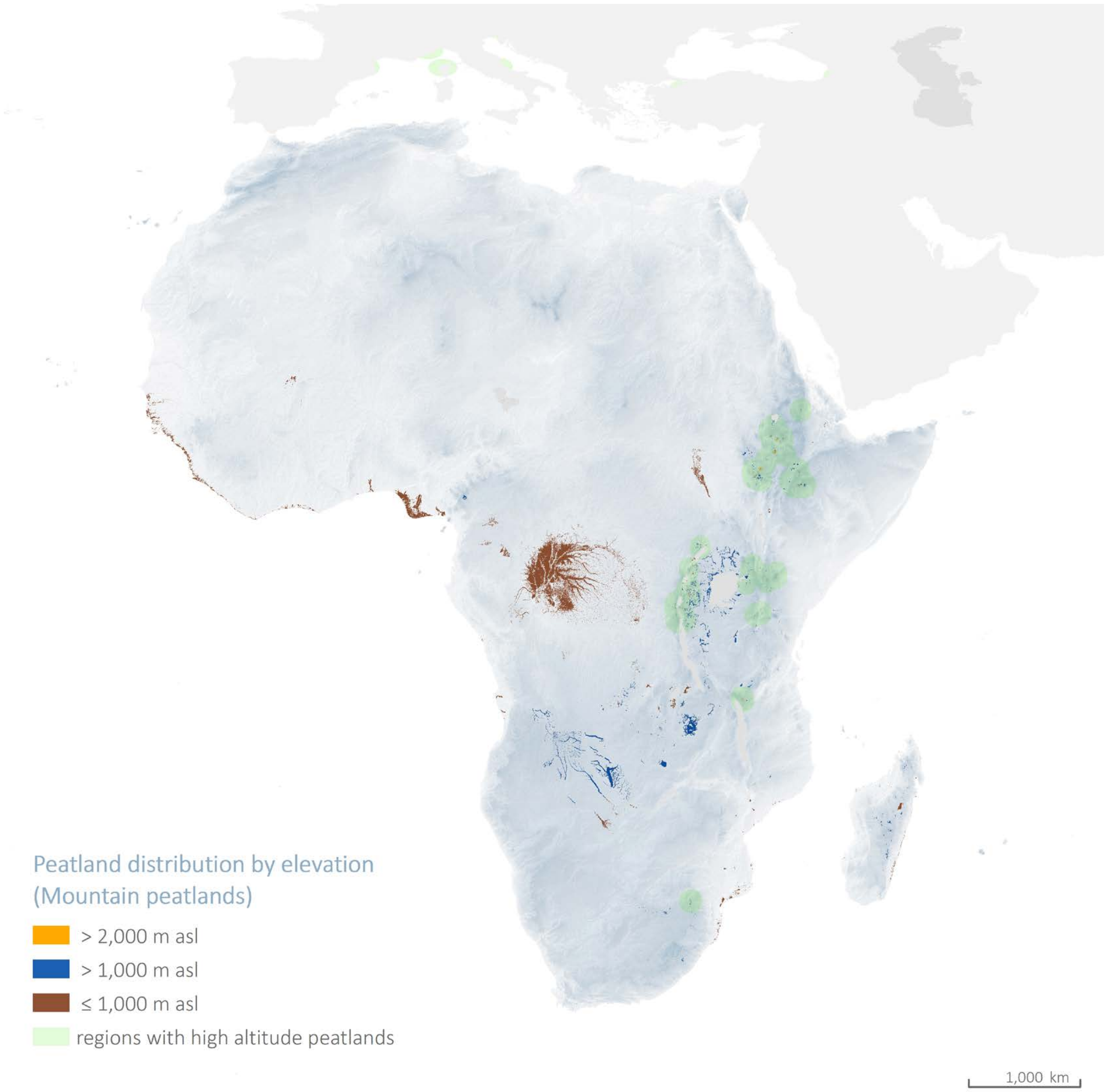


Figure IV.22 Distribution of Mountain Peatlands in Africa by elevation (in meters above sea level).
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

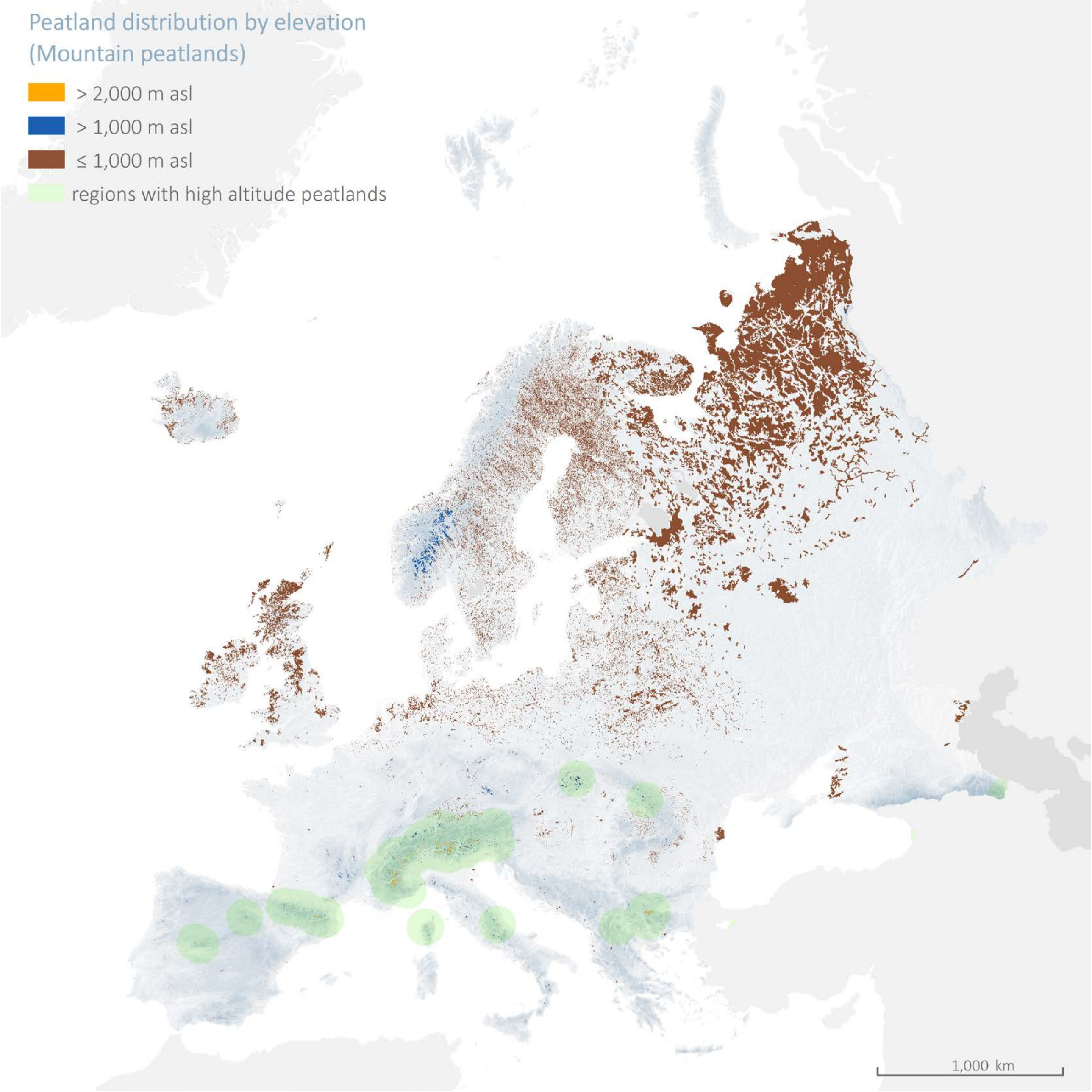


Figure IV.23 Distribution of Mountain Peatlands in Europe by elevation (in meters above sea level).
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

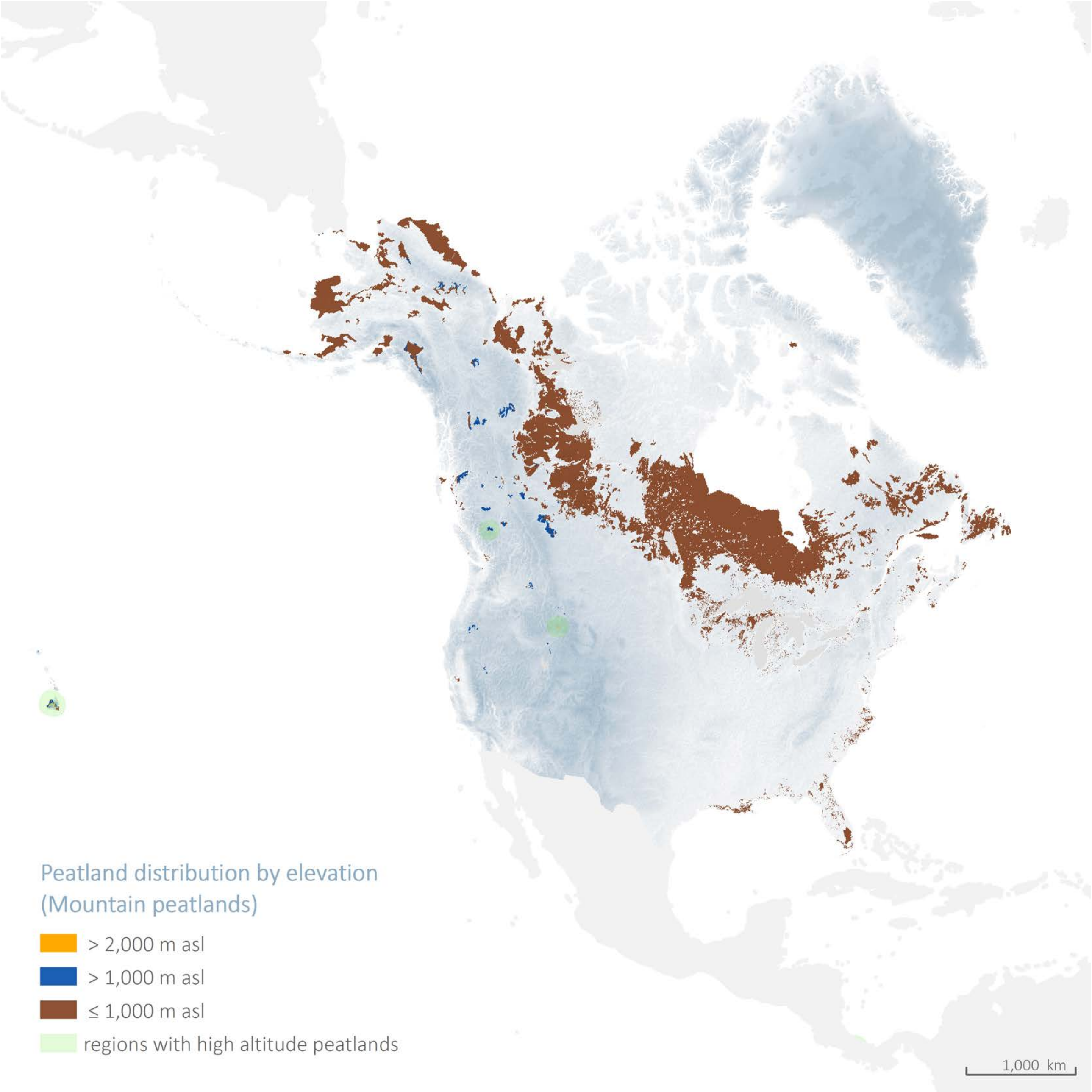


Figure IV.24 Distribution of Mountain Peatlands in North America by elevation (in meters above sea level).
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

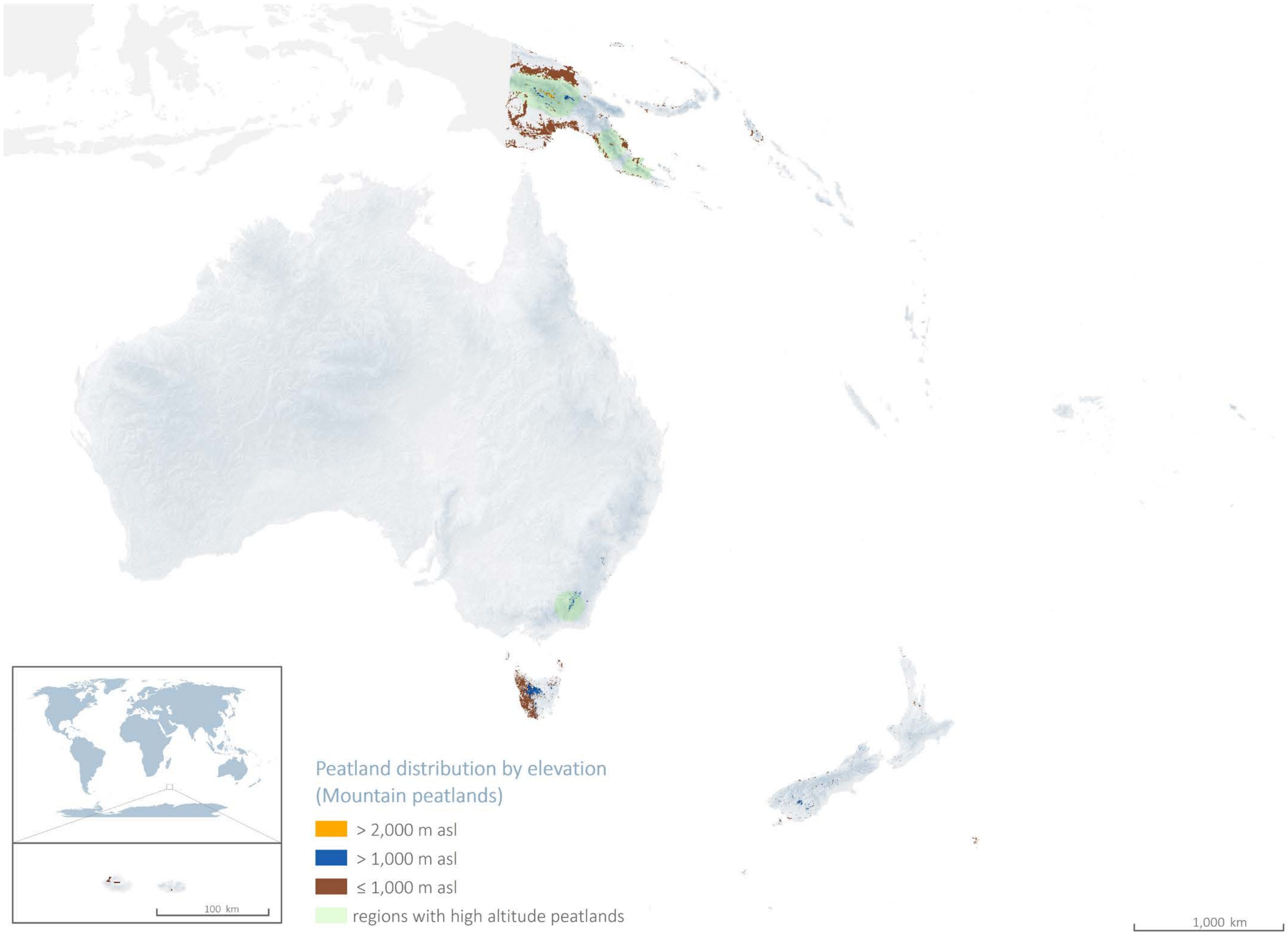


Figure IV.25 Distribution of Mountain Peatlands in Oceania by elevation (in meters above sea level).
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

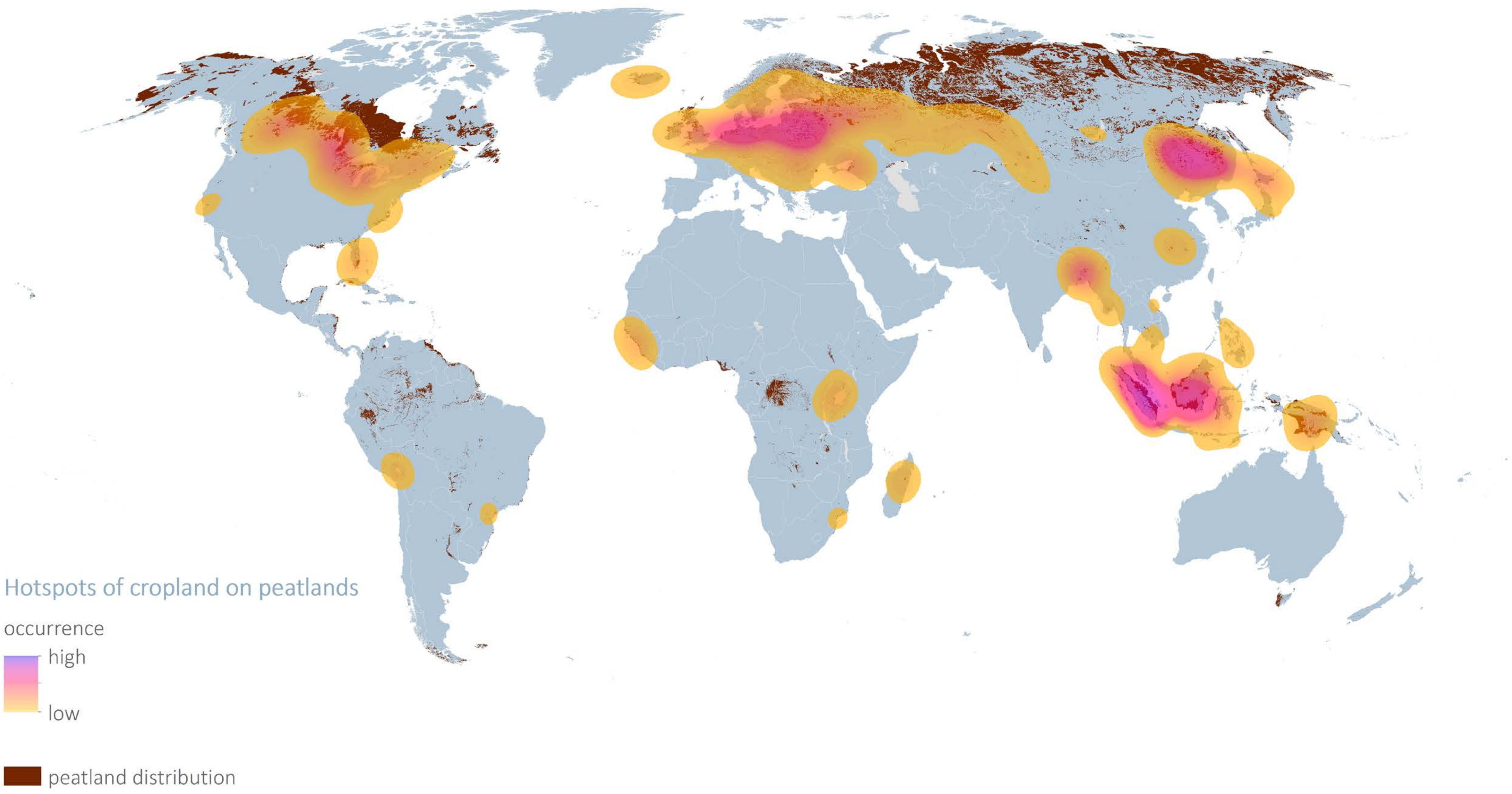


Figure IV.26. Hotspot of croplands on peatlands worldwide.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

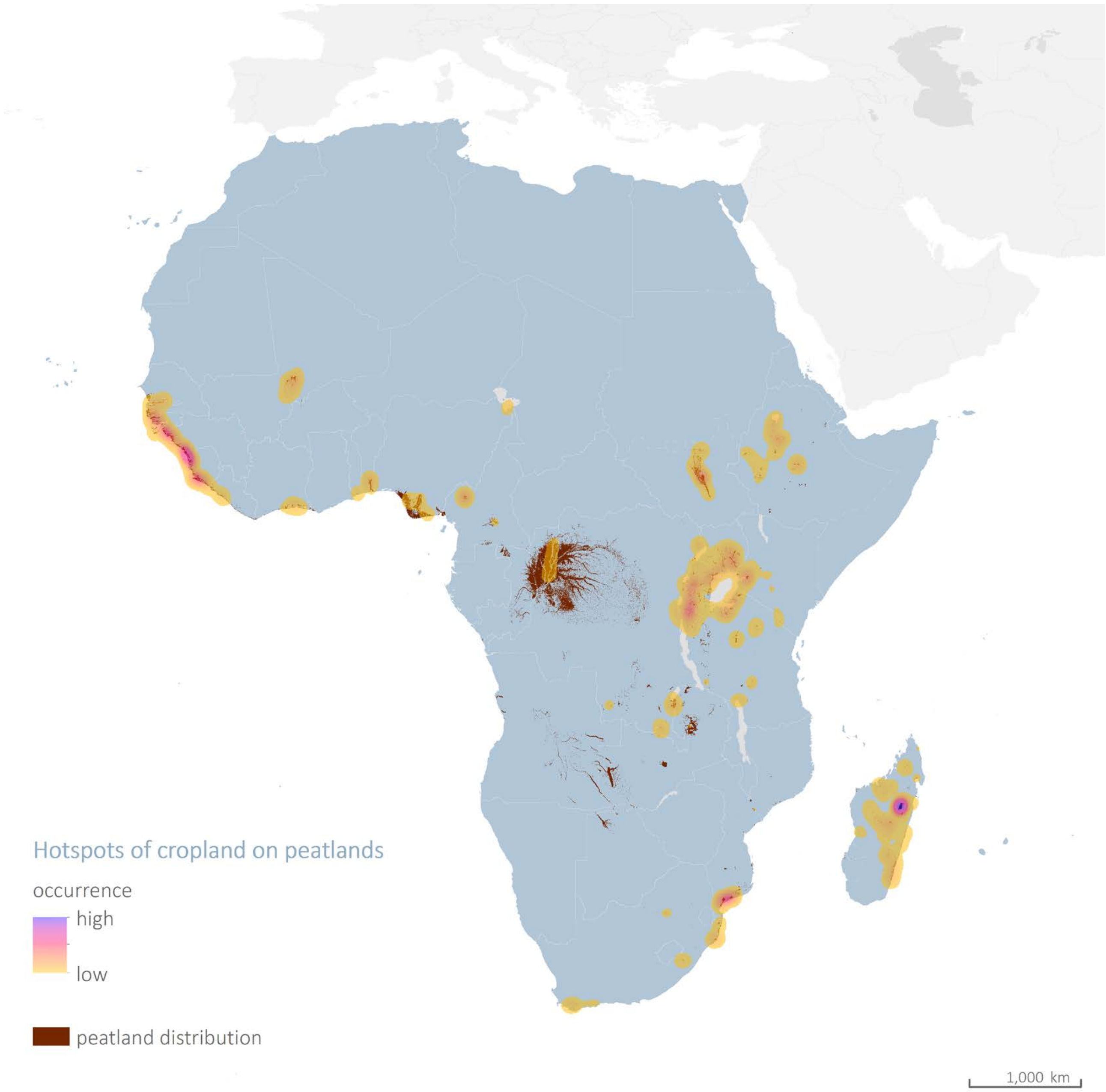


Figure IV.27. Hotspots of croplands on peatlands in Africa.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

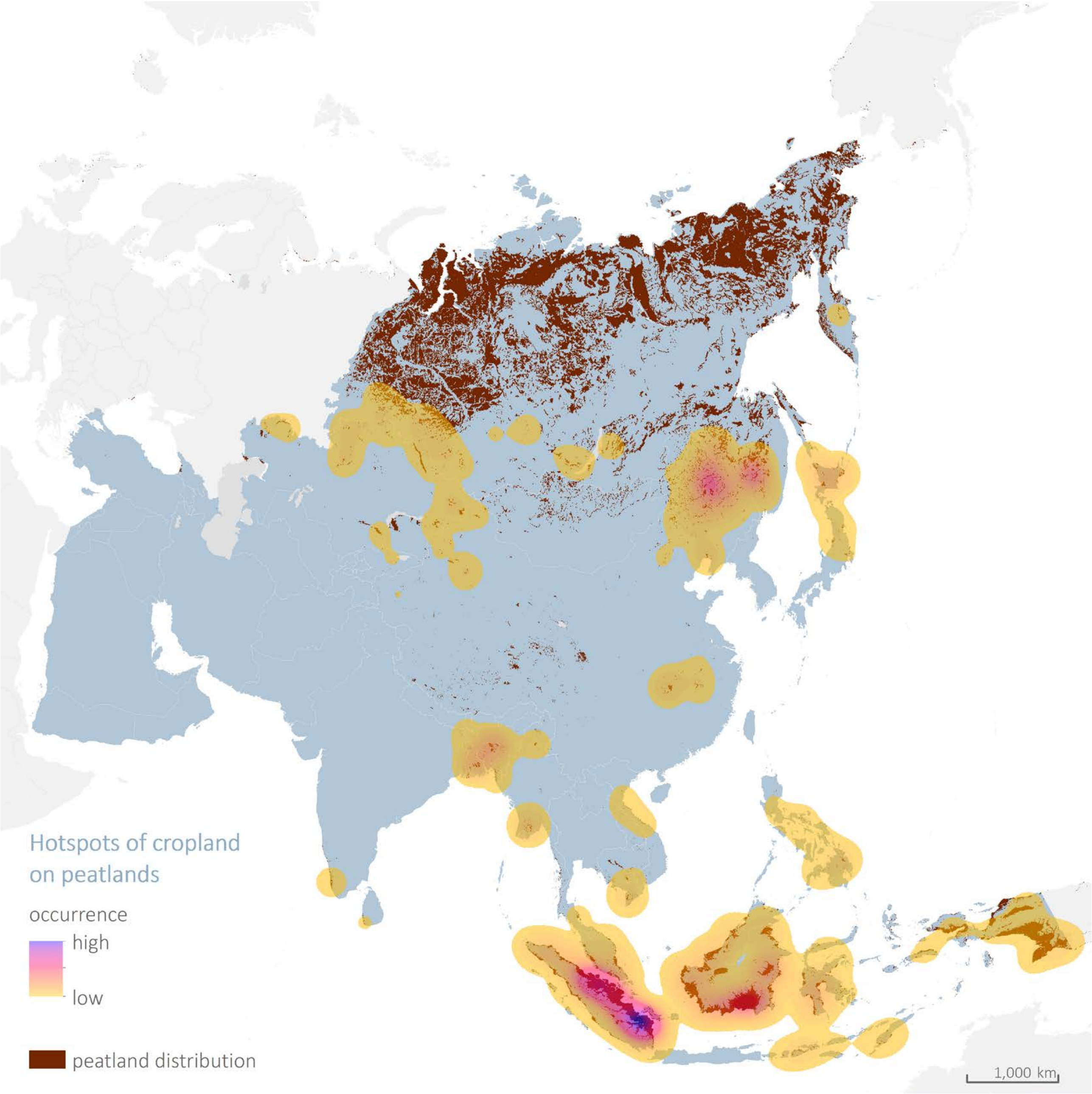


Figure IV.28 Hotspots of croplands on peatlands in Asia.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

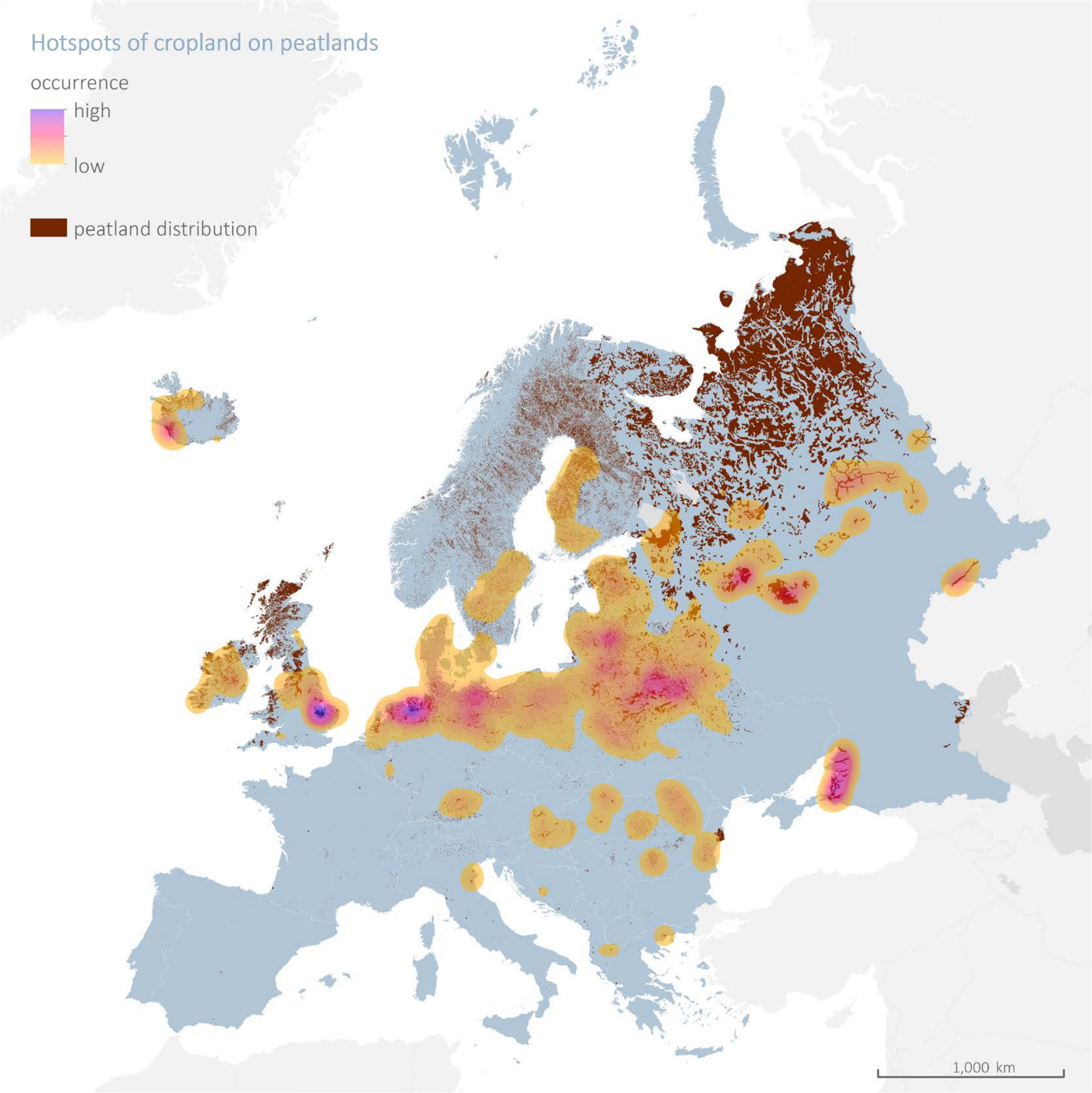


Figure IV.29 Hotspots of croplands on peatlands in Europe.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

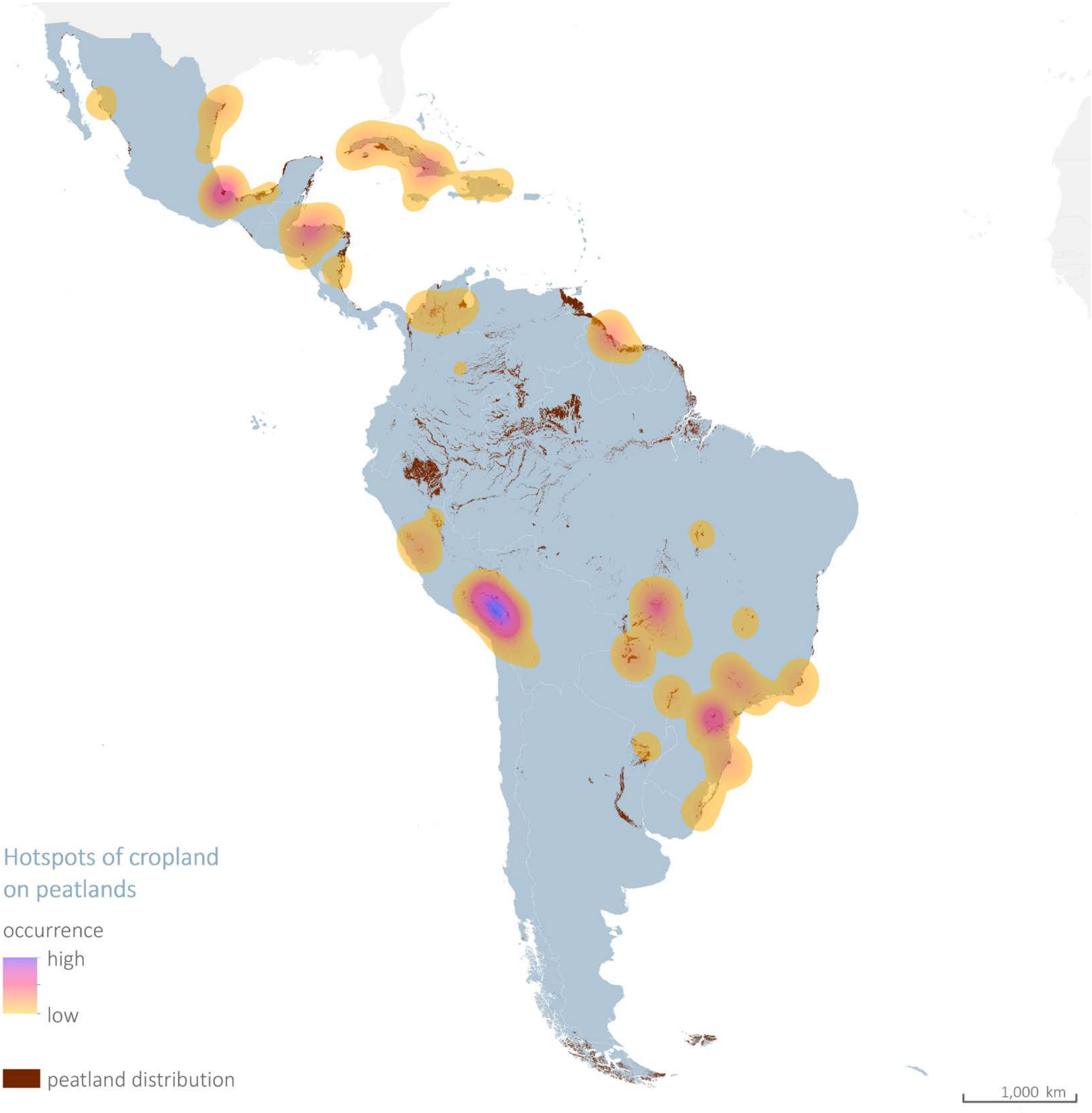


Figure IV.30 Hotspots of croplands on peatlands in Latin America and the Caribbean.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

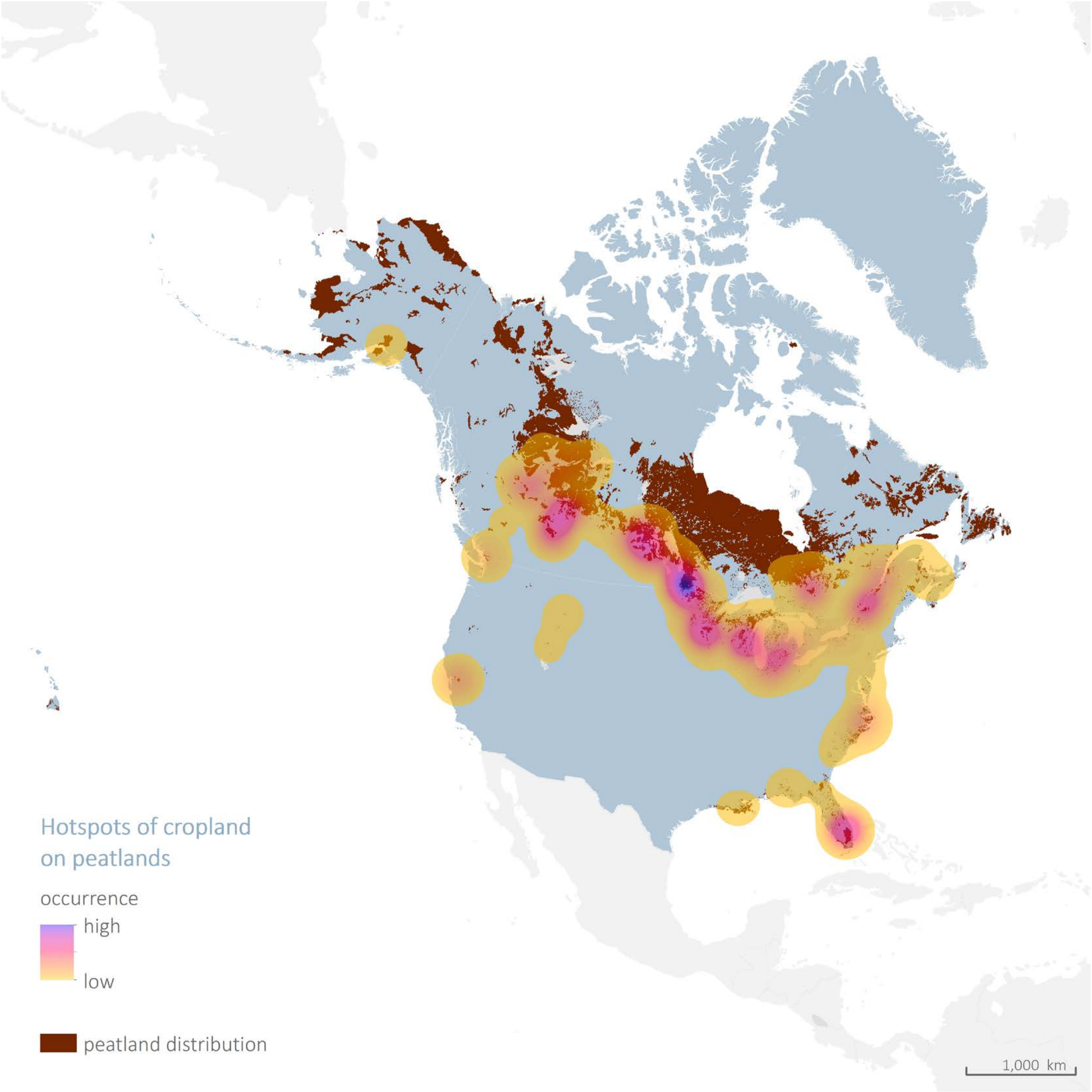


Figure IV.31 Hotspots of croplands on peatlands in North America.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

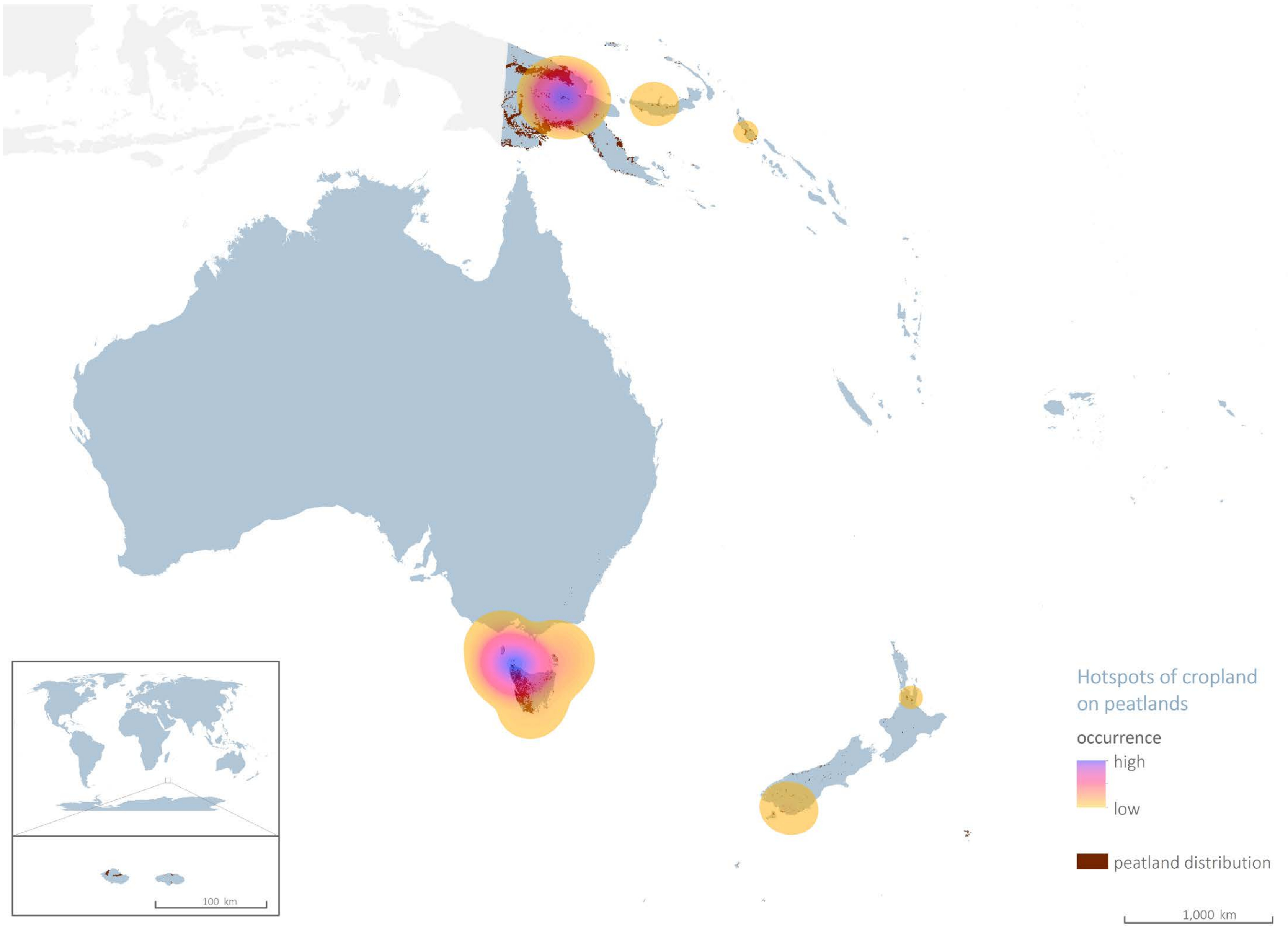
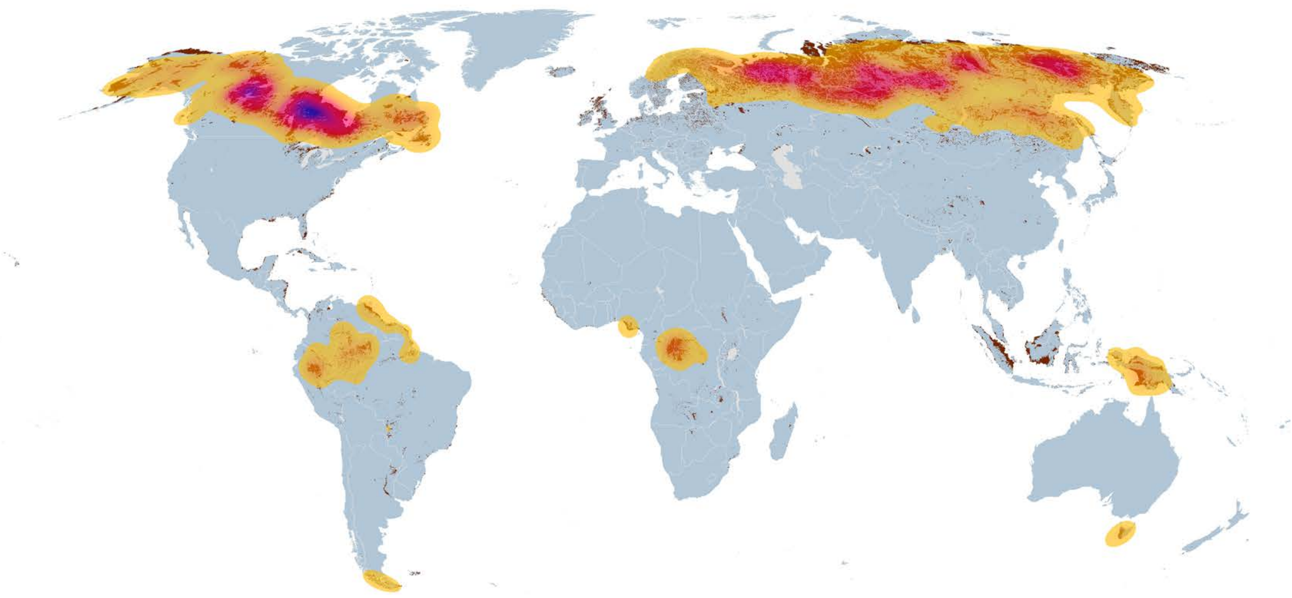
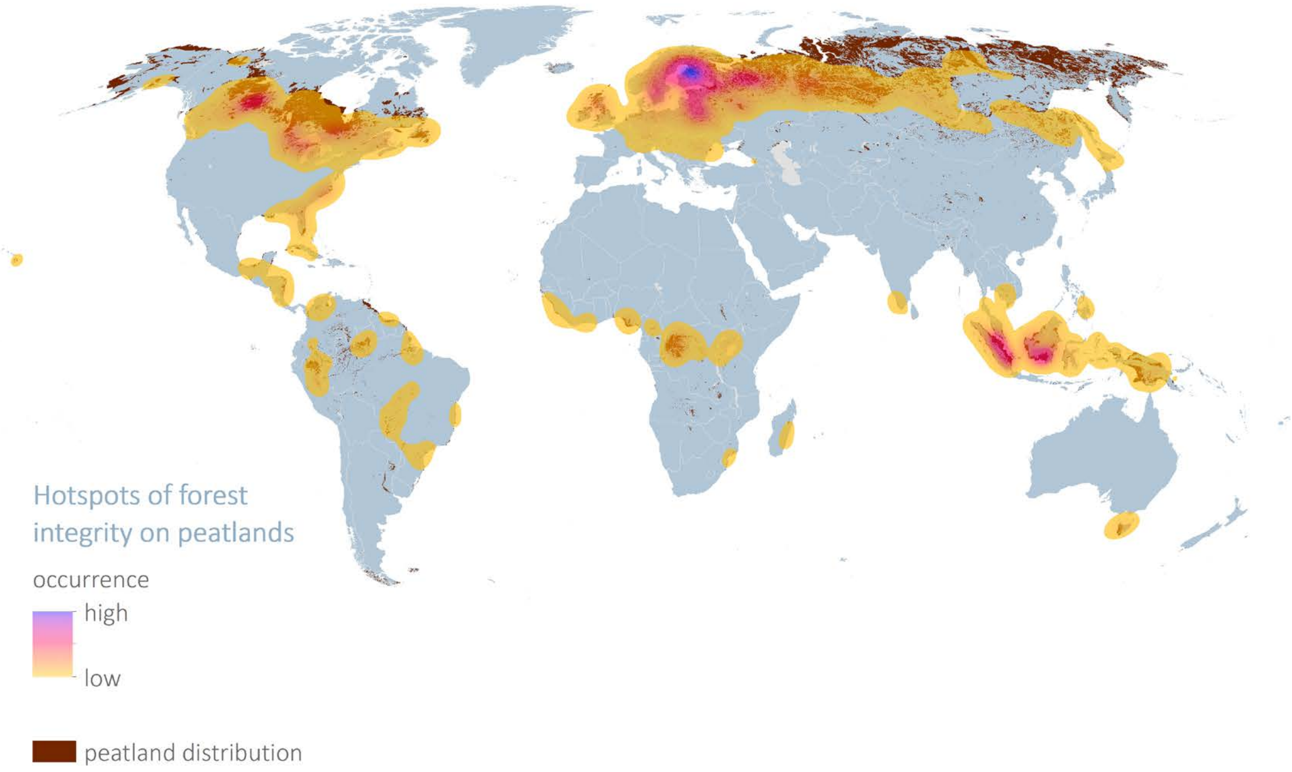


Figure IV.32 Hotspots of croplands on peatlands in Oceania.

Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.



High forest integrity



Low forest integrity

Figure IV.33 Hotspots of forest integrity on global peatlands.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

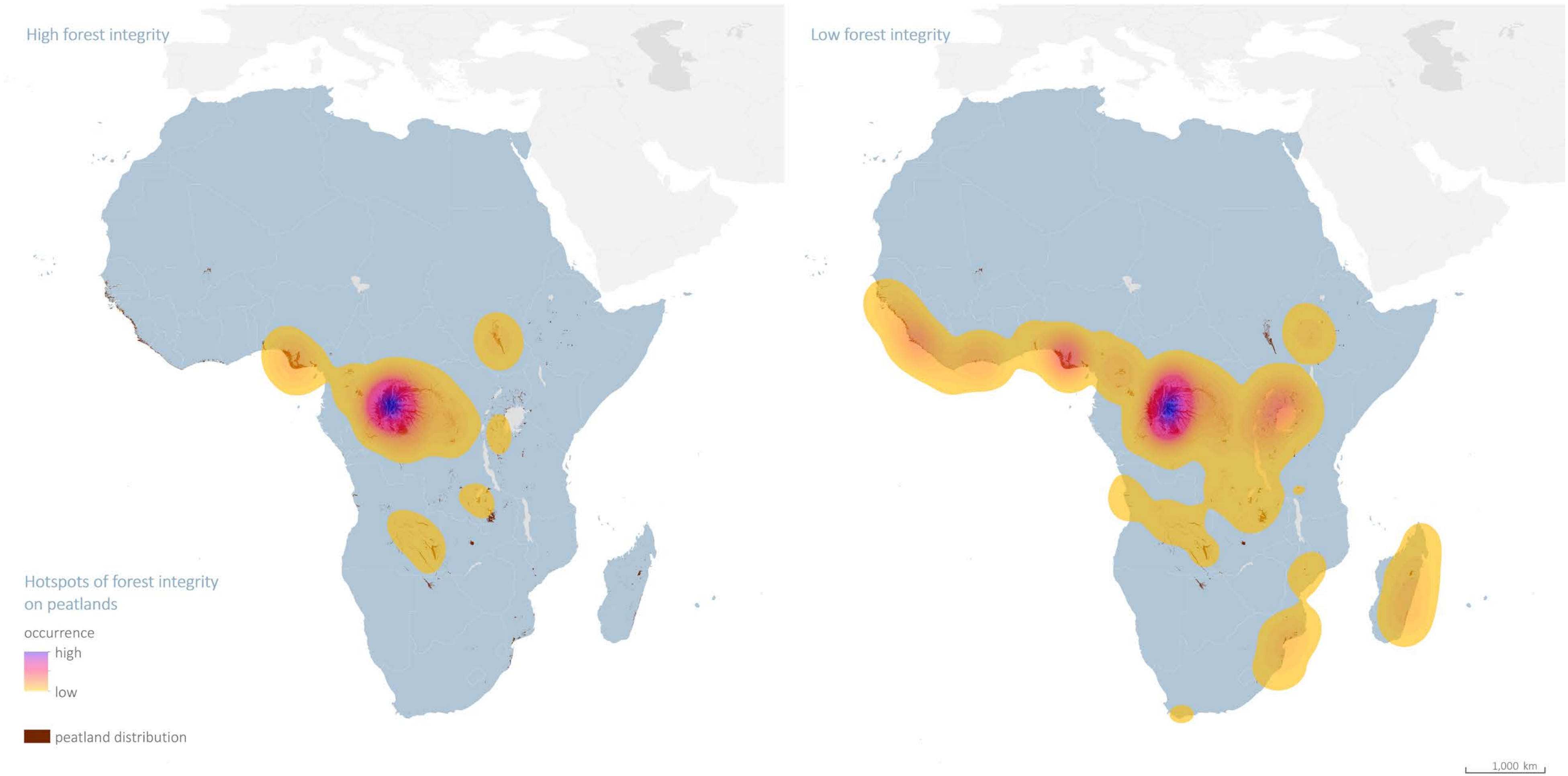


Figure IV.34 Hotspots of forest integrity on peatlands in Africa.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

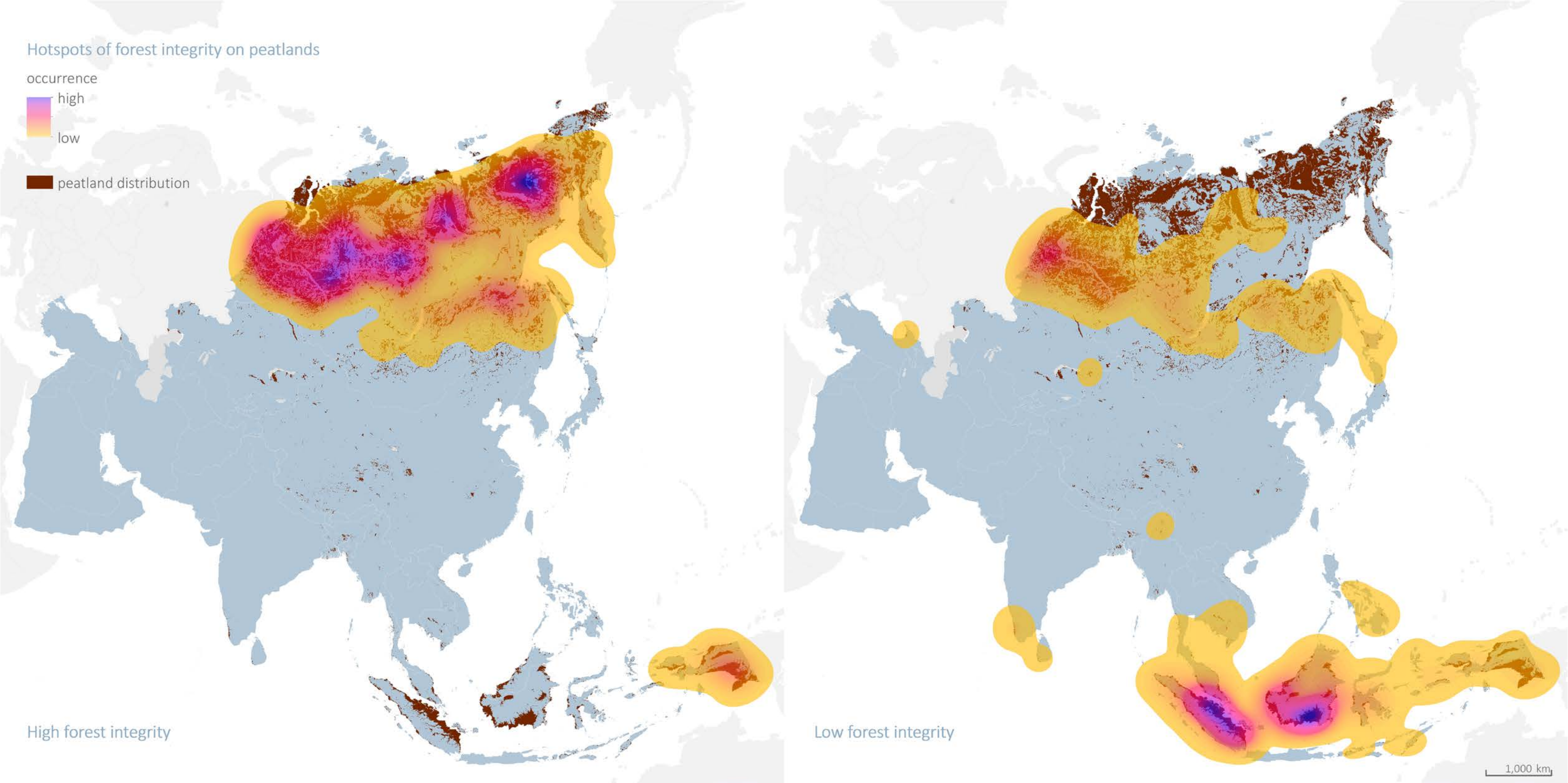


Figure IV.35 Hotspots of forest integrity on peatlands in Asia.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

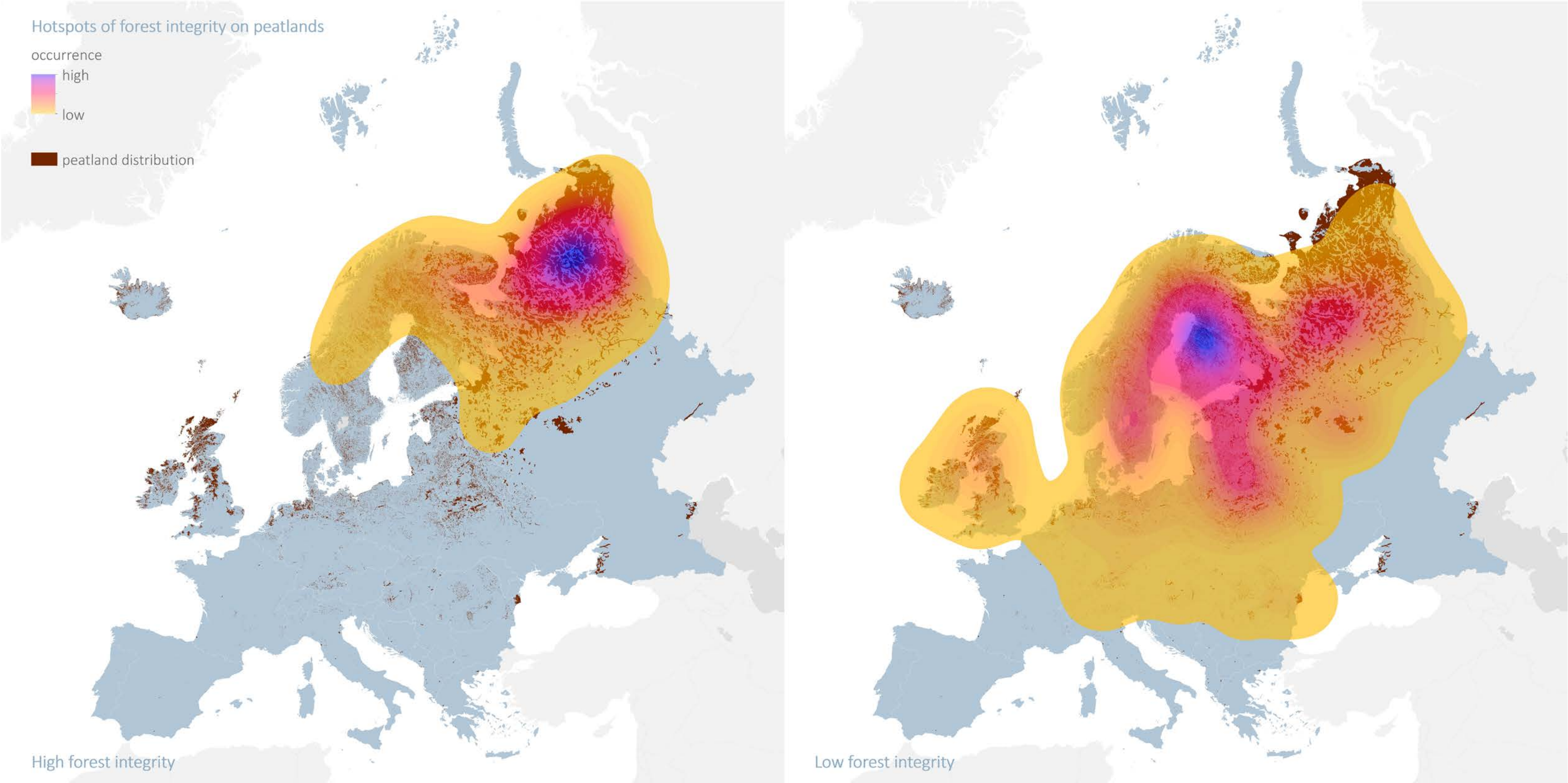


Figure IV.36 Hotspots of forest integrity on peatlands in Europe.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

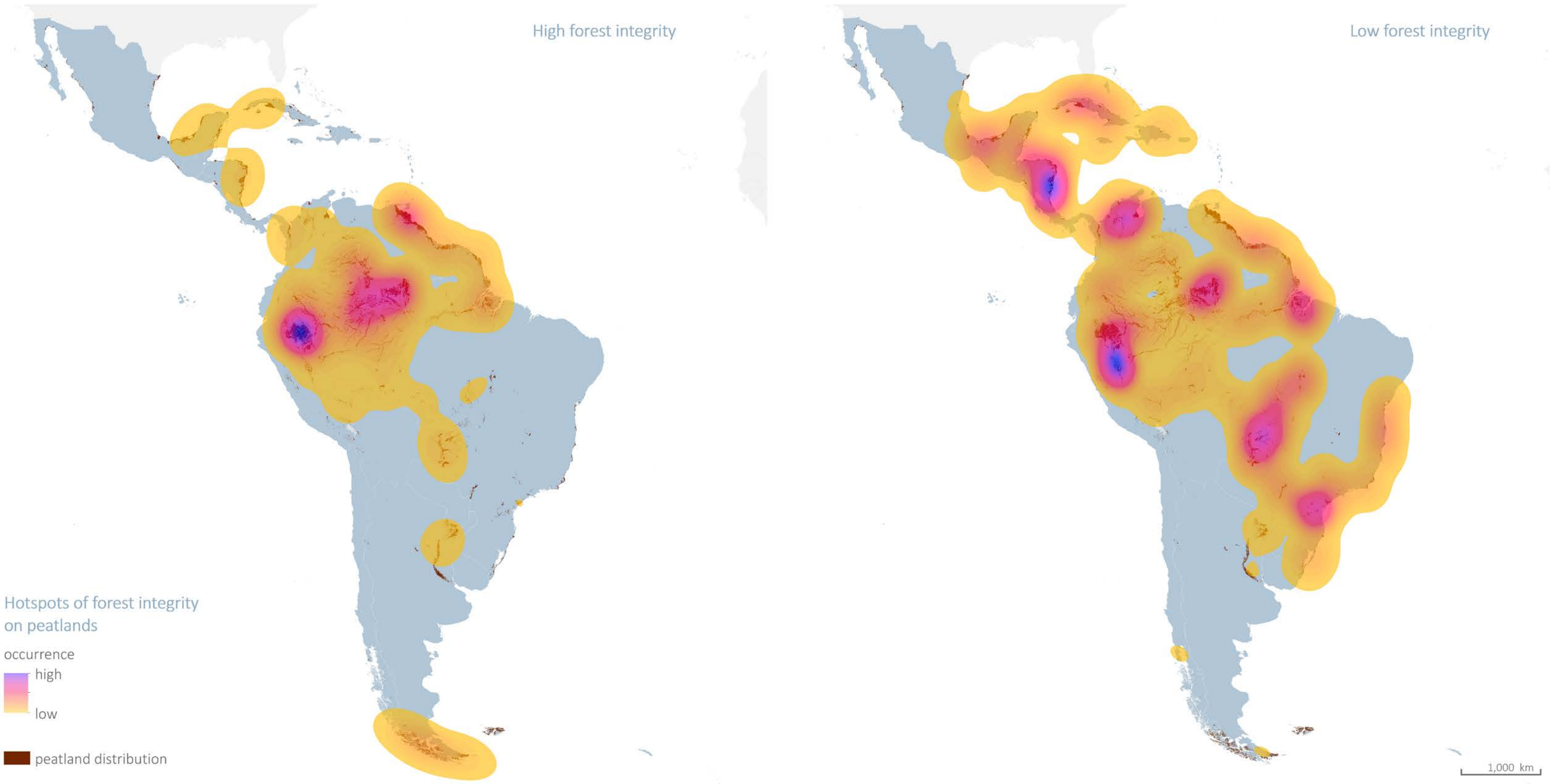


Figure IV.37 Hotspots of forest integrity on peatlands in Latin America and the Caribbean.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

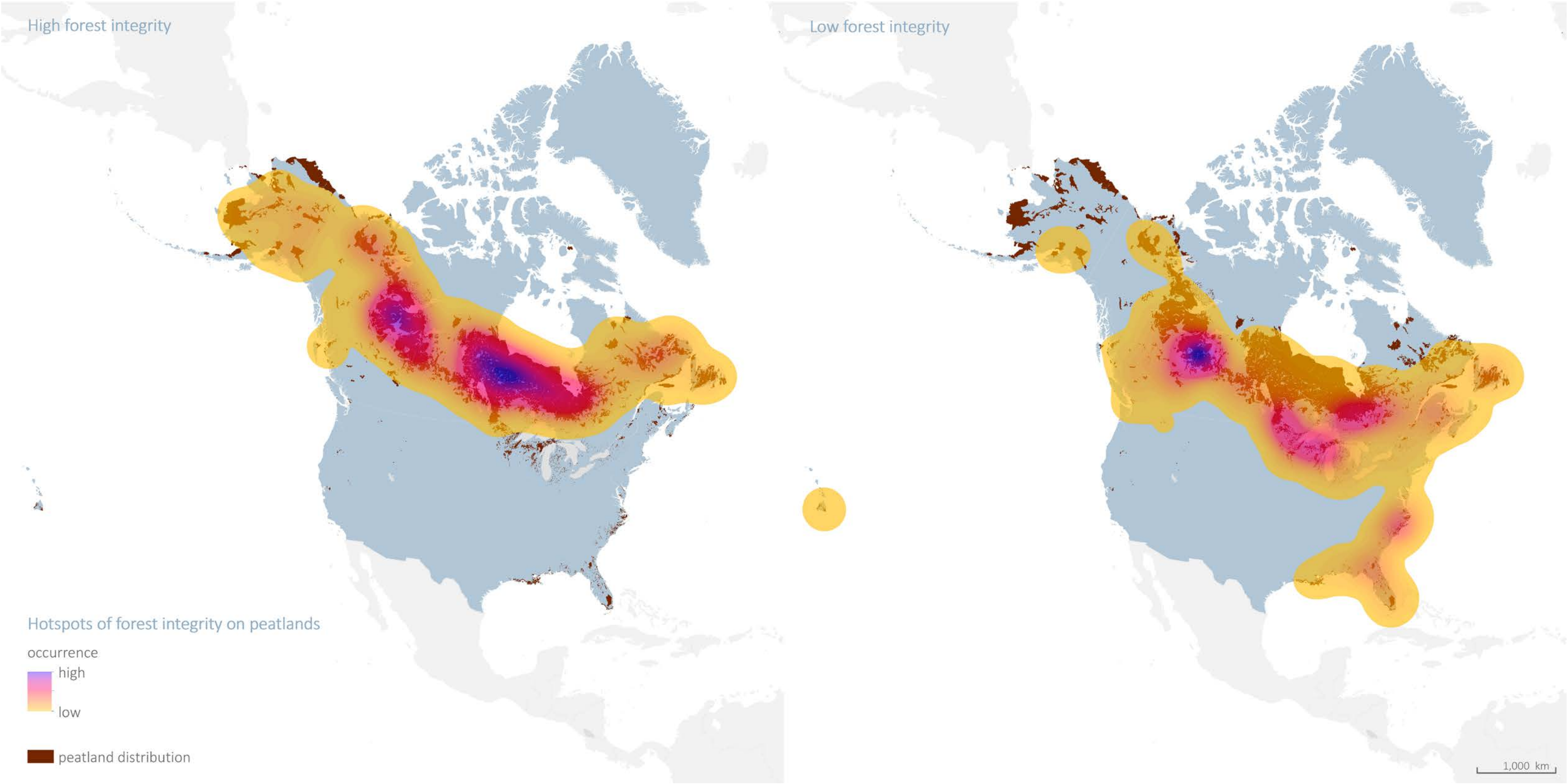


Figure IV.38 Hotspots of forest integrity on peatlands in North America.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

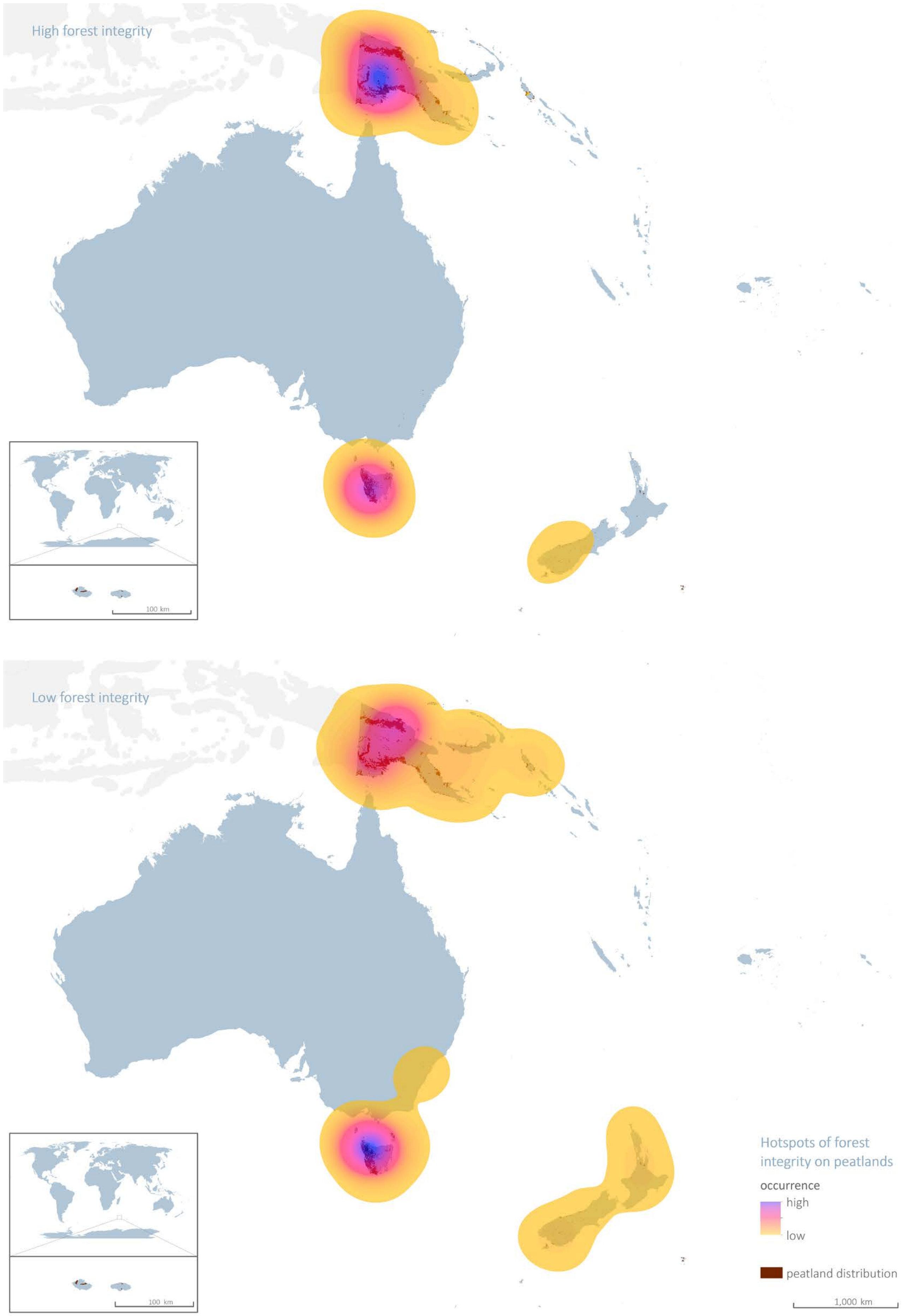


Figure IV.39 Hotspots of forest integrity on peatlands in Oceania.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Annex IV.2. Additional Tables

Table IV.2.1. Examples of peatland policy action in Europe.

Country	Targets set in National Peatland Policies	Implementation Actions
Andorra	National Landscape Strategy and National Biodiversity Strategy with Wetlands Action Plan (2017) included the state of the country's wetlands, 2015, and strategic management plan 2017-2024.	Four strategic priorities and twenty actions to conserve wetland habitats and their ecosystem services, while seeking the involvement of local communities and society as a whole (Reed *et al.* 2019)
Belarus	Law of the Republic of Belarus "On the Protection and Use of Peatlands" (Belarus Government 2019)	Implementation principles: -strictly conserve mires in a natural or near-natural condition -extract peat mainly from deposits already influenced by drainage -agriculture on peat soils using methods that ensure minimum loss of organic matter and preserve soil fertility
Denmark	Out of the total of 171,000 hectares agricultural soil in Denmark with more than 6% organic carbon, 100,000 hectares (58%) should be rewetted (undrained) and extensified by 2030	Agreement on the green transition of Danish Agriculture 2021. Rewetting priority for using Common Agricultural Policy (CAP) funds.
Finland	30,000 hectares of croplands on peat soils to be converted to paludiculture. Holistic peatland management planning to be subsidized and current forest subsidies for the re-drainage of the peatlands to be ceased in 2024	Government allocated €30 million Euros for the implementation of the paludiculture target. New act on sustainable forest management subsidies to be set in 2023.
France	Restoring 50,000 hectares by 2026, promoting protection of wetlands, creating 2 Ramsar sites / year	Mapping of all wetlands by 2024, support to economic and recreational actors in improving their knowledge and practices to preserve wetlands and developing low-carbon methods.
Germany	National Peatland Protection Strategy foresees 5 Mt CO_2e reduced emissions from drained peatlands by 2030	€4 billion Euros earmarked for Natural climate solutions in 2022-2026, including ~€2 billion Euros for peatland restoration/paludiculture. Additional funds for paludiculture
Hungary	All mires nationally protected by law (Act on Nature Conservation)	30% of mires already in protected areas
Liechtenstein	Peatlands protected by the law on nature protection (Naturschutzgesetz): nature conservation areas, protected by regulations or nationalized to ensure long-term conservation. Peat exploitation prohibited by law (Reed *et al.* 2019)	Government funded conservation strategies: example reed cutting, invasive species control
Lithuania	Restoring peat-forming processes in 8,000 hectares of agriculturally utilized, drained peatlands by 2026 to reduce GHG emissions, restore wetland processes create favourable conditions for biodiversity habitats, and increase GHG uptake. All biggest peatland complexes have the status of Strict Nature Reserve and Biosphere Reserve.	Ministry of Agriculture earmarked 16 MEur for restoration of 8,000 hectares from EU Recovery and Resilience Facility (RRF 2021); investment "Increasing absorption capacity of the GHG" (in preparation) from EU and national funds for preservation of peat and restoration of hydrology (in preparation).
Netherlands	1 million tons CO_2e reduction of GHG emissions from peatland in agricultural use by 2030	6 regional peatland strategies to be realized through a bottom up, adaptive approach using national funding
Norway	Restoring at least 15% degraded ecosystems by 2025	105 bogs restored in 2015-2021, state allocated funding towards wetland restoration

Country	Targets set in National Peatland Policies	Implementation Actions
Russia	Ensuring restoration of all peatlands drained for extraction and abandoned in the European part of Russia (ca 80,000 hectares)	Preparing inventory of drained peatlands as background for 2023 NDC updates, including peatland restoration obligations in the NDC (Sirin *et al.* 2021). Development of a national voluntary carbon market
Serbia	Decree of proclamation of protected area based on Law on Nature protection, 3,118 hectares peatlands protected	Focus on hydrological regime and monitoring populations of mosses. Supported by Ministry of Environmental Protection (RSD 400,000)
Slovakia	Peatlands protected by the Act on Nature Protection (543/2002), restoration facilitated via the National Biodiversity Strategy with Action Plan, and the National Wetland Management Plan with Action Plan.	Several peatlands re-wetted through drain blocking. No known peat extraction activity (Reed et al. 2019).
Spain	Inventory of wetlands as part of the Spanish Inventory of Natural Heritage and Biodiversity (Law on Natural Heritage and Biodiversity 2007)	Wetland protection measures must be included in the Demarcation Hydrological Plans of the Water Law
Sweden	Rewetting considered as a method of emission reduction to reach net zero emissions until 2045; 100,000 hectares forested peatland and 10,000 hectares agricultural peatlands rewetted by 2045 (50% of it by 2030). National plan for the protection of peatlands, and a programme for restoring wetlands: Thriving wetlands, habitats to have favourable conservation status	Government allocated 775 MSEK to re-wetting peatlands 2021-2023.
Switzerland	The remaining intact fens and bogs are protected by law. Rewetting peat soil in protected areas, for nature and/or landscape conservation purposes, Peat soils not included in protected areas identified and mapped designing large hydrological buffer zones, for water from the catchments to provide a sufficient water supply to peatlands.	The remaining intact fens and bogs are protected by law and their state is monitored on a regular basis. “Flachmoorverordnung” and “Hochmoorverordnung”, Swiss Confederation

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CHAPTER 4

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CHAPTER 5

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CHAPTER 6

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CHAPTER 7

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CHAPTER 8

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CHAPTER 9

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