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Full Length Research Paper

Efficiencies of three insect collection methods in Lamto, Côte d'Ivoire

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Insects are of ecological and economic importance. This study was carried out to compare the efficiency of the three main insect sampling methods namely, sweep net, hand sampling and the light trap and also to show the biodiversity distribution from Lamto habitats for good biological conservation. A total of 379 individuals belonging to 9 orders were collected. Significantly, more individuals were collected by sweeping net compared to hand sampling and light trap. From the capture rate, highest rate was recorded for sweeping net (0.720) followed by hand (0.232) and light trap (0.047). The lowest value of Shannon's index was 0.672 with the light trap followed by hand (1.375) and the highest was 1.940 with sweeping net in Lamto's habitats. The insect orders recorded with the hand were Heteroptera, Coleoptera, Homoptera, Hymenoptera, Orthoptera, Diptera and Isoptera (F = 11.340, *P* value = 0.006). Light trap was more suitable to capture Lepidoptera (3.250%), Coleoptera (0.750%) and Homoptera (0.500%) (F= 6.659, *P* value= 0.0001). The abundance index recorded with the sweeping net commonly varied between 0.0 and 18.250%. Both sweeping net and hand insect sampling techniques were the most efficient and showed the highest insect orders complementarity. However, the use of sweep net, hand sampling and light trap were recommended to have good collection of insects.

Key words: Sweep net, light trap, hand sampling, insects' conservation, capture effectiveness.

INTRODUCTION

Territorial insects are more diverse groups of animal and are important components of ecosystem. They play important roles in the economic and ecological success of agroecosystems and are distributed in all habitats (forest and savannah) of Lamto. Large population of insects may be isolated into sub-populations from one to another due to habitat fragmentation (Hunter, 2007). These habitats (forest and savannah) indirectly through microclimate change (Li, 2017) and represent a highest importance to insect biodiversity (Wearn, 2017) and to insect abundance (Diniz et al., 2010; Elia et al., 2012; Muvengwi et al., 2017). Lamto plays an important role in supporting biodiversity conservation, for instance, provision of foods, microhabitats for the growth and distribution of insect populations. There are four seasons which are a long dry season from December to February,

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a long rainy season from March to July, a short dry season in August and a short rainy season from September to November. The methods used to collect insects include light trap, hand and sweep net (Noyes, 1989; Shimoda and Honda, 2013). Moreover, the choice of an adequate sampling methodology is crucial. Hands are the traditional method for collection of epigaeic invertebrates. It has been widely used for sampling insects in biodiversity inventories (Ramírez-Hernández et al., 2018), population and community ecology (Hunter, 2007; Ramírez-Hernández et al., 2018). The light trap is the most commonly used sampling device to study the daily activity of nocturnal insects. The reason for the wide use of hand and light trap in invertebrate sampling is their simplicity of setting and using, and their low cost. However, the interpretation of hand and light trap data is subject to many problems because they rarely reflect the true abundance of the target organisms being sampled (Shweta and Rajmohana, 2016; Ramírez-Hernández et al., 2018). However, the effectiveness of light trapping as an insect sampling method was influenced by many environmental factors that influence the efficiency of the traps (Upadhyay et al., 2000; Ramírez-Hernández et al., 2018). Despite these shortcomings, light traps and hand have continued to be used (Upadhyay et al., 2000; Ramírez-Hernández et al., 2018). The effectiveness and complementarity of three sampling methods such as sweeping net, hand sampling and light trap for collecting insects were assessed to show the biodiversity distribution from Lamto habitats for good biological conservation.

MATERIALS AND METHODS

Description of study site

The study area is Lamto station (6° 13 N, 5° 2 W) located in the center of Côte d'Ivoire (West Africa) in the transition forest-savannah. The landscape of Lamto is a mosaic which brings together scraps of dense semi-deciduous forests, gallery forests and savannahs (Menaut, 1971; Devineau, 1975).

Entomological sampling

Insects were collected from 23 October to 27 October 2007. Sampling was carried out between 05:30 to 08:00 from a forest and savannah vegetation using the sweep net and the hand and between 19:00 to 20:00 with the light trap, for a period of four days. Sweep net was used while walking around the road in the forest and adult insects were collected from the vegetation. In savannah, adult insects were collected from the vegetation in random sites. The collected insects were killed by ethyl acetate vapour, sorted out into different orders and mounted in insect boxes. All small and soft bodied insects were preserved in 70% ethanol in specimen bottles labeled to show sample station, sample method and collection date.

Identification of insects

Insects were identified up to order level with the help of entomologists and by using a binocular lens and identification keys of insects (Roth, 1974; Maurice, 1980; Delvare and Aberleng, 1989). Thus, the number of individuals collected under each order during the study period was recorded.

Data analysis

Collected insects were sorted out into orders. Total number of individuals collected under each order was used for diversity analysis. Diversity indices such as Shannon's index were calculated by using Estimate S (version 9.1.0, 2013). An analysis with ANOVA allowed comparing between mean diversity indices and mean abundance index between the three insect collection methods.Subsequently, we calculated the abundance index (AR) and the occurrence frequency (Fo) according to the formulas, respectively:

$$AR\ (\%) = \frac{a \times 100}{b} \quad (1)$$

a: Number of total individuals of order collected with the method I; b: number of total individuals collected with a method i.

$$Fo\ (\%) = \frac{Na \times 100}{N} \quad (2)$$

Na: Number of sampling of individuals of order collected with method I; N: Number of total sampling with method i.

RESULTS AND DISCUSSION

A total of 379 individuals belonging to 9 orders were collected. From the capture rate, highest rate was recorded for sweep net (0.720) followed by hand (0.232) and light trap (0.047) (Table 1). According to Shweta and Rajmohana (2016), sweep net are better than the other method to collect insects.

The lowest value of Shannon's index was 0.672 with the light trap followed by hand (1.375) and the highest was 1.940 with sweep net in Lamto's habitats (forest and savannah) (Table 2). There was a significant difference with F = 324.458, *P* value = 0.0001. Noyes (1989) and Shweta and Rajmohana (2016) studied parasitic hymenoptera capture rates and hymenoptera claiming sweep net to be most effective, respectively.

The insect orders recorded with the three insect collection methods in Lamto's habitats were Odonata, Lepidoptera, Coleoptera, Heteroptera, Homoptera, Hymenoptera, Orthoptera, Isoptera and Diptera. In fact, the majority of insect recorded were phytophagous (Lecordier, 1975).

Light trap was more suitable to capture Lepidoptera (3.250%), Coleoptera (0.750%) and Homoptera (0.500%) (F = 6.659, *P* value = 0.0001) (Table 3). In fact, nocturnal insects are collected exclusively through light trap. According to Pachkin et al. (2019) and Marchioro et al. (2020), the light traps were more attractive for the representatives of Coleoptera, Homoptera and

Table 1. Capture rate for the light trap, the hand and the sweep net.

Method	Number of individuals collected	Capture rate
Light trap	18	0.047
Hand	88	0.232
Sweep net	273	0.720

Table 2. Diversity of light trap, hand and sweep net in sampling insects.

Method	Shannon's index	CV (%)
Light trap	0.672[c]	13.3
Hand	1.375[b]	3.7
Sweep net	1.940[a]	1.0
P-value	0.0001	
F	324.458	

The means assigned to the same letter within the same column are not significantly different for the 5% Fisher test (LSD).

Table 3. Abundance index of light trap in sampling insects.

Order	Light trap	
	Abundance index (%)	CV (%)
Diptera	0.000[b]	-
Orthoptera	0.000[b]	-
Isoptera	0.000[b]	-
Odonata	0.000[b]	-
Hymenoptera	0.000[b]	-
Heteroptera	0.000[b]	-
Homoptera	0.500[b]	16
Coleoptera	0.750[b]	11
Lepidoptera	3.250[a]	12
P-value	0.0001	
F	6.659	

The means assigned to the same letter within the same column are not significantly different for the 5% Fisher test (LSD).

Lepidoptera. Light trapping as an insect sampling method was influenced by many environmental factors. The observations are in agreement with those of Nair et al. (2004) and Sheikh et al. (2016). In fact, the efficacy of light trap was influenced by the vegetation around the sampling site and by lunar light (Holyoak et al., 1997; Brehm and Axmacher, 2006; Shimoda and Honda, 2013; Keszthelyi et al., 2019). According to Upadhyay et al. (2000) and Sheikh et al. (2016), not all the light source proved efficient to attract and collect all the nocturnal insect species in a particular habitat.

The insect orders recorded with the hand method were Heteroptera, Coleoptera, Homoptera, Hymenoptera, Orthoptera, Diptera and Isoptera. The abundance index commonly varied between 0.5 and 11.75%. The highest abundance was recorded with the Isoptera (11.75%) and the lowest was recorded with the Heteroptera (0.5%). The abundance index of Heteroptera, Homoptera, Diptera, Orthoptera, Hymenoptera, Coleoptera and Isoptera were statistically different (F= 11.340, P value = 0.006) and were 0.5, 1.25, 1.75, 1.75, 2.5, 3 and 11.75%, respectively (Table 4).

The abundance index recorded with the sweep net commonly varied between 0.0 and 18.250%. The highest abundance was recorded with the Lepidoptera (18.250%) and the lowest was recorded with the Isoptera (0.0%). The abundance index of Isoptera, Homoptera, Diptera, Orthoptera, Heteroptera, Coleoptera, Odonata,

Table 4. Abundance index of hand in sampling insects.

Order	Hand	
	Abundance index (%)	CV (%)
Lepidoptera	0.000[b]	-
Odonata	0.000[b]	-
Heteroptera	0.500[b]	10
Homoptera	1.250[b]	16
Diptera	1.750[b]	16
Orthoptera	1.750[b]	16
Hymenoptera	2.500[b]	16
Coleoptera	3.000[b]	14
Isoptera	11.750[a]	14
P-value	0.006	
F	11.340	

The means assigned to the same letter within the same column are not significantly different for the 5% Fisher test (LSD).

Table 5. Abundance index of sweep net in sampling insects.

Order	Sweep net	
	Abundance index (%)	CV (%)
Isoptera	0.000[e]	-
Homoptera	3.250[de]	16
Diptera	5.000[d]	14
Orthoptera	6.500[cd]	12
Heteroptera	7.000[cd]	18
Coleoptera	7.000[cd]	17
Odonata	10.000[bc]	15
Hymenoptera	11.250[b]	11
Lepidoptera	18.250[a]	13
P-value	0.0001	
F	14.192	

The means assigned to the same letter within the same column are not significantly different for the 5% Fisher test (LSD).

Hymenoptera and Lepidoptera were statistically different (F = 14.192, P = 0.0001) and were 0.000, 3.250, 5.000, 6.500, 7.000, 7.000, 10.000, 11.250 and 18.250%, respectively (Table 5).

The lowest abundance index was due to the fact that the sampling period was theses insect period reproduction. In this sampling period, the high relative humidity reduced the activity of these insects (Butler et al., 1999; Ramamurthy et al., 2010).

Amongst the three insect's collection methods, sweep net showed the maximum ability followed by hand and light trap (Table 6). The occurrence frequency of insects of various orders in light trap, hand and sweeping net were all varied from 0.000 to 100 percent (Table 6). The total catch of light trap, hand and sweeping net were 25, 75 and 75% in Homoptera; 50, 100 and 100% in Coleoptera; 100, 0 and 100% in Lepidoptera; 0, 75 and 100% in Hymenoptera, Orthoptera and Diptera; 0, 0 and 100% in Odonata and Heteroptera and 0, 100 and 0% in Isoptera, respectively (Table 6). The observations are in agreement with those of Butler et al. (1999) and of László et al. (2012) which have mentioned that humidity of the habitat produce a rich sample of insects in general. Both sweep net and hand sampling were the most efficient and showed the highest species complementarity. Indeed, highest occurrence frequency of Coleoptera individuals with the sweep net, hand sampling and light trap showed that Lamto's habitats was sound and allow good conservation of biodiversity.

Conclusion

The methods used to collect insects include light trap,

Table 6. Occurrence frequency of light trap, hand and sweep net in insect sampling.

Order	Light trap	Hand	Sweeping net
Homoptera	25	75	75
Diptera	0	75	100
Orthoptera	0	75	100
Isoptera	0	100	0
Odonata	0	0	100
Hymenoptera	0	75	100
Coleoptera	50	100	100
Heteroptera	0	0	100
Lepidoptera	100	0	100

hand and sweep net sampling. A total of 379 individuals belonging to 9 orders were collected. Sweep net was the best method to collect different groups of insects. From the capture rate, highest rate was recorded for sweep net followed by hand sampling and light trap. Sweep net recorded the highest number of individuals. Furthermore, the results revealed that light trap do not give efficiently to provide reliable inventories from Lamto. Both sweep net and hand sampling were the most efficient and showed the highest insect orders complementarity. However, we recommend the use of the three methods-sweeps net, hand sampling and light trap to made good collection of insects from Lamto.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Daily activity patterns and relative abundance of medium and large mammals in a communal natural protected area on the central coast of Oaxaca, Mexico

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Anthropogenic disturbances cause direct and indirect effects on the global decline in biodiversity. For better planning strategies on the conservation of medium and large mammals in Oaxaca, we present an analysis of daily activity patterns of medium and large mammals and their relative abundance in a Communal Natural Protected Area (CNPA) on the central coast of Oaxaca, Mexico. Sampling was carried out between November 2014 and September 2015, during the dry season and the rainy season, using forty camera traps placed within the CNPA El Gavilán and installed along wildlife trails, especially on pathways with clear evidence of use by wildlife. Date records for 10 species of medium and large mammals, obtained with 12,160 day/camera traps. *Leopardus pardalis* was active during the night but exhibited diurnal and nocturnal tendencies. *Herpailurus yagouaroundi*, *Nasua narica*, *Dicotyles angulatus* and *O. virginianus* were defined as cathemeral species. The most abundant medium mammals were *Dasypus novemcinctus* (RAI= 1.23), *Didelphis virginiana* (RAI= 1.15) and *Nasua narica* (RAI= 1.05). Our results can provide insights for the conservation of species in the CNPA El Gavilan. We recommend the continuance of studies on the temporal and seasonal variations of the activity patterns in order to maintain mammalian species conservation.

Key words: Conservation, relative abundance, mammals, Oaxaca, patterns.

INTRODUCTION

Biodiversity is recognized as a living heritage common to all humanity (Manfo, 2013). In the past 30 years remarkable progress has been made towards understanding how the loss of biodiversity affects the functioning of ecosystems and thus affects society (Bradley et al., 2012; Baboo et al., 2017). Biodiversity

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loss might affect the dynamics and functioning of ecosystems (Bargali et al., 1992a, b), and the supply of goods and services migh grow dramatically (Gosain et al., 2015; Mourya et al., 2019).

Anthropogenic disturbances cause direct and indirect effects on the global decline in biodiversity (Cardinale et al., 2012). The direct effects manifest in obvious ways as habitat loss and declines in wildlife population, while the indirect effects present themselves as disruptions in species' behaviours and interspecific interactions (Frey et al., 2017). In this sense, a better understanding of these indirect impacts is needed, especially in those highly threatened ecosystems such as the tropical dry forests (TDF), which are threatened by high deforestation, forest fires, overhunting, wildlife trade, human population growth and tourism development (Ortiz-Pérez et al., 2004).

Camera trapping (CT) has been suggested as an emerging methodology for understanding the indirect impacts described above (Frey et al., 2017); however, this technique has been widely used in ecology and conservation for species' distribution, estimating population densities and inventorying biodiversity (O´Connell et al., 2011; Long et al., 2013). Tipically, CT has focused on the spatial and numerical aspects of species and population ecology (Karanth and Nichols, 1998; Tobler et al., 2008; Linkie and Ridout, 2011) and has less often been used to examine species' behaviours and interactions (Frey et al., 2017).

Daily activity patterns (DAP) of animals in the wild are the product of animals´ adaptations to periodic environmental change and involve anatomic, physiological and behavioral changes (Morgan, 2004). In addition, circadian rhythms allow animals to anticipate environmental changes, making use of the best time of day for certain activities (Kronfeld-Schor and Dayan, 2003). So, DAP can be subdivided in four chrono-ecotypes: diurnal, nocturnal, crepuscular and cathemeral (active behavior occurs equally at night and during the day). These types are not rigid among mammal species but can vary depending on need, as determined by environmental conditions (Erkert et al., 1976).

In Oaxaca State, Mexico, the TDF occupies 16% of its territory and exists as two types of forest: deciduous tropical forest and semi-deciduous tropical forest (Torres-Colín, 2004; Trejo, 2010). In this ecosystem, the animal diversity is high, and particularly in the Planicie Costera del Pacífico (central coast), the overall species' richness is the highest in the state (González-Pérez et al., 2004), and mammal species' richness represents 63.6 and 25.4% of the total species recorded in Oaxaca and Mexico respectively (Briones-Salas and Sánchez-Cordero, 2004). The species richness of mammals, excluding the species of the Chiroptera order, on the central coast of Oaxaca comprises a total of 49 species belonging to 10 families and eight orders (Briones-Salas et al., 2016). They represent one of the most important biological groups because they are involved in a large number of ecological processes within the ecosystems they inhabit (Gonzalez-Christen, 2010). Additionally, one of the strategies for biodiversity conservation is the creation of the Areas Destinadas Voluntariamente a la Conservación (Communal Natural Protected Areas), which operates as a mechanism for the conservation of biodiversity and local natural resources through the participation of local human communities (Rodríguez-Luna et al., 2011).

With the aim of contributing to better planning strategies for the conservation of medium and large mammals in Oaxaca, we present an analysis of daily activity patterns of medium and large mammals and their relative abundance in a Communal Natural Protected Area on the central coast of Oaxaca, Mexico.

MATERIALS AND METHODS

Study area

Fieldwork was conducted in the Communal Natural Protected Area (CNPA) El Gavilán, located in the municipality of Santa María Tonameca on the Central Coast of Oaxaca, Mexico. This CNPA is located in the transition area between the coastal plain and Sierra Madre del Sur physiographic province (Figure 1). The climate is warm and sub-humid, with an annual mean temperature of 26.8°C, anual mean precipitation of 2245 mm (García, 1973) and a long period of drought from November to May (Trejo, 2010). Some tree species in this region are *Ceiba parvifolia* Rose, *Lysiloma divaricata* (Jacq.) JF Macbr, and *Plumeria rubra* L. (Torres-Colín, 2004). The basic forms in these forests are schrubs, vines and cacti (Trejo, 1998), with the predominant species being *Acacia cochliacantha* Willd., *A. farnesiana* (L.) Willd., *A. cornigera* (L) Willd., *A. Ziziphus* amole (Sessé and Moc.) MC Johnst, *Guaiacum coulteri* A. Gray., *Opuntia decumbens* Salm-Dyck, among others (Salas-Morales et al., 2003).

Data collection in the field

Sampling was carried out between November 2014 and September 2015, during the dry season (November-May) and the rainy season (June-September). Forty camera traps (20 Moultrie cameras, 10 Stealth cameras, and 10 Bushnell Trophy cameras) were used to record the activities of medium and large mammals with body mass greater than 1 kg (Chiarello, 2000; Marques and Fabián, 2018). The camera traps were placed in four groups (10 cameras per group) within the CNPA El Gavilán and installed in one-camera stations along wildlife trails, sidewalks and especially on pathways with clear evidence of use by wildlife (Gonthier and Castañeda, 2013). Each station was treated as an independent sampling location, and the distance between each station was 500 m. We set all cameras to a height of approximately 0.5 m above the ground (Botello et al., 2008; Buenrostro Silva et al., 2015). Camera traps were operational 24 h per day, and batteries were frequently replaced to guarantee the camera traps would continue working (Marques and Fabián, 2018).

Classification of chrono-ecotypes

Independent photographic records were classified and quantified

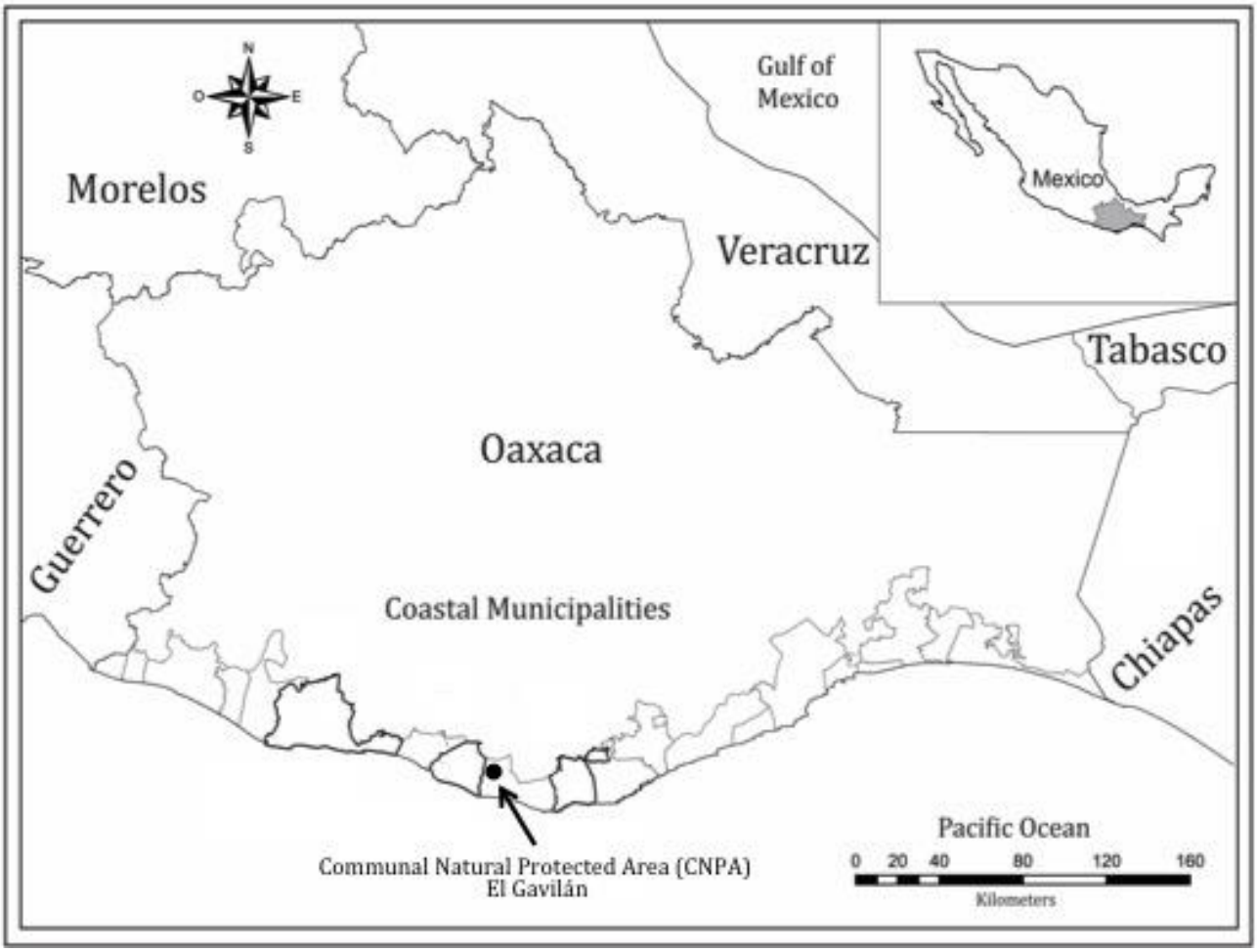

Figure 1. Geographical location of the Communal Natural Protected Area (CNPA) El Gavilán, Oaxaca, Mexico.

according to activity periods defined by Gódinez (2014). The crepuscular morning was considered between 06:00 to 08:00, and crepuscular evening was considered between 18:00 to 20:00. The intervals between these were considered to be diurnal and nocturnal.

Data were analyzed with Oriana software version 4 (Kovach, 2011) for circular statistics using the Raleigh test of uniformity and Rao's spacing test, with the objective of examining data that are distributed in a circular manner, such as time (Lehner, 1996). Circular statistical analyses of 10 species were carried out following Marques and Fabián (2018) procedures; there was a minimun of 11 photo-captures, with the objective of determining the mean vectors of hours in activity, the circular standard deviation and variance and their respective 95% confidence intervals. The mean vector has two properties: mean angle (μ) and length (r). The first is expressed as the time of day angle that represents the mean time of each species' activities. The second property can vary from 0 to 1, with higher values indicating that observations are grouped around the mean, while smaller values indicate that observations are not concentrated (Marques and Fabián, 2018).

A Raleigh test of uniformity (Z) was performance to determine whether simple times were significantly different from what would be expected by chance. Higher values of Z indicate greater concentration of the data around the mean (lower probability that data are uniformly distributed). Probabilities below the significance level of 0.5 indicate that data are not distributed uniformly and are evidence of a trend. Rao's spacing test (U) assesses spacing between adjacent points around a circle. Small p values mean that spacing is not uniform (Marques and Fabián, 2018). The Mardia-Watson-Wheeler test (Zar 2010) was used separately for each of the 10 species recorded to investigate if there were significant differences in time of activity between both seasons (Vera and Fábian, 2018). The Kruskal-Wallis test (Zar, 2010) was used to verify whether there were differences in activity over the 24-h period for the medium and large mammals as a whole. The relative abundance index (RAI) was calculated based on the number of independent photographic records per 100 camera-trap days (sampling effort) with the formula RAI= n/days * 100, where n = number of photocaptures o independant photographic records, days = sampling effort and 100 = standard correction factor. The RAI was calculated for each species in both seasons (dry and rainy) and compared through a *t* test (Zar, 2010). Independent photographic records were considered when there were (1) consecutive photographs of individuals of different species, (2) consecutive photographs of individuals of the same species separated by more than 24 h or (3) non-consecutive photographs of individuals of the same species. In the case of photographs of gregarious species where more than one individual was observed, the number of independent records considered was the same as the number of individuals observed in the image (Monroy-Vilchis et

Table 1. Independent photocapture records (IPR) in Communal Natural Protected Area El gavilan, Oaxaca, Mexico.

Species	IPR	D(%)	C(%)	N(%)
Leopardus pardalis	105	8 (7.6)	0	97 (92.4)
L. wiedii	75	0	5 (6.6)	70 (93.4)
Herpailurus yagouaroundi	46	3 (6.5)	8 (17.4)	35 (76.2)
Nasua narica	128	35 (27.34)	27 (21.1)	66 (51.56)
Procyon lotor	58	0	0	58 (100)
Didelphis virginiana	191	0	68 (35.6)	123 (64.4)
Dasypus novemcinctus	150	0	85 (56.6)	65 (43.4)
Dicotyles angulatus	86	37 (43)	14 (16.3)	35 (40.7)
Odocoileus virginianus	95	23 (24.2)	35 (36.8)	37 (39)
Sciurus aureogaster	84	84 (100)	0	0

D= diurnal; C= crepuscular; N= nocturnal; Scientific names of mammals according to Wilson and Reeder (2005).

al*.,* 2011; Buenrostro-Silva et al*.,* 2015). The time for the first detection of each species was calculated as the number of days used between setting up the camera-traps and the first registration of each species captured (Monroy-Vilchis et al*.,* 2011; Buenrostro-Silva et al*.,* 2015). All statistical analyses were made with the XLStat ecology version (Addinsoft Co.).

RESULTS

The sampling effort expended in CNPA El Gavilan returned 1,018 independent photographic records with full time and date records for 10 species of medium and large mammals, obtained with 12,160 day/camera traps. The only species with diurnal tendency was *Sciurus aureogaster*. The nocturnal species was *Procyon lotor*, while *Leopardus wiedii*, *Didelphis virginiana*, and *Dasypus novemcinctus* exhibited nocturnal and crepuscular tendencies, but were also active during the night. *Leopardus pardalis* was active during the night but exhibited diurnal and nocturnal tendencies. *Herpailurus yagouaroundi*, *Nasua narica*, *Dicotyles angulatus* and *O. virginianus* were defined as cathemeral because they did not exhibit any particular tendency, with activities evenly distributed across all periods (Table 1 and Figure 2).

The majority of photocaptured species had activity concentrated in certain periods, principally nocturnal periods. Four species (*H. yagouaroundi*, *N. narica*, *D. angulatus* and *O. virginianus)* showed times of activity uniformly distributed across 24 h (Table 2). However, these four cathemeral species did not exhibit significant differences in activity between both seasons. Among the ten species photocaptured in both seasons, there were no significant differences in activity times (Table 3).

The most abundant medium mammals were *D. novemcinctus* (RAI= 1.23), *D.virginiana* (RAI= 1.15) and *Nasua narica* (RAI= 1.05). *Procyon lotor* (RAI= 0.47) and *Herpailurus yagouaroundi* (RAI= 0.378) were less abundant (Table 4). The time of the first detection of each species ocurred between three and 43 days (Figure 3).

DISCUSSION

The relationship between the movement activity of animals and the time they spend at rest is one of the most important characteristics it shares with other members of its own species (Marques, 2004), and all this depends on a number of factors. For example, daily activity is determined both by external environmental factor (light, temperature, weather, precipitation, etc.) and the endogenous factors (physiological state) of the animals themselves (Ogurtsov et al., 2018). The types of activities are determined by a combination of conditions that generally ensure a relatively safe existence for the species (safety of obtaining food, survival of young animals, etc.) (Ogurtsov et al., 2018).

In this study, the majority of these species had predominantly nocturnal activities with a tendency to use the first half of the night most intensely in both seasons, whereas the diurnal species (*Sciurus auregaster*) tended to use the beginning of the day. The behaviour of nocturnal species may reflect a quest for thermal comfort during the earlier hours of the night when the temperature has not yet reached its lowest point (Marques and Fabián, 2018), or it could be a strategy to minimize predation (Van Schaik and Griffiths, 1996; Heurich et al., 2014). On the other hand, the activity of the diurnal species intensifies at the beggining of the day as they search for food when the temperature has not yet reached its highest point. Valdéz and Téllez (2005) mention that *S. aureogaster* has two peaks of activity during the day, in the morning (07:00 to 09:00) and in the afternoon (15:00 to 17:00), and it matches one of the peaks of activity with our records.

D. virginiana, *D. novemcinctus* and *L. wiedii* were species with nocturnal and twilight activity patterns,

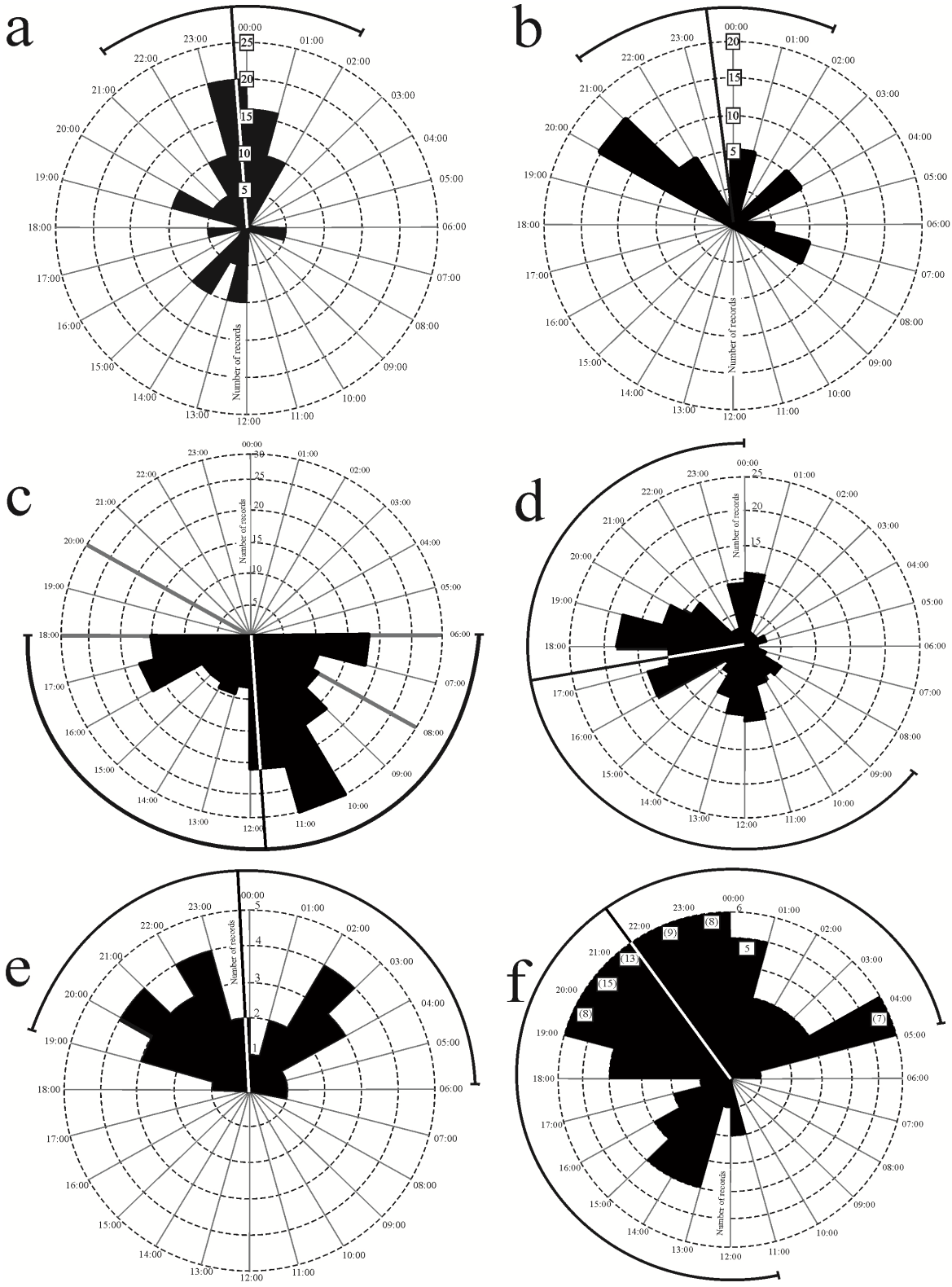

Figure 2. Activity patterns of six species of medium and large mammals in the Communal Natural Protected Area of El Gavilan, Oaxaca, México. The numbers around the edges of circles indicate time of day. The circular concetric dashes lines and numbers in black boxes indicates the number of records; the radius line indicate the mean vector; the external curved line represents the confidence interval for the mean. a= *Leopardus wieii*, b= *Procyon lotor*, c= *Nasua narica*, d= *Dicotyles angulatus*, e= *Didelphis virginiana*, f= *Dasypus novemcinctus*.

Table 2. Circular statistics analysis of times of activity of medium and large mammals in Communal Natural Protected Area El Gavilan, Oaxaca, Mexico.

Species	r	Mean vector	Circular variance	Circular standard deviation	95% Confidence Interval	Z	U (μ)
Leopardus pardalis	0.473	23:47	0.275	04:07	21:32; 02:02	82.153 (p<1E-11)	213.017 (p<0.01)
L. wiedii	0.271	23:28	0.342	05:40	21:53; 02:03	67.261 (p<1E-12)	204.862) (p<0.01)
Herpailurus yagouaroundi	0.157	21:32	0.291	03:23	18:28; 00:42	56.572 (p=1.85)	142.581 (0.5>p>0.1)
Nasua narica	0.667	22:56	0.483	06:38	20:16; 00:36	35.694 (p<1E-1)	198.573 (p<0.01)
Procyon lotor	0.350	01:17	0.352	04:13	23:42; 02:52	4.683 (p=3.31-12	162.3 (0.5>p>0.1)
Didelphis virginiana	0.549	03:29	0.185	03:52	00:09; 06:49	6.731 (p=0.031)	196.752 (p<0.01)
Dasypus novemcinctus	0.362	00:38	0.404	04:18	00:02; 03:14	3.635 (p=0.031)	148.083 (p<0.01)
Dicotyles angulatus	0.275	11:23	0.193	07:43	08:08; 02:38	4.295 (p<1E-11)	142.759 (p<0.01)
Odocoileus virginianus	0.684	22:06	0.274	03:48	18:51; 02:21	7.631 (p=0.007)	196.714 (p<0.01)
Sciurus aureogaster	0.012	09:35	0.382	01:37	08:39; 10:31	0.017 (p=0.892)	124.865 (p<0.05)

r= Properties of mean vector; Z= Rayleigh tests of uniformity; U= Rao´s spacing test.

possibly due to the predatory-prey relationship. In the Isthmus of Tehuantepec, Oaxaca, similar results were found for these species (Cortés-Marcial and Briones-Salas, 2014). The assemblage of felids in the NPA El Gavilan includes three medium-sized species (*L. pardalis*, *L. wiedii* and *H. yagouaroundi*). *L. pardalis* and *L. wiedii* are primarily nocturnal species (de Oliveira, 1998; Sunquist and Sunquist, 2002; Pérez-Irineo and Santos-Moreno, 2016), but in this study *L. wiedii* exhibited twilight and nocturnal activity while *L. pardalis* had diurnal and nocturnal activity. Our results are in part to the point of Los Chimalapas region, where Pérez-Irineo and Santos-Moreno (2016) found diurnal and nocturnal activity patterns in *L. pardalis* and *L. wiedii*. Our study provides similar evidence that *L. wiedii* coexists with *L. pardalis.* Altought *H. yagouaroundi* is a poorly studied species, there are records of it in all the neotropics region (Carvajal-Villarreal et al., 2012; Valenzuela-Galván et al., 2013; Cortés-Marcial and Briones-Salas, 2014; Buenrostro-Silva et al., 2015; Briones-Salas et al., 2016; Pérez-Irineo and Santos-Moreno, 2016). Aranda (2005) mentions that this species has daytime habits, but here we documented it as exhibiting cathemeral activity with a major nocturnal tendency.

The rest of the cathemeral species recorded in this study shows similarities with those reported by Cortés-Marcial and Briones-Salas (2014). *Nasua narica, Dicotyles angulatus* and *Odocoileus virginianus* showed broad activity patterns, probably related to their feeding habits, and their body size allows them to forage them both day and night (Van Schaik and Griffiths, 1996). *O. virginianus* has been recorded with cathemeral patterns in arid environments in the Tehuacan-Cuicatlan Biosphere Reserve, Oaxaca, with a tendency of use between 06:00 and 12:00 (Mandujano and Hernández, 2019); however, in the northeast of Mexico, it was found to have nocturnal tendencies (Gallina and Bello, 2014).

The most abundant medium mammals in our study were *D. novemcinctus*, *D. virginiana* and *N. narica*, and it is possible that their abundances are related to their alimentary habits (Pina et al., 2004; Mesa-Zavala et al., 2012). Our results match with reported by Monroy-Vilchis et al. (2011), Pérez-Irineo and Santos Moreno (2012), and Cortés-Marcial and Briones-Salas (2014). The absence of arboreal species may be related to the sampling design used, due to this one is being searched to the records of terrestrial mammals, and not for species with arboreal habits (Aranda, 2012). Although there were records of other mammals, it was not possible to analyse their acitivity patterns due to low registration rate. For example, *Puma concolor* is a territorial species and requires large field extensions to be able to realize its activities (Bustamante, 2008; Monroy-Vilchis et al., 2011). In our study there was only one record of this species.

Conclusions

This study documents the daily activity patterns of

Table 3. Differences in activity times between cathemeral species in both seasons in Communal Natural Protected Area El Gavilan, Oaxaca, Mexico.

Group of species	Dry vs. Rain
3 crepuscular-nocturnal species	W= 5.972; p = 0.673
Leopardus pardalis	W= 2.638; p= 0.371
L. wiedii	W= 4.229; p= 0.176
Herpailurus yagouaroundi	W= 11.1; p= 0.004 *
Nasua narica	W= 2.497; p= 0.287
Procyon lotor	W= 0.716; p= 0.699
Didelphis virginiana	W= 2.243; p= 0.326
Dasypus novemcinctus	W= 2.487; p= 0.287
Dicotyles angulatus	W= 2.683; p= 0.261
Odocoileus virginianus	W= 0.824; p= 0.662
Sciurus aureogaster	W= 1.188; p= 0.552

*Significative difference.

Table 4. Relative abundance index (RAI) of medium and large mammals in the Communal Natural Protected Area El Gavilan, Oaxaca, Mexico.

Especie	IPR	RAI	IPR (n)	RAI/ Dry	IPR (n)	RAI/ Rain
Leopardus pardalis	105	0.86	72	0.99	33	0.67
Leopardus wiedii	75	0.616	39	0.53	36	0.73
Herpailurus yagouaroundi	46	0.378	27	0.37	19	0.39
Nasua narica	128	1.05	76	1.04	52	1.06
Procyon lotor	58	0.47	36	0.49	22	0.44
Didelphis virginiana	191	1.15	93	1.28	98	1.99
Dasypus novemcinctus	150	1.23	82	1.13	68	1.38
Dicotyles angulatus	86	0.707	49	0.67	37	0.75
Odocoileus virginianus	95	0.78	53	0.73	42	0.85
Sciurus aureogaster	84	0.69	62	0.85	22	0.45

IPR= Independant photographic record; RAI= Relative Abundance Index.

some medium and large mammals in the tropical dry forest on the central coast of Oaxaca, but very few similar studies in the Mexican neotropics exist to make comparisons. Additionally, our results on relative abundance show the more abundants species and its importance for monitoring and maintaining mammalian biodiversity. Our results can provide insights into the conservation of species in the CNPA El Gavilan.

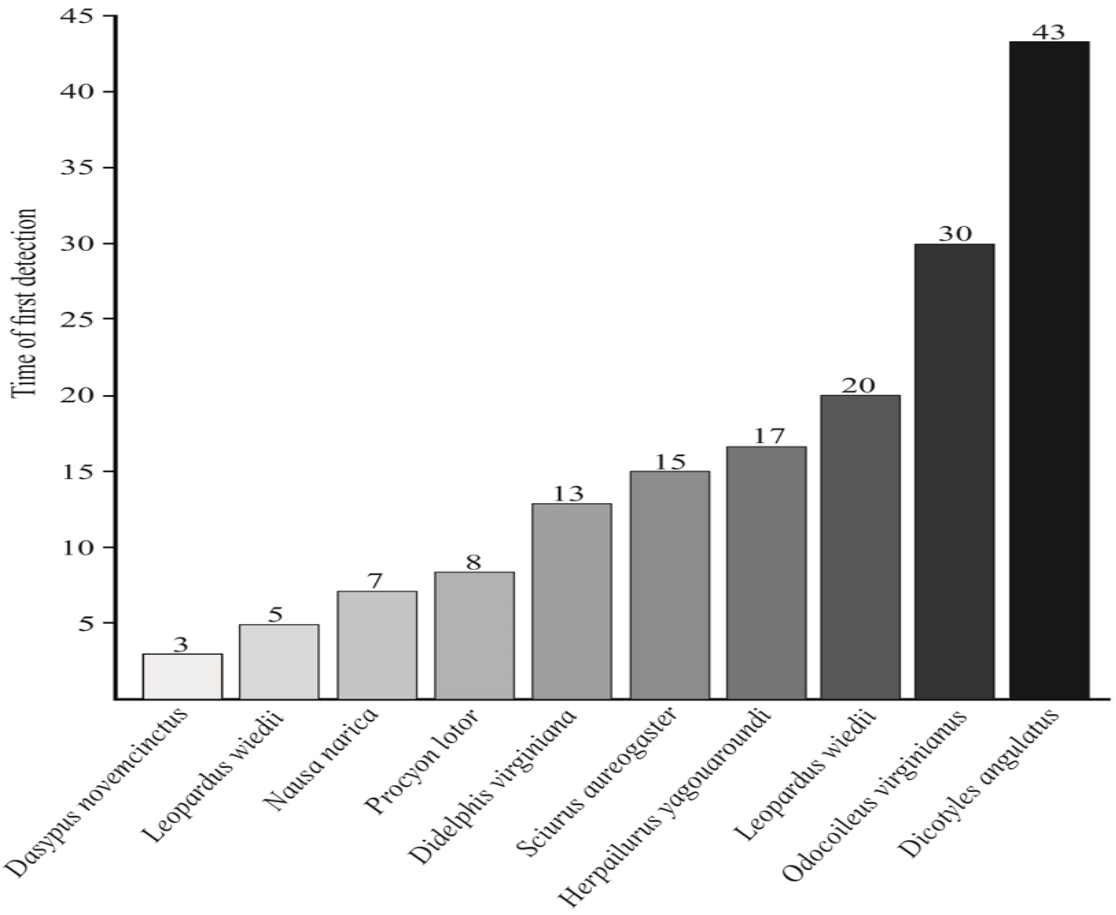

Figure 3. Time of first detection of medium an large mammals in the Communal Natural Protected Area El Gavilan, Oaxaca, México. The numbers above the bars indicate the time of first detection by this specific species.

We recommend the continuance of studies on the temporal and seasonal variations of the activity patterns in order to maintain mammalian species conservation.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Communities' perceptions regarding the impact of Hoima-Tanga crude oil pipeline on the loss of biodiversity in Swagaswaga Game Reserve, Tanzania

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This study was conducted to evaluate perceptions of communities surrounding the Swagaswaga Game Reserve regarding the impact of the proposed Hoima-Tanga crude oil pipeline on biodiversity loss. The pipeline will transect the game reserve and some of the neighbouring villages. The study involved 156 randomly selected respondents from four purposefully selected villages located at 0 to 10 km and 11 to 20 km from the game reserve. The respondents comprised 55 females and 101 males, aged between 20 and 70 years. Semi-structured questionnaire was used. Only 57% of the respondents were aware of the proposed project, and the majority of these respondents reside in villages located closer to the game reserve. Their major concern was loss of biodiversity, which was more frequently expressed by those living close to the game reserve (58.3%) than by those living further away (5%). Respondents also expressed concerns about the lack of clarity regarding land compensation. The latter was expressed significantly more frequently by respondents residing close to the game reserve. This study demonstrates the lack of community awareness about the project. The study concluded that, comprehensive community engagement in project planning coupled with technical capacity building will be a key to guaranteeing community involvement in conservation activities.

Key words: Biodiversity loss, communities' perceptions, oil pipeline, Swagaswaga Game Reserve.

INTRODUCTION

The efficiency of ecosystem function is important for the survival of biodiversity (Haines-Young and Potschin, 2012). Human activities certainly have a substantial influence on changes in environment, alteration of ecosystem functioning and biodiversity loss (Gunderson et al., 2012; Pecl et al., 2017). In most cases, these activities are particularly those related to habitat degradation and ecosystem instability (Metzger et al., 2006). For instance, although the exploitation of natural gas and oil has had immense positive impacts on

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national economies and the social well-being of mankind in many countries (Haggerty et al., 2014; Weber, 2012); oil infrastructure construction which usually include clearing of land, development of roads and the digging of terraces (Brittingham et al., 2014), have often been linked to environmental destruction and degradation. Studies in Tanzania have also shown that the presence of offshore hydrocarbons (Kuwayama et al., 2015) in marine parks of Mafia Island and Mnazi Bay have been linked to notable environmental risks (Souther et al., 2014). Generally, oil and gas production activities have often been associated with negative ecological impacts; including loss of biological diversity (Pelletier and Coltman, 2018) and limited ecological functioning (Copeland et al., 2009).

More specifically, the construction of oil pipelines in previously undisturbed natural habitats and protected areas has often generated various negative impacts on environmental stability (Laurance et al., 2009), as such pipelines provide easy access to pristine habitats, habitually resulting in habitat loss and conversion (Finer et al., 2008). Such activities have also been linked to various threats to wildlife (Scholte, 2011; Thirgood et al., 2004), stemming in part from the destruction of water catchment areas, streams and rivers (Kuwayama et al., 2015). Indeed, Craigie et al. (2010) reported that the population of large mammals in African protected areas has been halved since 1970 due to the negative effects of various forms of anthropogenic activities, notably in West Africa's protected areas. Additionally, the world's total biomass of wild mammals relative to humans and their allies (livestock, poultry, etc.) has drastically declined over previous decades (Bar-on et al., 2018).

Furthermore, oil spills from damaged or poorly maintained pipelines, which have occurred in some countries, often release highly toxic hydrocarbons, such as benzene and polynuclear aromatic hydrocarbons, into soil and water sources (Taylor et al., 2011), affecting the survival of aquatic and terrestrial organisms (Jones et al., 2015). Likewise, noise pollution emanating from pipeline construction activities has also been shown to interfere with foraging behaviour, reproductive success, parental investment and predation risk (Shannon et al., 2015). Dust generated during construction of infrastructure is also known to reduce vegetation quality by rendering it less palatable as a result of being avoided by ungulates (Ndibalema et al., 2008).

Recently, Ugandan and Tanzanian authorities have agreed on the construction of an oil pipeline from Hoima in Uganda to Tanga Port in Tanzania (Byaruhanga, 2018). The proposed Hoima-Tanga crude oil project is 1410 km-long oil pipeline running from Buseruka sub-county in Hoima District in Uganda's Western Region through Bukoba in Tanzania, looping around the western shores of Lake Victoria and traversing through Shinyanga, Singida and Dodoma, finally ending at Tanga Port along the Indian Ocean (Barlow, 2020). The pipeline transects various wilderness habitats, such as protected areas, and underutilised land parcels. In Central Tanzania, the proposed oil pipeline route is constructed while overlapping the Swagaswaga Game Reserve (SGR) and some villages surrounding this game reserve (TPDC Unpublished Report, 2016). Although the route of the pipeline has already been planned, much information on how biological diversity in the game reserve are going to be impacted by the project are not known. Similarly, there was no community engagement in planning the project, this situation may have negative impact on natural resources conservation. Therefore, the aim of this study was to investigate the general awareness, opinions and perceptions that communities had about the proposed pipeline project on loss of biodiversity in Swagaswaga Game Reserve.

MATERIALS AND METHODS

Study site

This study was conducted in four villages surrounding Swagaswaga Game Reserve (Figure 1). Swagaswaga Game Reserve is found between Chemba and Kondoa Districts in Dodoma Region. It was entitled to be a Game Reserve in 1997 with total coverage of 871 km^2. It combines the former Songa Forest Reserve (187 km^2), Simbo, Swagaswaga and Handa forests (400 km^2) and other forest areas adjacent. The area is dominated by miombo woodlands, which offer habitats for a number of wildlife species, such as Lions (*Panthera leo*), Leopards (*Panthera pardus*), Spotted hyenas (*Crocuta crocuta*), Black backed jackals (*Canis mesomelas*), Cape buffalos (*Syncerus caffer*), Greater kudus (*Tragelaphus strepsiceros*), African elephants (*Loxodonta africana)*, Hippopotamuses (*Hippopotamus amphibius*), Bush pigs (*Potamochoerus larvatus*), Warthogs (*Phacochoerus africanus*), large snakes, Buffalos (*Bubalus bubalis*), among many others (TAWIRI Unpublished Report, 2009).

Study villages selection criteria

The study involved four selected villages that border the game reserve. Two villages (Swagaswaga and Serya) were located within 0 to 10 km from the game reserve, whereas the other two (Isari and Hondomairo) were within 11 to 20 km from the game reserve. Selection criteria based on the confirmation that the pipeline route will pass through Swagaswaga and Serya villages, however the exactly location was not yet identified since surveys were still ongoing during our study. We also made the assumption that communities residing in these villages would have increased access to the game reserve as a result of the improved road network and that the negative consequences of pipeline construction on their farm and grazing land than those further away (Lawuo et al., 2014). Thus, in general, distance from the game reserve and the presumed pipeline route provided the major criteria for selection of the villages for study.

Selection of respondents

Respondents from the four villages were randomly selected from the list of households in each village, comprising approximately 10% of the total households per each study village. A total of 156 respondents from Swagaswaga (n = 43), Serya (n = 50), Isari (n = 31) and Hondomairo (n = 30) participated in the study. The total

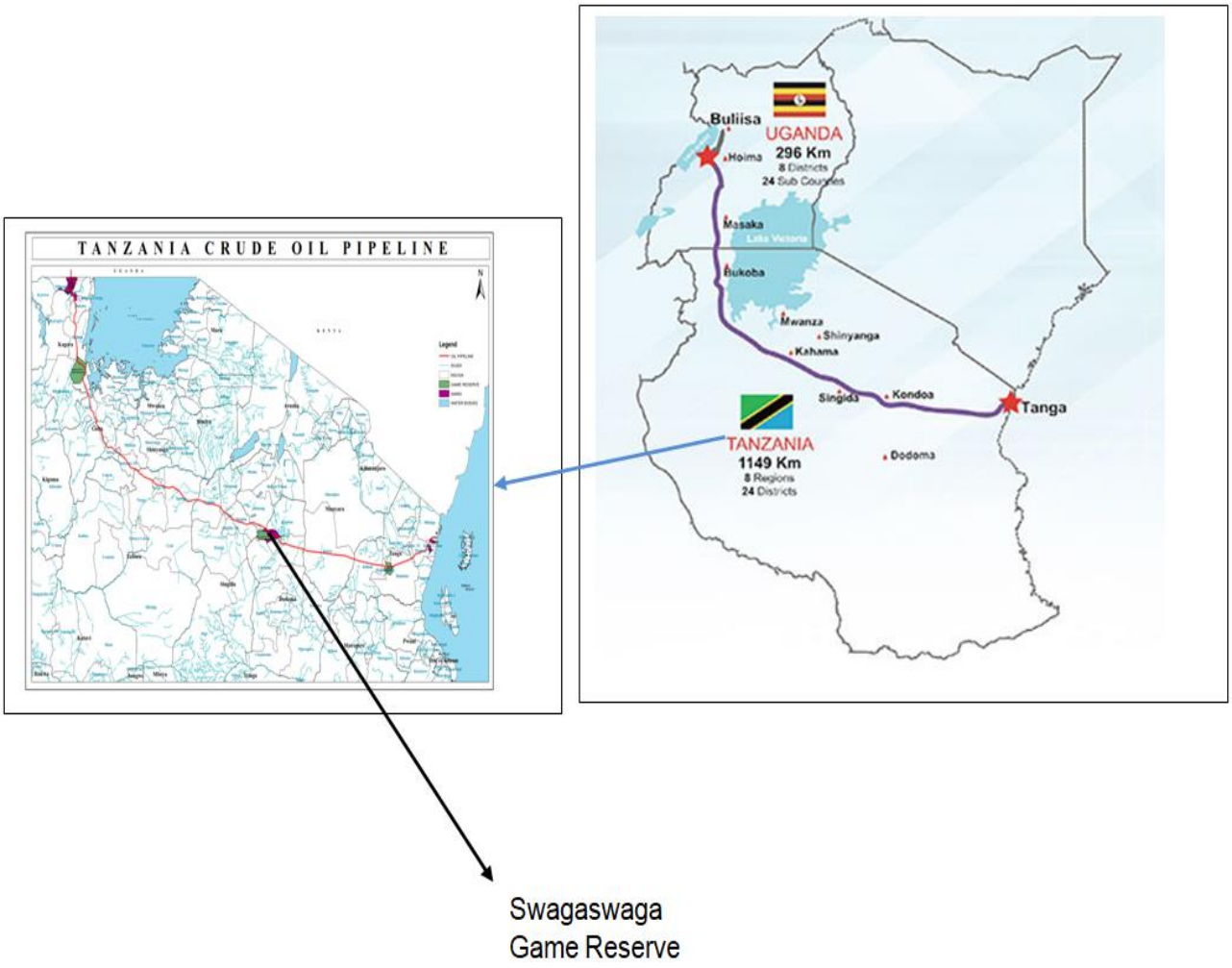

Figure 1. A map of the proposed crude oil pipeline route (red line) passing through several game reserves including Swagaswaga Game Reserve in Tanzania.
Source: The Tanzania Petroleum Development Corporation (TPDC), 2016.

comprised 55 females and 101 males aged between 20 and 70 years. Selection of sample size was determined by the concept of information power and principle of saturation. According to Malterud et al. (2016), in qualitative research the more the number of participants leads to more data rather than information (principle of saturation). In addition Malterud et al. (2016) revealed that in order for the research study to have an information power, it should hold the lower sample size (N).

Developed tools for the study

During this study, qualitative research methodology where semi-structure interview and focus group discussion were employed to allow the researcher to make a detailed study on the theme, that is, how the pipeline project will have an impact on their livelihood as well as to the natural resources. Hay (2016) notes that qualitative research is concerned with clarifying human environments and human experiences within a variety of conceptual frameworks. According to Hadi and Closs (2016) qualitative research is more explanatory in nature seeking to provide insight on how individuals understand the matter on discussion.

The questions assessed their awareness (Are community aware of the proposed project?), opinions (what are their views regarding the project? Are they accepting or rejecting the project?), perception (what are their attitude on the project toward the loss of biodiversity? will the project influence illegal hunting and how?) and what will be the impacts of the project to habitat quality?

Questionnaire pilot testing, validation and ethical issues

Questionnaires were developed in accordance with the main objective of the study. Generated questions aimed at answering research questions. Face and content validation methods were used to validate the questionnaire whereby expert people in the topic under study were involved in evaluating whether the questions capture the topic under investigation. The pilot study was conducted in order to study the population characteristics, to check acceptability of the study, to correct the questions and pre-testing the questionnaire whether they are relevant and easily understood by respondents. Ethical issues were taken into consideration where all information given by respondents were considered confidential; during interview, each questionnaires were assigned with number

Table 1. A binary logistic regression analysis with respondents" „"awareness, opinions and perceptions ‘’ of the project toward the biodiversity loss as response variables and respondent’s age, gender and education level as explanatory variables.

Predictor	Awareness $Wald_a$	p≤	Opinion $Wald_o$	p≤	Perception $Wald_p$	p≤	Poaching $Wald_l$	p≤
Distance to PA	36.268	0.0001	27.59	0.0001	44.835	0.0001	25.485	0.000
Age	0.01	0.921	0.008	0.927	1.604	0.205	1.676	0.195
Gender	0.023	0.88	0.003	0.956	0.017	0.895	6.854	0.009
Education level	0.002	0.966	0.463	0.496	4.802	0.028	0.107	0.743
Constant	10.713	0.001	2.468	0.116	7.161	0.007	0.006	0.939

“$Wald_a$, $Wald_o$, $Wald_p$ and $Wald_l$"" are Chi-square coefficient for awareness, opinions, perceptions and influence in illegal hunting (poaching). „"P"" represents the level of statistical significance.

not respondent name. Furthermore, redundant questions and those which required private or sensitive information were avoided.

Data analysis

Descriptive statistics were used to generate means and percentages. Chi-square tests were used to identify significant differences at $p < 0.05$. Finally, we used generalized linear regression or binary logistic regression analysis to identify the best predictors.

RESULTS

Socio-demographic characteristics

Overall, 156 respondents were interviewed, of which 64.7% (*n = 101*) males and 35.3% (*n= 55*) were females. The respondents were of different ages, ranging from 20 to 70 years. Majority (*n* = 137) of the respondents had completed at least primary school education, whereas the rest (*n*= 19) had no formal education. The majority (*n* = 151) earned their livelihood from crop and/or animal agriculture, and only (*n* = 5) respondents were public servants.

Awareness of local community regarding the crude oil pipeline project

When respondents were asked if they were aware of the pipeline project, 57.1% of the respondents were aware (however there was no official information given to them). A binary logistic regression was conducted with “awareness/no awareness’’ as a dependent variable, and distance to protected area (PA), respondents’ age, gender, and education level predictors. Distance to PA was the only significant variable ($Wald = 36.3$, $p < 0.001$), respondents’ age, gender and education level were not significant factors (Table 1).

Local communities’ opinions toward the project

Most of the respondents expressed a positive opinion on the project (53.2%). A binary logistic regression was conducted with the “accepting/rejecting the project’’ as a dependent variable and distance to PA, respondents’ age, gender, and education level as independent variables. Distance to PA was the only significant variable ($Wald = 27.59$, $p < 0.001$), while the other three variables were not significant (Table 1).

Local communities’ perceptions on the project towards loss of biodiversity

Majority (63.5%) of respondents near the game reserve and those with formal education (77%) were having a negative perception on the proposed crude oil pipeline to biodiversity loss. A binary logistic regression analysis was conducted with “the project will cause loss of biodiversity/no loss of biodiversity’’ as a dependent variable, and distance to PA, respondents’ age, gender, and education level as explanatory variables. Distance to PA and education level were the only significant variables ($Wald = 44.84$, $p < 0.001$) and ($Wald = 4.80$, $p < 0.05$), respectively, the other factors were not significant (Table 1). The potential loss of biodiversity within and outside the game reserve has been thought to stem from habitat loss and its associated effects (35.5%), improved road network and pollution (18.6%) and increased human population growth (6.4%).

The influence of crude oil pipeline construction on illegal hunting (poaching)

The proposed pipeline was also thought to potentially result in the increased illegal hunting of wildlife (63.5%). A binary logistic regression analysis was carried out with ‘’the project will increase illegal hunting/the project will not increase illegal hunting’’ as a dependent variable, and distance to PA, respondents’ age, gender, and education level as predictors. Nevertheless, distance to PA ($Wald = 25.49$, $p < 0.001$) and respondents’ gender ($Wald = 6.85$, $p <0.05$) were the only significant variables. Other variables were not significant (Table 1). The potential

Table 2. A stepwise logistic regression analysis with vegetation status before the project as a dependent variable, and distance to PA, respondents' age, gender, and education level as independent variables.

Predictor	B	Wald	p≤
Distance to PA	-0.025	0.381	0.537
Age	0.398	2.568	0.109
Gender	1.195	4.315	0.038
Education level	-0.418	0.224	0.636
Constant	-3.861	6.301	0.012

Table 3. A stepwise logistic regression analysis with vegetation status during the project as a dependent variable, and distance to PA, respondents' age, gender, and education level and as independent variables.

Predictor	B	Wald	p≤
Distance the PA	0.376	44.131	0.000
Age	0.047	0.024	0.877
Gender	0.325	0.189	0.664
Education level	-0.813	0.422	0.516
Constant	-4.554	4.205	0.040

drivers of increased illegal hunting include easy access to the protected area as a result of newly opened habitats (73.7%), rapid human population growth (11.5%) and increased fuel availability (7.1%) for motor vehicles and bikes.

Vegetation status before and during the project

Local communities were asked on the current vegetation status and if they think there will be changes during the project construction. Vegetation considered was large trees and shrubs. The majority (86%) of respondents claimed that there are still many miombo trees and shrubs in the game reserve. A binary logistic regression conducted with "trees status before the project" (many or few)" as a dependent variables and distance to PA, respondents' age, gender, education level and as independent variable. Respondents' gender differed statistically significant in tree status before the project (Wald = 4.32, $p < 0.05$), while the other three factors were non-significant (Table 2).

Expected vegetation status during the project

Again, majority of respondents (59%) claimed that the pipeline project will reduce vegetation cover. A stepwise logistic regression was conducted with "the project will destruct the vegetation cover "(yes, no)" as a dependent variable and distance to PA, respondents' age, gender, and education level as independent variables. Distance to PA was the only significant variables (Wald = 44.13, $p < 0.001$), while other three factors were non-significant (Table 3).

DISCUSSION

Despite of the fact that the proposed regional oil pipeline has often been the subject of national discussion in which the national socio-economic gains and those of the villages involved in the project have been highlighted; the welfare of biological diversity in the game reserve also needs a critical attention since the national and local economy gain may come with the expenses on natural habitats and biodiversity (Mason et al., 2015). Relationship amongst project development, communities' livelihood and conservation appears intrinsic to be considered simultaneously. It is important to find a way to improve and strengthen this relationship for future sustainable conservation.

Awareness of communities regarding the Hoima-Tanga crude oil pipeline construction project

The study revealed that only 57.1% of the residents in the study area were aware of the project. The majority of the respondents who had any knowledge of the pipeline were located within 10 km from the game reserve. This is because the proposed pipeline route was planned also to

be constructed passing through some parts of village's vicinity to the game reserve hence increasing the fear of losing their possessions (farms, grazing lands and homes). However, there was neither formal information nor community involvement in planning the project. This finding indicates that communities in the study sites, despite of being primary stakeholders to the proposed pipeline project, have yet to be adequately engaged and informed to establish their political buy-in and to garner the needed collaboration and cooperation necessary both during and after the construction of the pipeline. The engagement of these residents is central in minimising social agitation, guaranteeing maximal cooperation while reducing exploitation pressure to the natural resources in the game reserve (Sharareh and Badaruddin, 2015). This lack of awareness therefore calls for the need to develop a strategic plan for community engagement and advocacy. Community participation approach is crucial since actively involvement of local people in planning projects can reduce sabotage of infrastructures and improve their involvement in protected areas management activities (Amrita and Sarmistha, 2015).

Local communities' opinions toward the project

Majority of villagers (53.2%) closer to the game reserve were having a negative opinion because the project brought with it land acquisition for the pipeline itself, services road and other amenities like camps for workers. There were no specified clear terms of compensation for land loss which terrified the local people. From the local peoples' perspective, this impact is alarming rather than bringing prosperity to the local society and biological diversity since it has consequences for the longer-term sustainability of the local community both as a socioeconomic resource base and as a natural ecosystem (Amrita and Sarmistha, 2015). It has been proved elsewhere in Africa for example; that oil and gas exploitation, production and transportation has led to alienation of land use right from the local communities' ownership with no clear terms of compensation and/or even negotiation (Kuenzer et al., 2014).

Kuenzer et al. (2014) study in Niger Delta discovered that oil infrastructures were major source of land alienation and poverty in the region leading to low productivity per person and increased landlessness while leaving local people with no option for their livelihood hence persistent poverty (Sarrasin, 2013). Rural economy of local communities closer to Swagaswaga Game Reserve depends immensely on land for agriculture and grazing. These activities provide them with vital products for domestic and market consumption hence making natural environment such as land beneficial to the community. For this reason, land acquisition will not compromise local communities that depend on the region's land for their well-being.

Alienation of land will leave them with no option for their livelihood hence forcing poor farmers to degrade more environments for settlement, grazing land and agriculture; moreover, intensifying illegal exploitation of wildlife for food and income generation (Sarrasin, 2013).

Local communities' perceptions on the crude oil pipeline construction project towards loss of biodiversity

Majority (63.5%) of villagers residing close to the protected area and those with formal education (77%) had negative perceptions of the project due to the threat of the potential loss of biodiversity within the game reserve. Local people in the vicinity of the game reserve had negative perception due to the fact that change in land use would have an influence on overharvesting of natural resources in the game reserve for their livelihood. Education positively influenced local people perception toward loss of biodiversity whereas respondents with formal education were having negative perception on project towards loss of biodiversity. This may be due to the fact that they are able of reading different articles, documents and magazines that are related to conservation. Also, they may be involved in different training and meeting aimed at natural resources conservation. Some of the factors they thought that would contribute biodiversity loss were reduce habitat quality in the game reserve since it plays a big role in determining species distribution patterns, and population viability (Mortelliti et al., 2010).

The other factors were population growth especially during the construction leading to various forms of natural resources harvesting (Laurance et al., 2009). Likewise, the transformation of heterogeneous habitats to pave way for the pipeline, also thought to have substantial impacts on biodiversity, environmental degradation and wildlife survival. A study by Souther et al. (2014) revealed that homogeneous small patches support few species, which in turn deter gene flow between population resulting into alteration of genetic diversity and structure overtime therefore reduced ability to adapt environmental changes (Keinath et al., 2017). In addition, like in many countries, oil pipelines may be associated with various forms of pollution (Bilen et al., 2008) and often leaving behind toxic materials and a depleted environment that threatens ecosystem health. This has been proven in Niger Delta whereas accidental oil spills have frequently had negative impacts on the environment and biodiversity (Osuji and Nwoye, 2007).

Influence of the project to illegal hunting (Poaching)

The study also revealed that local people near the game reserve (63.5%) and female (74.1%) were concerned

about an increase in illegal hunting of wild animals influenced by the project. Being closer to the game reserve, these local people may have experienced different factors that had led to illegal hunting before; for instance, change in habitat quality, weather extreme and others. Female respondents were very honest compared to male; this may be due to the factor that they are less involved in illegal hunting activities compared to men. On the other hand, male respondents stayed reserved due to the factor that they either had hidden information on illegal hunting or they were directly involved in such activities.

Causes for illegal hunting as described by local people

As a consequence of the project, improved access to the protected area was described to influence illegal hunting. Clearance of vegetation and opening of thick, intact forests and shrubs in the game reserve will usually leave the areas more open and easily accessible by poachers and hunters (Wilkie et al., 2000). In West and Central Africa for example, the Congo basin which contains 20% of world's tropical forests (Joppa et al., 2008) has been found to lose most of the gorillas through poaching escalated by vegetation clearing and improved road network (Nellemann et al., 2010). Human population growth during the construction of the pipeline was projected to be higher near the game reserve (due to immigration) while increasing bush meat demand among the population. Families will afford purchasing bush meat due to increased income. Likewise, income generated from employment and small-medium scale enterprises will make it easier for bush meat transporters to access energy sources for their vehicles.

Vegetation status before and during the project

According to the local peoples' perspective the status of vegetation cover is still intact. Local people with the age of 45 and above stated that there are still many large trees especially "miombo", and shrubs in the game reserve. This may be due to the factor that being living near this game reserve for many years they know the trend and status of vegetation cover. Again, when they were asked if the project will destruct the vegetation cover which play a big role as habitats for wild animals, local people near the game reserve were having perceptions that the project will harm the vegetation especially lager trees and reduce its abundance. Being living closer to the protected area they may be seeing other anthropogenic activities that are taking place in the game which have negative effects on vegetation abundance. Therefore, making them to conclude that the crude oil pipeline construction project will have such effects.

Existence of ecological system viability depends much on preservation of ecological composition, structure, function, processes and interactions (Parrish et al., 2003). Alteration of biological processes and functions caused by habitat destruction consequently reduces biological diversity and composition (Waters et al., 2016). According to Waters et al. (2016), fossil fuel extraction all around the world has been responsible for habitat destruction especially when extraction and oil infrastructures lie deep into protected areas. Taking an example of Amazonian rainforest which is the earth's diverse place whose habitat has been destroyed much by oil extraction activities through deforestation, clearing for accessible road (Scanes, 2018) while threating species. Thus, this study discovered that the crude oil pipeline construction through SGR will lead into impaired habitat and degraded environment which will reduce its capacity to accommodate wild species.

CONCLUSION AND RECOMMENDATION

The expressed concerns call for pipeline project proponents and protected area authorities to partner with ward and village governments to properly engage local communities. While it is important for authorities to devise community-based strategies for engagement and advocacy to ensure the optimal cooperation of communities, it is essential that they are also technically empowered in areas of innovative land use patterns, crop and animal husbandry practices, environmental management and wildlife protection to improve their livelihoods. Introduction of mandatory education to oil projects owners to enhance knowledge and awareness on environmental issues and the damage caused by the pipeline projects on ecological biodiversity is of importance for their conservation.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Potential of Acacia for poverty alleviation in Rorya District-Tanzania

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Rorya is one of new districts in Tanzania established in 2007. The district is a reflection of typical rural life in Africa South of Sahara where rural communities inhabiting dry woodlands and dependent on natural resources for their sustenance do not consider indigenous tree species as valuable resources of income. The study was conducted in the low lands of Rorya district-Tanzania to assess contribution of wild *Acacia* species for sustenance among rural communities. Ethnobtanical survey and standard sapling procedures were used for data collection and description of *Acacia* distribution patterns. Distribution and diversity of *Acacia* species is affected by multiple factors some of which could not be addressed by the arithmetic models employed in this study. Of all the sampled *Acacia* species, *A. seyal* ranked topmost as potential tree resource for a wider local and cross border market. Unlike other sampled *Acacia*s, *A. seyal* has comparatively rapid biomass turnover within a short period. Density of *A. seyal* is much higher in swampy black cotton soils. Despite the economic potential of the species, significant proportion of *Acacia* woodlands is cleared annually for charcoal. Though *Acacia seyal* stumps coppices readily, combination of clearing and over grazing can convert the *Acacia* woodland to typical grasslands within a shorter duration of 20 years. At the same time, there is neither a conservation guideline nor land tenure arrangement in place for sustainable conservation. The study is recommending urgent legislative and land tenure reforms to control the current free access and encroachment that has nastily denuded the wood lands. *Acacia* being good source of pollen, commercial placement of bee hives is advocated as a supplementary economic activity in parallel with selling of wood fuel.

Key words: *Acacia*, *Vachellia, Senegalia*, sustainable development.

INTRODUCTION

Life on the earth is totally dependent on the natural resources which are the resultant of structure and functioning of the ecosystems. The ecosystem provides services which regulate the cycling of material and nutrient and flow of energy among organisms (Bargali et al., 1992a, b; Parihaar et al., 2014; Bargali, 2018). Anthropogenic pressures lead to land degradation and reduced the natural resources at an alarming rate during

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the recent past (Padalia et al., 2017; Bargali et al., 2018; Bargali et al., 2019). Due to this the pressure on easily available and more productive resources increased continuously and have been pushed towards the threat which needs the sustainable management and utilization. Rorya district in Tanzania is a mirror image of other areas in the world and in African region with similar ecological degradation and social economic challenges. The district is characterized by regular hunger, poverty, draught and over dependence on natural resources for survival (Mugini, 2012). Up to 1980s the study area was fairly covered with intact vegetation with *Acacia seyal* and *A. sobusta* being dominant species especially in Mori and Nyaburongo valleys. These two valleys have approximate dimensional stretches of 20x40 km and 25x10 km for Mori and Nyaburongo valleys respectively thus accounts to about 10% of the forest cover in the district. According to 2012 national census (Wikipedia, 2020), Nyaburongo and Mori Valleys served approximate population of 83,767 in 6 wards including Nyathorogo - 14,809 people, Rabour - 11,259, Kisumwa - 12,447, Komuge - 13,651, Nyamunga - 13,161 and Kyang'ombe - 18,438.

Communities around the said woodland have been dependent on these natural resources for firewood, poles, timber, bricks burning, farm hedge, logs, thatching grass and grazing. The valleys have been water catchment for rivers Mori, and Nyaburongo for supported fishing of Mud and Lung fish. Nevertheless, the fish particularly lung fish have disappeared from the rivers following the current biodiversity loss and tremendous decline in water catchment capacity. Besides, the biodiversity loss in the past three decades was exacerbated by the emergence of commercial charcoal making and supply of logs for Co-Bricks factory specialized in burnt earth bricks. Consequently, the woodland was quickly converted to grassland by roughly one-third within a span of 30 years from late 1970s to 2000. Charcoal business is regarded as source of quick money among the youth compared to traditional livestock keeping and peasantry. Majority of active age group embrace charcoal burning with a consequence to *Acacia* woodland fast shrink. Moreover, fast annual population growth rate at 2.8% hiked demand for farming land and consequently encroachment into the *Acacia* woodland for settlement and new farms. Preference for charcoal by rural communities is gradually surpassing use of firewood and is perceived as a civilization. Disappointingly there has never been a tree planting culture or a habit for conserving natural forests in the area. Destruction of *Acacia* woodland in Rorya district is aggravated by lack of legislations against free access and chopping down of natural vegetation. Consequently, the woodlands have been a typical common property as they do not fall within the customary jurisdictions that are labeled with cultural restrictions. Quality of the *Acacia* woodland plunged further with the increased herds of cattle. The objective of this study was to advocate establishment of local legislations and land tenure reforms for restored productivity of the *Acacia* woodlands in the Mori and Nyaburongo valleys for improved livelihoods and ecological resilience.

MATERIALS AND METHODS

Study area

The study was carried out between October 2002 and November 2018 in the catchment areas of rivers Nyaburongo and Mori in Rorya District located at Latitude 1°02' - 1°32'S and Longitude 33°45' - 34°35'E (Figure 1). The land in the study area consist of gneiss, quartz and schistose rocks, covered in the elevated parts with marl and red clay, and in the valley with a rich black loam (Lyaruu and Eliapenda, 2001).

Ethnobotanical survey

Ethnobotanical survey on *Acacia* Mill. (also applies to genera *Senegalia* Raf., *Vachellia* Wight and Arn and *Faidherbia* A.Chev.) was conducted to optimize their sustainable uses for environmental and socio-economic development. Semi-structured interviews from 94 correspondents, standard field inventory and participant observation techniques were used to collect information. Main ethnobotanical uses were fuel wood (charcoal and fire wood), agriculture, grazing, extraction of construction poles, other wood based uses and herbal medicines. In order to assess the consumption of charcoal, estimates were done at two permanent stations. Recording was done from August 16 to September 14, 2014 when extraction for charcoal is at the peak. The recording could not capture information on charcoal consumed locally in villages. One bag of charcoal = 28.4 kg of round wood (Ishengoma, 1982).

Sampling for quantitative estimates

Four transect lines were established, one line along either sides of each of rivers Mori and Nyaburongo at an interval of 200 m away from the real course of the river. This was done to avoid likely bias by high stocking along the river banks. Sampling plots were placed systematically along the transects at 1 km intervals.

Nested quadrat sampling method according to Stohlgren et al. (1995) was used to sample plants within the sample plots. Each sampling plot was partitioned into three levels of sampling; trees were enumerated in big quadrats measuring 50 x 20 m, shrubs in 5 x 2 m quadrats, herbs were sampled in smaller quadrats of 2 x 0.5 m. For the case of Acacias, there were no herbs so the inner quadrat was skipped.

Data analysis

Various models were used to analyze the effect of plant use by local communities to the diversity and distribution of plants *in-situ*. Some equations indicate quantitative preference to a particular plant by local communities presented as follow.

Use value (UV_s)

This is the arithmetic model used to determine plant species commonly used by many informants for a particular ethnobotanical use category. The higher values of *UVs* for a particular plant are an

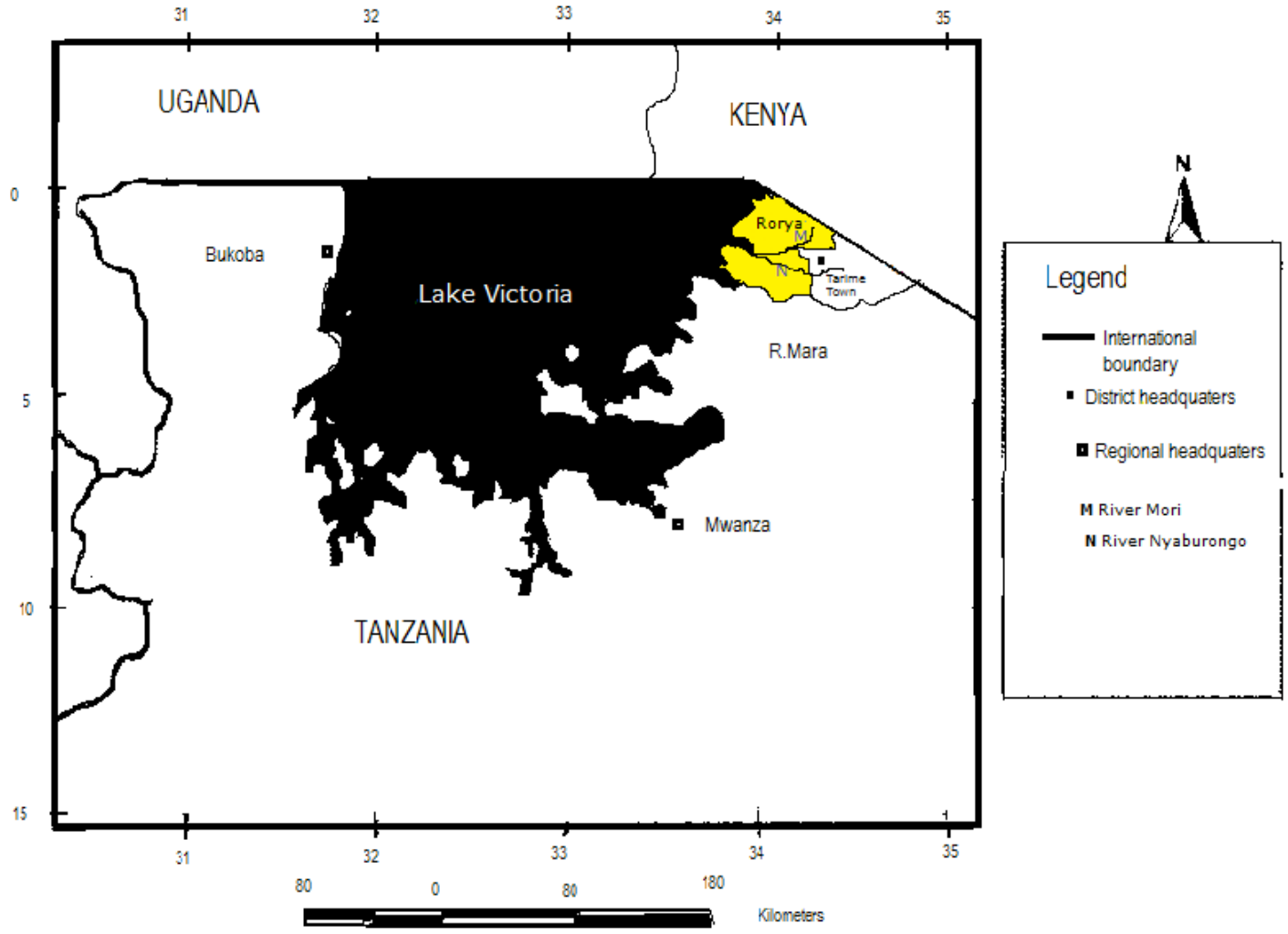

Figure 1. The basin of Lake Victoria showing catchments of Rivers Mori in Rorya District**.**
Source of map: Nyirabu (2001).

indication of more preference or higher use frequency and vice versa.

$$UV_s = \frac{\sum_i UV_{is}}{n_s}$$

Where; UV_s = overall use value for a particular species; UV_{is} = use values of a species by one respondent; n_{is} = total number of respondents interviewed on the use of a particular species.

Tree density

To estimate density of trees (number of stems per ha) the relationship according Philip (1983) was used as:

$$N = \frac{1}{n}\left(\frac{\sum n_i}{a_i}\right)$$

Where; N = Number of stems per hectare; n_i = number of trees in representative plots; a_i = plot area in (ha).

Species diversity

Shannon and Weaver (1948) diversity index (H') was used to assess the diversity of a sample or community. The value of Shannon and Weaver diversity index is usually found to fall between 1.5 and 3.5 and only rarely surpasses 4.5 (Margalef, 1972). Shanon and Weaver diversity index increases with the number of species in the community but in practice, for biological communities, it does not exceed 5.0 (Kent and Coker, 1992).

According to Kent and Coker (1992), the Shanon and Weaver diversity index (H') was calculated from the relationship:

$$H' = \sum_i^s P_i \ln P_i$$

Where: H'= Shanon and Weaver diversity index; s = the number of species; In = natural logarithm; P_i = the proportion of individuals found in the i^{th} species.

Relative frequency (R.F)

Relative frequency (R.F) was determined to assess distribution of species within the study area. R.F of plant species in different sampling units was calculated by using the relationship:

$$\text{R.F} = \frac{\text{Number of quadrats in which species (i) is found}}{\text{Total number of all quadrats}} \times 100$$

RESULTS AND DISCUSSION

Ethnobotanical uses

Eleven species of the previous broad genus Acacia Mill. were recorded namely *Acacia seyal* (Delile) P. Hurter. (*Vachellia seyal*), *Acacia polyacantha* (Willd) Seigler & Ebinger. *(Senegalia polyacantha), Acacia robusta* (Burch.) Kyal. & Boatwr. (*Vachellia robusta*), *Acacia hockii* (De Wild.) Seigler & Ebinger. (*Vachellia hockii*), *Acacia drepanolobium* (Harms ex Y.Sjöstedt) P.J.H.Hurter. (*Vachellia drepanolobium*), *Acacia senegal* (Linn.) Willd. *Acacia lahai* Steud. & Hochst. ex Benth. (*Senegalia lahai*), *Acacia nilotica* (L.) P.Hurter & Mabb. (*Vachellia nilotica*), *Acacia xanthophloea* (Benth.) Banfi & Galasso. (*Vachellia xanthophloea*), *Acacia tortilis* (Forssk.) Gallaso & Banfi. (*Vachellia tortilis*), *Acacia brevispica* Harms (*Senegalia previspica*) and *Acacia albida* (Delile) A. Chev. (re-clasified as *Faidherbia albida*).

Several ethnobotanical use categories were mentioned by respondents on the use of species, however for the sake of clarity, only major local uses were recorded including agro-forestry, bricks burning, charcoal, cow pen, firewood, fodder, farm hedges, logs, medicine, poles, food, posts rafters, resins, shade, sledge, timber and tool handles. Bee keeping was mentioned as one of the potential economic activity that can be pursued in the woodland, however because the area is a public land with free access. The investment is not feasible with the current economic trends unless some adjustments in land use are introduced to support the initiative.

Fuel wood

All residents of rural Rorya District use firewood as a source of fuel. The most preferred species for firewood are hard, low burning, non-succulent, less smoky wood in an order from *Teclea nobilis, Rhus spp* and *Acacia* spp. Traditionally, firewood for domestic use involve collection of naturally dry twigs, except for mass collection during ceremonies. This household consumption of firewood has negligible effect to the plant diversity. Consumption of firewood per household in Rorya District was estimated at 2±1 headloads per week. Similarly, Kajembe et al. (2004) reports consumption of firewood per household in Mawiwa-kisara catchments Forest in Kilosa District, Tanzania as 1 to 7 headloads per week with an average of 3 headloads per household per week. High demand of firewood hoists by increasing demands both in the nearby Barric gold mines and to the high populated fishing camps on Lake Victoria shorelines where firewood is the only source of energy for cooking and in part for fish curing. This increased consumption makes it one of the money earning wood-based products in the district. Firewood is sold to these camps at Tsh 2000.0 per headload. Increase in the market value of firewood in the basin of Lake Victoria is an opportunity for income generation through marketing of firewood. This can be sustained if local people are sensitized to plant and maintain individual woodlots of fast growing *Acacia seyal*. Unfortunately, the woodlands in the valleys of rivers Mori and Nyaburongo are public land with free access for grazing and for wood extraction. There are no guidelines or land tenure arrangements in place to regulate and control human activities in an area.

Another source of fuelwood in Rorya District that is gradually gaining popularity is charcoal. The estimates of charcoal marketed locally and across the border to Kenya are presented in Table 1. The counting was done at the fixed counting stations along the main roads to Musoma town, Tarime town and on the way to Kenya.

At least 27 plant species are exploited for charcoal whereas *A. seyal* is one of the most preferred due to good quality charcoal and their high stocking around the kilns. Extraction for charcoal was estimated as 358.84 tons/year. Wood biomass was estimated as 3.3 tons/ha. Up to 72.5 ha were being cleared annually for charcoal. About 113 charcoal makers were recorded each producing 111.8±12 bags of charcoal per annum. Selling price was Tsh. 5,500/bag. Hence the mean income per charcoal dealer was Tsh. 615,026/annum. The estimated round wood biomass of *A. seyal* of 3.3 tones/ha was comparable to findings by Malimbwi et al. (1994) in Kitulangalo forest reserve in Tanzania for other *Acacia* species as 3.99, 0.33, 3.8 and 032 tons/ha for *Acacia nigrescens*, *Acacia usambarensis, Acacia nilotica* and *Acacia polyacantha,* respectively. The area is losing 72.5 ha per year through charcoal burning alone. Since 1980s when the use of charcoal was intensified, an area approximately 60 km^2 between Kowak and Chereche villages is already converted into typical grassland

Before 1980s, *A. seyal* and *A. robusta* relatively constituted a close canopy within the study area especially in large part of Luo-imbo plains, Suba and Ingwe Divisions though at present, due to unsustainable utilization, they are depleted for charcoal making and brick burning by the defunct Kowak Co-bricks project. The current biomass is only 3.3.tons/ha that is comparatively low to 40.5 tons per ha as reported by Otieno (2000) in Miombo woodland in Babati District Tanzania. Currently the average DBH of *Acacia* spp in Nyaburongo valley is 7 to 8.8 cm that is equated to a DBH of samplings. Probably, another reason why deforested *Acacia* woodland may fail to regenerate in the

Table 1. Amount of marketed charcoal bags per counting stations from the Mori and Nyaburongo valleys.

Source	Nyaburongo and Mori valleys	
Counting station	**Sirari**	**Kinesi**
Dates		
16/8/2014	50	17
17/8/2014	0	4
18/8/2014	50	16
19/8/2004	0	6
20/8/2014	0	7
21/8/2014	0	13
22/8/2014	0	12
23/8/2014	100	8
24/8/2014	50	9
25/8/2014	50	8
26/8/2014	0	10
27/8/2014	50	5
28/8/2014	50	11
29/8/2014	0	2
30/8/2014	0	2
31/8/2014	0	14
1/9/2014	100	4
2/9/2014	0	12
3/9/2014	50	9
4/9/2014	50	5
5/9/2014	0	12
6/9/2014	0	7
7/9/2014	0	12
8/9/2014	50	6
9/9/2014	0	4
10/9/2014	0	6
11/9/2014	0	13
12/9/2014	50	6
13/9/2014	0	3
14/9/2014	100	10
Bags/month	800	253
Bags/month	1053	
Tons/month	29.9	

woodlands of Rorya District is the continual decline in the seed bank. Trees in the area are cut young before the establishment of enough seeds reserve in the soil, then the sites remain bare long enough for seed reserves to diminish. Bergsten (1993) commented that even when a highly degraded soil stabilizes, it contains few seeds that may retard succession. Natural re-colonization of the trees in the affected area cannot be realized through tree seed because such seeds have disappeared from the soil (Lyaruu, 1995).

Timber/poles

Of all sampled *Acacia* species, mature *A. robusta* is the most preferred choice for construction poles. Lack of construction poles from other indigenous tree species has intensified exploitation of *A. robusta* as the closest alternative. The mature *A. robusta* are chosen for poles due to the ingrained resinous secretions that check termites and other insect borers. At present the species are totally clear felled from Nyaburongo valley. Unfortunately, according to local people, *A. robusta* does not coppice at maturity from either root suckers or stumps. Pole cutting causes adverse effect to the quality of forest because only trees of prime and straight stems are cut. According to Kajembe et al. (2004) this leads to lower quality of growing stock and depletion of the gene most used due to their abundance though less durable and borer-prone. *A. seyal* poles are used after local

pre-treatment that is achieved by immersing green poles in ponds or rivers for at least 3 months. Within the period of 3 months the poles acquired considerable tensile strength and resistance against wood-borers. This skill is unique in that area and not reported previously.

Fully grown *A. polyacantha* in the study areas measure at least 30 cm DBH thus qualify them mainly for furniture, coffins and door tops. With modernization, dead relatives are buried in coffins instead of traditional hides/mats; office chairs are replacing cultural stools, cupboards instead of pots, wooden doors for woven withies etc.

Effect of rice farming on *Acacia* species

Black cotton soils are the ecological niche for both *V. seyal* and *V. robusta*. The same soils favor cultivation of rice. Rice farms were started in Nyaburongo and Mori valleys in 1990s. This has piloted clearing of vegetation (mainly *Acacia seyal* and *A. robusta*) around the farms to keep away bird pests (*Quelea*). Trees around rice farms attract pest-birds to alight on before raiding the crops. The surrounding trees and shrubs are cleared to up to 50 m from the edge of the farm on all sides as a way of pest control. Most of these cleared farms are abandoned in consecutive years in search for new sites in such a way that more areas of woodland are destroyed.

Logs

Bricks burning consume large quantity of logs mainly from *A. seyal and A. robusta*. These uses threatened plant diversity as they consume large trees that forms the top canopy of the habitats they are found. As a result, the removal of wood products from the natural ecosystems supersedes the rate of their recruitment. As more modern houses are built by using burnt bricks, more logs from *A. seyal* are consumed for bricks burning. Fortunately, the rate of *A. seyal* to regenerate is fast that can synchronize the drain.

Effect of free grazing to the *Acacia* woodlands

Conversion of *Acacia* woodlands to grasslands in the catchments of Rivers Mori and Nyaburongo may be irreversible unless some strict remedial measures are engaged. The area is cleared for charcoal and concurrently subjected to heavy grazing such that regeneration of *Acacia* saplings is affected. This is in accordance to Walter (1973) who claimed that vegetation change due to grazing may not be reversible in connection to “bush encroachment” which may take place as a result of heavy grazing. Pastoralism in the district is in a form of free grazing, and often, livestock keeping conflict with agriculture due to shrinking public land. Fodder trees of high canopy are cut by shepherds to be browsed by goats. Livestock keeping also involves cutting of thorny *Acacia* species for making of cattle sheds. Pastoralism leads to soil compaction around water sources especially of river Mori and its distributaries, gully erosion along grazing trails and overgrazing of some palatable species. The impact of grazing can be clearly seen in Nyancha, Suba and Luo-imbo Divisions where suitable pasture grasses such as *Andropogon eucomus*, *Cynodon dactylon* and *Panicum maximum* are overgrazed and have been replaced by unpalatable coarse grass such as *Sporobolus natalensis* and *Enteropogon macrostachys*. According to this study, the later species are indicators of reduced rangeland quality and equally, browsing of tree coppices worsens in dry months when palatable grasses are scarce. Chidumayo and Marunda (2010) comment that grasses and herbs alone cannot support a livestock industry in the semi-arid regions; browse, especially from *Acacia* species plays an essential part. Similar observation in Zimbabwe is reported by Hayward (2004) that in time of drought, when cereals and grass fails, *Acacia* trees provide fodder crops to livestock as well as a range of products for domestic and economic use.

Despite the intensified browsing in the *Acacia* woodlands, it is herewith established that the stumps of *A. seyal* can coppice and attain a height of 15 cm within 8 months. In this study however, the stumps that are exposed to an area of heavy grazing such that fresh coppices are browsed consistently, and do not grow enough to carry out photosynthesis, the roots starve and the stumps dry-up after a period of 3 to 5 years depending on the size of the stump. It was observed in this study that large stumps > 10 cm survived longer than 5 years, while small stumps <10 cm that were clear felled in the past five years were all dead. Timberlake et al. (2010) support that the ability to sprout takes advantage of the extensive root system and the substantial food storage in the remaining parts of the parent plant.

Overgrazing and clear felling of woodlands for charcoal is exhausting most rangelands in the study area, yet another challenge exist; funds accrued from charcoal are re-invested into more stocks of cattle and again grazed onto the same already deforested ecosystem. The outcome has been more destruction of pastures, low yield and frequent livestock diseases. Peasant’s life is characterized by overuse of land and vegetation accompanied by degradation due to lack of inputs. Poverty and hunger, which are common in peasant life, lead to environmental degradation, deterioration of agriculture and hence create more poverty and hunger (FAO, 1991). Livestock production is undoubtedly the most suitable industry for the utilization of the rangelands but full regard must be made for sustainability not exploitation (Chidumayo and Marunda, 2010).

Diversity of *Acacia* species

The diversity and distribution status of *Acacia* species in

Table 2. Diversity status of *Acacia* species.

Species	Altitude	soils	N	H'	RF (%)	Frequency of occurrence
Acacia lahai	1100-1400	Loamy sand	3	0.60	11.5	Occasional
Acacia robusta	1100-1300	Clay	30	2.70	44.4	Low
Acacia senegal	1100-1200	Loamy clay	1	0.25	3.8	Occasional
Acacia seyal	1100-1200	Clay	120	3.22	77.0	Abundant
Acacia hockii	1200-1600	Most soils	38	1.5	38.5	Fair
Acacia drepanolobium	1100-1200	Clay	2	0.7	22.2	Occasional
Acacia brevispica	1200-1300	Loamy sand	4	0.1	3.8	Occasional
Faidherbia albida	1100-1300	Loamy soils		0.1	3.8	occasional
Acacia polyacantha	1100-1600	Most soils	>1	0.1	3.8	Occasional

Rorya district is presented in Table 2. Distribution and diversity trends of most recorded *species* in the study area do not coincide with findings in other studies in the region. With an exception of *A. seyal*, *A. hockii,* and *A. robusta* with 120, 38 and 30 number of stem/ha respectively, the rest of the recorded species have densities less than 4 stem/ha, and Shannon and Weaver Index (H) values below the average range of 1.5 to 4.5. This is because of their exceptionally low number of stem per hectare (Table 2). In a similar study within the same region in Serengeti ecosystem, Mligo (2015) estimated average H' for woodland at 2.06 to 2.38. The stem density for most species in the study area are falling far short when compared to findings by Marshall et al., (2012) who estimated densities of East African *Acacia* in their diversity hotspots as 83, 60, 136, 28, 178, 46, 11.56 and 17 stems/ha for *A. brevispica, A. drepanolobium, A. hockii, A. lahai, A, nilotica, A. robusta, A. Senegal, A. sieberiana, A. tortilis* and *A. xanthophloea,* respectively. Basing on H' values by Mligo (2015), it is implied that *A. seyal* in the study area (H'=3.2) is of fair diversity status. This is a strength supporting its inclusion in socio economic development programs. The densities of the rest of *Acacia* species are too low for immediate economic venture. *Acacia hockii* is tolerant to most soils and has moderate density, however it is a small shrub most appropriate for household fuel wood use. More *Acacia* species are sparsely distributed in the middle altitude from 1200 to 1400 m above sea level (asl) rich in sandy loam, neutral to alkaline pH. These neutral soils and higher altitudes are more supportive to agricultural crops. As a result natural vegetation including *Acacia* species are cleared to get more space for settlement and farms. *Acacia* species are not regarded with high esteem for conservation around the settlements. Marshall et al., (2012) also reported that many of the high *Acacia* diversity areas in East Africa have not previously been highlighted as of major importance for conservation of the genus. At lower altitudes between 1101 and 1200m asl (Table 2), *A. seyal, A. robusta* and *A. drepanolobium* dominated by being distributed in black cotton soils in Luo-imbo Division. These low altitudes are comparatively dry with average annual rainfall of 800 to 1000 mm that bears transitional features to semi desert vegetation. *A. seyal* is luckily performing best in these soil types that are less preferred for traditional food crops.

A. seyal is a potential source of income to about 20 villages in Rorya District if controlled extraction for charcoal is achieved. The species has good quality charcoal and can regenerate very fast to extractable Diameter at Breast Height (DBH) of 15-20 cm within 5 to 10 years. This is the growth rate of 3 cm per year. The growth rate of *A. seyal* in Nyaburongo and Mori valleys is superior to a report by Okello et al. (2006) that the majority of tree species have diameter increments ranging from 0.03 to 2.6 cm per annum. *Acacia* species regenerate fast naturally from soil seeds and from old stumps. Nevertheless, areas that are completely denuded of natural soil seed banks, planting can be initiated through imported seeds. Simple conservation guidelines and land tenure allocating monopoly to individuals will favor resilience of the woodland within 10 to 15 years. *A. seyal* species in this regard are a target species for their rapid biomass build-up and fast growth. Within a period of five years, retained *Acacia* species reaches an average diameter at breast height of 15 cm. This measure is sufficient for commercial charcoal making, poles and for firewood for sale to the available wood fuel markets. Major impending challenge is that *Acacia* woodlands in Nyaburongo and Mori valleys are public lands without a defined regulation on access. If nothing is done now to regress losses in the woodlands, then this precious resource will turn into bare woodlands for the ill fortune of rural communities who are dependent on it.

Conclusion

Rorya district is endowed with several *Acacia* species that are distributed unevenly due anthropogenic related activities. Of all, *A. seyal* is the most abundant with

multiple ethnobotanical uses and obvious possibility for commercial extraction for charcoal. *A. seyal* accumulate wood biomass very fast than most imported species. The species can contribute not only to ecological stability but more on improved income of the households through selling of charcoal and firewood to the urban users under sustainable management. *Acacia* are able to colonize disturbed sites rapidly and act as natural repair kits on depleted soils (Hayward, 2004). *Acacia* therefore, offer great potential in areas of Africa where increasing population and livestock, together with series of drought have led to deforestation and severe land degradation (*ibid*). In a different scenario, this study recorded a positive local invention whereby the less durable *Acacia* species is pretreated to assume considerable strength for construction purposes. In addition, *A. polyacantha* previously considered less useful is now a potential source of timber for furniture and consequently is domesticated in home gardens or farms. Improved capacity of the *Acacia* woodlands in the valleys of Mori and Nyaburongo rely on re-addressing devastating forces in the area namely, free access for grazing, uncontrolled charcoal making, encroachment for farming and settlement. For immediate and permanent solution, responsible local governments must formulate guidelines and land tenure arrangements that grant sole ownership and user rights to individuals and dedicated social groups capable of managing demarcated land portions within the *Acacia* woodlands. The new guidelines will control charcoal burning and other human activities with adverse effect to the woodland ecosystems.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Floristic diversity and stand structural analysis of gallery forests in Ajei highland watershed community forest, North West Cameroon: Implications for forest conservation and management

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The study was aimed at contributing to sustainable management of Ajei Highlands Watershed Community Forest, one of the vulnerable and highly threatened biological hotspots remaining within the Cameroon western highlands through an analysis of its woody species diversity and stand structure. The results of inventory of its 12 gallery forest patches through 17 permanent sample plots (20 m x 50 m) with multiple spatial scales subplots (1, 10 and 100 m^2) using Whittaker plot sampling method showed that a total of 3644 individuals were recorded (124 species showing exclusive affinity to forest patches, 90 genera and 46 families). Diversity indices were 4.34 and 0.93 for Shannon-Weaver and Simpson indexes, respectively, indicating a highly diverse forest. The mean density was 1820 ± 24 stems/ha and the basal area 27.72 ± 0.04 m^2/ha; with mean and maximum diameter of 9.3 and 140 cm, respectively. Species importance value index ranged from 0.35 to 35.19%, the most dominant species being *Macaranga occidentalis*, *Xymalos monospora* and *Rauvolfia vomitoria.* Euphorbiaceae, Apocynaceae, Moraceae and Rubiaceae were the most important families. Although this forest presented a high diversity and a certain floristic richness; few potentially commercial timber species were identified. Management options are prescribed within the framework of a participative management plan promoting watershed protection and habitat restoration, targeting livelihoods sustenance through agroforestry and reforestation activities favoring local tree species.

Key words: Woody diversity; watershed, gallery forest, community forest, Cameroon.

INTRODUCTION

More than 1.6 billion people depend on varying degrees on forests for their livelihood (SCBD, 2009) and forests play a key role in the economic development of many countries. According to FAO (2015), global forest cover

has drastically decreased from 4128 million hectare in 1990 to 3999 million hectare in 2015, corresponding to a drop from 31.1 to 30.6% (1.5% loss). The fragmentation and loss of tropical forest through deforestation and land degradation is the greatest threat to ecological services provided by these forests, such as biodiversity conservation (Hansen et al., 2020). This fragmentation process has resulted in increased riparian forest formation along watercourses across tropical forest highland regions serving as watersheds; and is considered as global biological hotspots, which have supported local populations with the provision of timber and non-timber forests products (Natta, 2003). The rapid change in land use for local subsistence in the Western highland region of Cameroon has resulted to an unprecedented destruction and fragmentation of riparian areas of gallery forests resulting in a few scattered forest patches on the landscape (Momo Solefack et al., 2018). These highland regions are rich in endemic plants and animal species (Momo Solefack et al., 2016; Wouokoue et al., 2017). The sub-montane and afromontane forests of Cameroon are sources of the most important fresh water streams in the country, particularaly in the western highlands, Noun, Benoue, Djerem, Lom, and Sanaga rivers for the Adamawa Massif (Lambi, 2001). Referring to high value conservation forests, gallery forests are classified as endangered ecosystems because they are marginal among the wooded vegetation and also because of their high degradation status.

Gallery forests in tropical savanna landscapes are mostly narrow strips of forest associated with creeks and rivers, in an otherwise unforested landscape (Veneklaas et al., 2005). Gallery forests in savannas represent one of the few examples of naturally fragmented tropical forests. They are generally rich in woody plant species typical of continuous forests and are postulated to have provided refugee for tropical forest species in areas deforested during the Pleistocene drought (Meave and Kellman, 1994). This forest type is important to the streams/river course; and also the biodiversity it harbours providing fertile moist soils, wood, water, shelter and non-timber forest products used by the populations to meet their needs (Ajonina and Tomedi, 2014).

Despite their recognized status, biodiversity potentials and their ecosystem services, gallery forests have remained unmanaged and ignored as key ecosystems in biodiversity conservation. This reason could be attributed to insufficient scientific knowledge on their potential to support local populations, and their contribution to climate change mitigation; thus, hindering their consideration in global conservation programmes. To combat these challenges, conservation options like community forestry encouraged the decentralisation and management of forest portions by the local population in order to support community development and biodiversity conservation. In several countries of the world, community forestry resulted in more sustainable management of forests when communities found it in their interests to conserve them (Maryudi et al., 2012; Kimengsi et al., 2019).

In a bid to redress threats of forest cover loss and promote community participation and alleviate poverty, the Cameroonian Forestry, Wildlife and Fisheries law, enacted in 1994, enshrined the concept of community forest, corresponding to a maximum area of 5000 ha, granting local community's access, to use and manage substantial portion of the non-permanent forest estate (MINFOF, 2009). The Ajei community forest in North West Region of Cameroon was established in January 2014. This community forest is one of the remaining forest patches in the lower ridge of the Bamenda highland region and serves as an important watershed for the streams that flow into the River Momo feeding the Mamfe-Cross River Basins (Ndip et al., 2018); and also providing drinking water for the surrounding communities (AHWaCoFoMB, 2016). However, the area is under threats with challenging human activities and natural phenomena, including: Shifting cultivation, slash and burn agriculture, settlement, bush fires, and encroachment by grazers and farmers (Temgoua et al., 2018). Temgoua et al. reported an ongoing deforestation with forest cover loss of about 240 ha in 30 years (1988-2018). Understanding tree species composition, diversity, and structure is a vital source of information in assessing sustainability of any forest, conservation of species, and management of the ecosystems at large (Ssegawa and Nkuutu, 2006; Addo-Fordjour et al., 2009). However, no study has yet been carried out in this forest to assess its floristic composition and diversity. This paper aims to contribute to the sustainable management of the Ajei highland watershed community forest by providing a sound scientific basis that maintains its ecological integrity through the analysis of its floristic woody diversity and stand structure.

MATERIALS AND METHODS

Study site

The study was carried out in the Ajei upland watershed community forest, located in Ngie subdivision, Momo division in the North West

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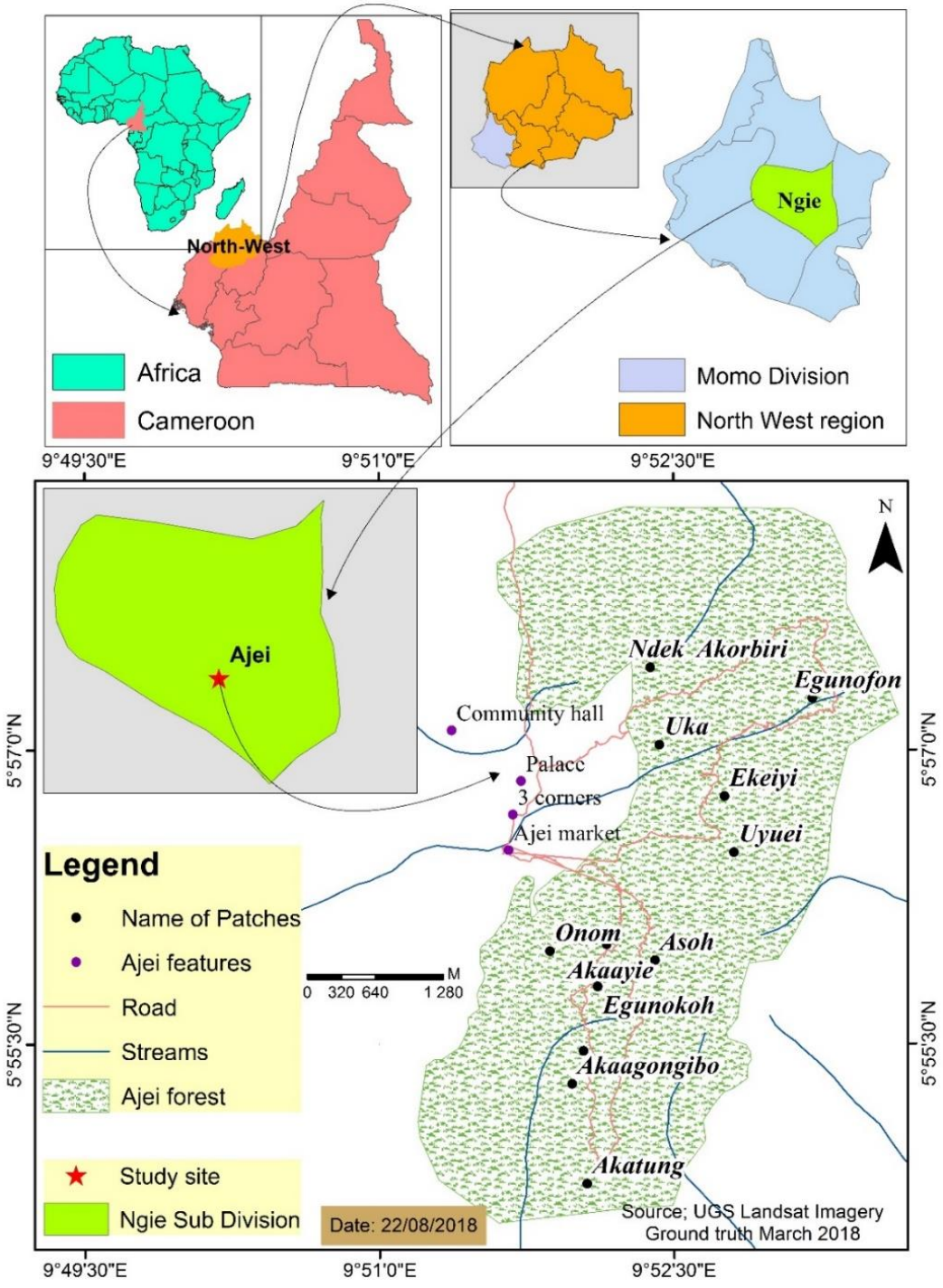

Figure 1. Location of the Ajei community forest in North West region.

Region of Cameroon (Figure 1). This forest is located between latitudes 5.920° and 5.970°N and longitudes 9.840° and 9.890°E and covers a surface area of 1739.3 ha. The study site falls in the transitional zone between the wet tropical or equatorial climate in south Cameroon and the Sudanese climate of North Cameroon. Annual precipitation ranges from 2200 to 3000 mm from March through October with an average of 240 rainy days and an average temperature of 21°C (minimum 15 and maximum 30°C). The topography and relief ranges between 1500 m above sea level, cumulating at the highest peak of Ndek Akorbiri (2040 m) being typical of an area underlain by granitic basement rocks. Soils derived from this parent rock material are generally poor, being

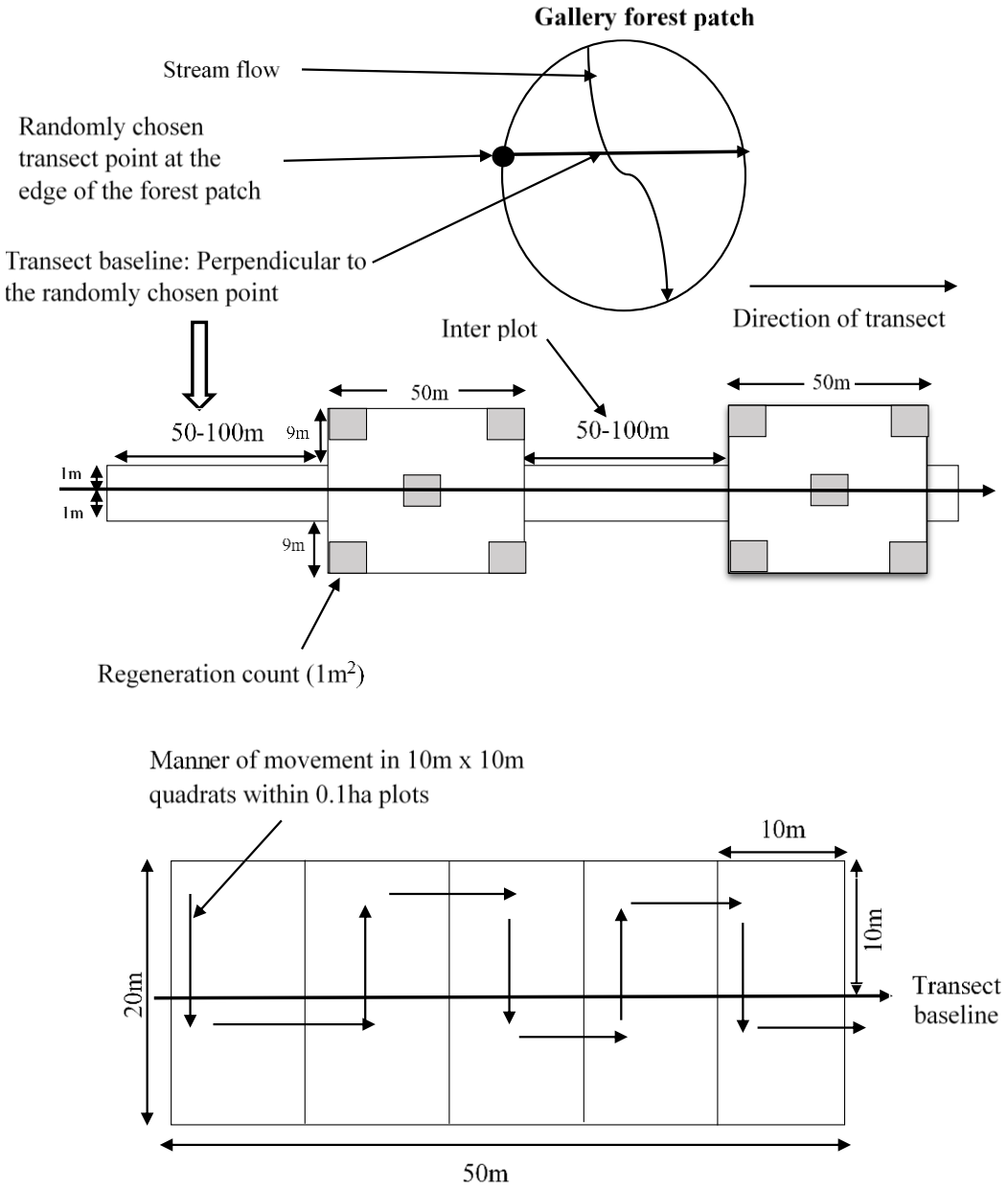

Figure 2. Plot layout on transect baselines in FPs using the Whittaker plot sampling method.

rapidly depleted of fertility through cropping and the erosive action of rain (AHWaCoFoMB, 2016). The vegetation is montane forests with interconnecting savanna habitats. Within the savanna, gallery forests occur as discontinuous strips of closed canopy woodland along the main streams. The Ajei upland watershed community forest is made up of 12 forest patches, some of the last remaining forest patches of the Bamenda Highlands. Plant species are typical assemblages of this montane landscape (AHWaCoFoMB, 2016).

Data collection

Data collection consisted of an inventory using a network of nested sampling units (plots, interplots, subplots and quadrats) in a transect arrangement following the Whittaker Plot Sampling Method (Shmida, 1984). The Whittaker plot sampling method was elaborated, adapted and implemented at multiple spatial scales (1 and 10 m^2) on 1000 m^2 permanent sample plots (Figure 2).

Plots were laid in all the 12 forest patches of the community forest spaced within a 2-m wide belt transect running perpendicular with the use of a compass from a randomly chosen GPS point close to the centre along one edge of forest patch crossing the stream to the other edge of the same forest patch. The transects were opened and pegged with polyvinyl chloride (PVC) plastic pipes in each forest patch also serving to demarcate the edges of the plots. Each transects and forest patch was identified with a

signpost. At every 50- or 100-m interval (depending on the width of the patch) along the 2-m belt transect (inter-plot distance), permanent sample plots (PSPs) of dimension 20 m x 50 m (1000 m^2) were systematically designed for the vegetation inventory (tree identification, measurement and tagging). The permanent sample plots were further sub-divided into ten 10 m x 10 m (100 m^2) temporal subplots to ease data collection and access on the 1000 m^2 plots (0.1 ha). On the inter plots (2 m × 50 m: 100 m^2, or 2 m × 100 m: 200 m^2) trees with dbh ≥ 10 cm in diameter were measured at 1.3 m (diameter at breast height); tagged and the point of measurement accurately marked out with red paint; while on plots (20 m × 50 m), diameter measurements were taken from trees with dbh ≥ 2.5 cm. At the edges and middle of each sample plot, 1 m × 1 m quadrats (1 m^2) were established principally for regeneration count (seedlings and saplings dbh < 2.5 cm). At the end, 17 permanent sampling plots (each 20 m × 50 m) were established along 12 transects of varying length between 100 to 500 m within the 12 gallery forest patches that make up the community forest.

Each tree species sampled were noted from which the woody species checklist of Ajei community forest was established. Species that could not be identified while in the field were sampled, pressed and preserved for further identification in the herbarium of the Limbe Botanic Garden. The species were identified according to the Angiosperm Phylogeny Group (APG) IV (2016) classification.

Data analysis

Data analysis was performed with Microsoft Excel 2016 of Microsoft office and Palaeontology Statistics (PAST) software package version 2.

Floristic composition and diversity

Floristic characterization was done by determining parameters such as: Diversity indices, relative density and dominance of species and families. Species richness corresponds to the number of species in a community or stand (Magurran, 2004). The number of families and the number of species present in the community forest were determined, as well as the number of individuals of each species.

The Shannon-Weaver Diversity Index (H') is a measure of the potential for interaction between the species that make up a community. This index takes into account the number of species present and the distribution of individuals within those species.

$$H' = -\sum (ni/N) \ln (ni/N)$$

where ni is the number of individuals of a given species i and N the total number of individuals. The Simpson's diversity index (D') is the probability that two randomly selected individuals are of different species. It is represented by the reciprocal of the Simpson's index (D). The maximum diversity is represented by the value 1 and the minimum diversity by the value 0.

$$D' = 1 - \sum (ni/N)2$$

The generic diversity index (IG) was calculated following the formula:

$$IG = \delta p/G$$

Where δp is the number of species and G the number of genera of the study population.

It helps to characterise the plant population stability (Sonke, 1998). A low value, close to 1 of this coefficient, indicates a high diversity of the flora (Ake Assi, 1984).

To describe the ecological importance of families and species within the total flora, the family importance value index (FIV; Mori et al., 1983) and the Importance value index (IVI); Curtis and McIntosh, 1950) were calculated using:

$$FIV = rDe + rDo + rDi$$

where rDe is the relative density (number of individuals of the family considered in relation to the total number of individuals × 100), rDo is the relative dominance (basal area of the family considered in relation to the total basal area of the stand × 100), and rDi is the relative diversity (number of species of the family considered in relation to the total number of species × 100).

$$IVI = rDe + rDo + rFr$$

Where rDe is the relative density (number of individuals of the species / the total number of individuals × 100), rDo is the relative basal area (basal area of the species / the total basal area of the stand × 100); and rFr is the relative frequency (frequency of a species / total of all frequencies × 100).

Stand structural parameters

Vegetation structure was determined by parameters such as density, basal area and distribution of individuals by diameter classes (size class distribution) commensurate with six distinct tree utility classes: <1 cm (seedlings); ≥1 cm to <2.5 cm (small saplings); ≥2.5 cm to <5 cm (medium sized saplings); ≥5 cm to <10 cm (small trees or posts); ≥10 cm to <30 cm (medium sized trees or poles); ≥30 cm to <50 cm (large trees or standards); and ≥50 cm (giant trees or veterans) (Barden et al., 1987).

Density and basal area were estimated using the formulas given by Kent and Coker (1992).

Density (D) is the number of individuals per hectare. It was calculated by converting the total number of individuals encountered in all plots to equivalent number per hectare, following this formula:

$$D = N/S$$

With D the density (stems ha^{-1}), N is the number of stems present on the considered surface and S the area considered (ha).

Basal area (BA) provides information on the area occupied by tree sections at 1.30 m from the ground. The formula is:

$$BA = \pi/4 \sum (Di^2)$$

Where BA is basal area (m^2 ha^{-1}) and Di is diameter (m) for each measured section (i).

Principal coordinates analysis was performed with Palaeontology Statistics (PAST) software to explore and to visualize similarities or dissimilarities of different forest patches.

RESULTS

Diversity, floristic composition and richness

In the 1.97 ha surveyed, a total of 3644 individuals were recorded, belonging to 124 species, 90 genera and 46

Table 1. Species richness and diversity indices of Ajei community forest.

Forest patch	Number of species	Sample area (ha)	Number of genera	Generic diversity index	Number of families	Number of stems	Shannon index (H')	Simpson index (D')
Uyuei	59	0.23	49	1.20	31	660	4.66	0.93
Akaayie	55	0.22	44	1.25	30	308	4.89	0.94
Akaagongibo	50	0.23	42	1.19	27	545	4.28	0.99
Onom	48	0.12	46	1.04	27	341	4.55	0.92
Akatung	43	0.24	39	1.10	25	194	4.81	0.95
Uka	38	0.12	34	1.12	21	207	4.19	0.90
Ekeiyi	35	0.11	33	1.06	19	211	3.94	0.88
Eshing/Njimikon	34	0.12	31	1.10	21	277	3.88	0.95
Egunokoh	32	0.11	29	1.10	21	155	4.12	0.91
Egunofon	25	0.12	22	1.14	14	135	4.03	0.91
Ndek Akorbiri	24	0.12	23	1.04	14	104	3.88	0.91
Entire Forest	**124**	**1.97**	**90**	**1.38**	**48**	**3644**	**4.34**	**0.93**

families (Table 1). About 84.67% of species were identified to species level, 12.09% identified to generic level, 2 species identified to family level and 1.26% (2 species) remain unidentified. From the floristic inventory, 4 life forms were identified. This includes: Trees, shrubs, lianas and palms. Trees were the most abundant with 70 species (56.5%), followed by shrubs with 47 species (37.9%), lianas with 5 species (4.0%) and palms with 2 species (1.6%).

The Shannon-Weaver diversity index (H') varied from 3.88 to 4.89 between different forest patches with a value of 4.34 for the entire forest, reflecting a high diversity of our study site. Simpson's diversity index was 0.93.

Table 1 show that the number of species per forest patches varies from 24 to 62, the richest patch being Asoh and the poorest Ndek Akorbiri. Values of the Shannon diversity index were highest in Akaayie and Akatung forest patches (H'= 4.89 and 4.81, respectively) and lower in Eshing/Njimikon and Ndek Akorbiri (H'=3.88). Simpon's diversity index was higher in Akaagongibo (0.99).

The relationship between the number of species and genus expressed by the generic diversity index was 1.32. This value shows an average of less than two species by genus. The number of genera having more than one species is few (13). The genus *Psychotria* was the most diverse with 9 species, followed by the genera *Ficus* (6 species) and *Cola* (3 species).

In terms of number of species per family, Rubiaceae was the best represented family with 15 species, followed by Euphorbiaceae (14), Moraceae (8), Meliaceae and Malvaceae (7), and Fabaceae and Sapindaceae with 5 species each. Families with one species were very common (32 families), while 8 families had between 2 and 4 species. The family importance values (FIV) of 20 most important families are presented in Table 2.

The five most important families were Euphorbiaceae (56.26%), Apocynaceae (25.94%), Moraceae (23.06%), Rubiaceae (21.51%), and Meliaceae (18.05%). 17 families had a FIV less than 3%.

It appears from Table 3 that the species with higher importance value index were *Macaranga occidentalis* (35.13%), *Xymalos monospora* (16.24%), *Rauvolfia vomitoria (*12.81%), *Tabernaemontana* sp. (11.64%) and *Cola acuminata* (11.40%). These first five species represent about 41% of the individuals counted. A high number of species were represented by three or fewer individuals in the overall sample of the 12 patches taken together (40 species). The complete list of species is presented in Appendix Table 1.

Stand structural analysis

Density and basal area

Analysis based on all woody plants of at least 1 cm dbh showed the stem density of 1820 ± 24 ha^{-1} (Table 4). When considering only individuals with dbh ≥10 cm, the stem density was 693 stems ha^{-1}. The smallest density (808 stems ha^{-1}) was found in Akatung and the highest (2870 stems ha^{-1}) in Onom. Basal area ranged from 19.4 m^2 ha^{-1} (Akaayie) to 39.4 m^2 ha^{-1} (Egunokoh) with a general mean of 27.72 ± 0.04 m^2 ha^{-1} for the entire forest. Basal area depends not only on the trees' density but also on the diameter of the trees. The mean diameter varied from 7.8 cm in Uyuei to 14.3 cm in Ndek Akorbiri with a general mean diameter of 9.3 cm for the entire forest. The maximium sized trees varied from 94 cm in Uka to 140 cm dbh in Egunokoh.

Diameter class abundance and distribution

Concerning the diameter class abundance and distribution

Table 2. Family importance values (FIV) of the 20 most important families in the the Ajei community forest.

No.	Family	Number of species	Number of individuals	Relative density (%)	Relative dominance (%)	Relative diversity (%)	FIV (%)
1	Euphorbiaceae	14	827	22.80	22.17	11.29	56.26
2	Apocynaceae	5	594	16.20	5.71	4.03	25.94
3	Moraceae	8	182	5.10	11.51	6.45	23.06
4	Rubiaceae	15	300	8.20	1.21	12.10	21.51
5	Meliaceae	7	144	4.00	8.41	5.64	18.05
6	Fabaceae	5	146	3.90	8.33	4.03	16.27
7	Malvaceae	7	74	2,00	8.44	5.65	16.09
8	Monimiaceae	1	378	10.40	3.52	0.81	14.73
9	Araliaceae	3	67	1.90	6.68	2.42	11.00
10	Hypericaceae	1	98	2.70	5.38	0.81	8.89
11	Sapindaceae	5	95	2.60	1.20	4.03	7.83
12	Annonaceae	3	81	2.30	2.68	2.42	7.40
13	Clusiaceae	4	78	2.10	1.28	3.23	6.61
14	Rutaceae	3	60	1.60	1.76	2.42	5.78
15	Sapotaceae	3	59	1.60	1.64	2.42	5.66
16	Ulmaceae	1	39	1.10	2.96	0.81	4.87
17	Myrtaceae	4	17	0.40	0.33	3.23	3.96
18	Simaroubaceae	2	33	0.90	1.07	1.61	3.58
19	Burseraceae	2	18	0.50	1.01	1.61	3.12
20	Arecaceae	2	29	0.80	0.54	1.61	2.95

(Figure 3), the densities were highest for stems with diameter less than 1cm (6235 stems ha^{-1}) (seedling category), followed by the diameter class 1 to 2.5cm (2941stems ha^{-1}) (sapling category); meaning more regeneration. Woody vegetation has few trees with diameter larger than 50 cm (1 stem ha^{-1}) (timber-sized trees). Stem densities were reduced with increase in diameter classes conforming to the characteristic inverted-J curve reflecting constant regeneration over time. Considering the diametric class distribution of each forest patch, the population size class frequency still exhibits a tendency towards an inverted-J curve distribution. In some forest patches (Uka, Ekeiyi, Ndek Akorbiri and Akatung) there is an absence of trees of diameter 1 to 2.5 cm; that is, sapling category (Figure 4). Only 2 forest patches (Onom and Egunokoh) showed the presence of trees of dbh ≥30 cm (reaching timber size).

The ordination by Principal Coordinate Analysis (Figure 5) indicated three groups of forest patches. Distances were expressed by similarity index of different forest patches in terms of species abundance, and showed a detectable gradient in the structure and floristic composition of the vegetation, reflecting variations in stem density and the abundance of certain species. The changes were interpretable in terms of topography and previous land use activities with Ndek Akorbiri (2040 m) and Egunofon (1811.18 m) distinctive at higher altitude. These forest patches have experienced little or no human intervention (particularly, the slash and burn agriculture practice), but are facing the consequences of bush fires from grazing activities, which annually consume the understorey situated behind only large old-growth trees, and few stems are left to succeed.

DISCUSSION

Diversity, floristic composition and richness

The Ajei community forest showed a floristic richness of 124 tree species, belonging to 90 genera and 48 families. In Cameroon, only a few known studies (Ndamason, 2016; Momo Soléfack et al., 2018) have been carried out to evaluate the vegetation composition of the gallery forests. For this reason, the results of this study cannot be compared with a wide range of other similar studies in Cameroon. The number of woody species found in this study is higher than that of 25 species found by Ndamason (2016) in Ijim Rigde gallery forest of Bamenda Highlands and also greater than that of 60 species found by Momo Soléfack et al. (2018) in the Koupa Matapit gallery forest. Fousseni et al. (2014) identified 61 tree species in a gallery forest in the sudanian savannah ecosystem of Togo. In the gallery forests found along

Table 3. Importance value index (IVI) of the 20 most important species in the Ajei community forest.

No.	Species	Number of individuals	Relative frequency (%)	Relative density (%)	Relative dominance (%)	IVI (%)
1	*Macaranga occidentalis*	636	2.35	17.45	15.33	35.13
2	*Xymalos monospora*	378	2.35	10.37	3.52	16.24
3	*Rauvolfia vomitoria*	259	2.35	7.11	3.36	12.81
4	*Tabernaemontana* sp.	281	1.96	7.71	1.97	11.64
5	*Cola acuminata*	55	1.76	1.51	8.13	11.40
6	*Ficus sur*	99	2.35	2.72	5.00	10.07
7	*Harungana madagascariensis*	98	1.96	2.69	5.38	10.02
8	*Polyscias fulva*	54	2.15	1.48	3.61	7.24
9	*Trichilia welwitschii*	43	1.76	1.18	3.88	6.82
10	*Croton macrostachyus*	51	2.35	1.40	2.73	6.48
11	*Ficus exasperata.*	64	1.76	1.76	2.46	5.97
12	*Albizia ferruginea*	41	1.76	1.13	2.82	5.71
13	*Millettia conraui*	69	1.96	1.89	1.78	5.63
14	*Trema orientalis*	39	1.17	1.07	2.96	5.21
15	*Bridelia micrantha*	45	2.15	1.23	1.56	4.95
16	*Albizia zygia*	16	1.37	0.44	3.03	4.84
17	*Eriocoelum macrocarpum*	51	1.57	1.40	1.57	4.53
18	*Uvaria* sp.	53	1.17	1.45	1.73	4.36
19	*Zanthoxylum heitzii*	37	1.76	1.02	1.23	4.01
20	*Ficus kamerunensis*	10	0.59	0.27	3.01	3.88

Table 4. Stand parameters for woody species in Ajei community forest.

Forest patch	Elevation (m)	Diameter (cm)		Density (Stems/ha)	Basal area (m^2/ha)
		Max	Mean		
Egunokoh	1680	140.0	11.5	1409±83	39.40±0.35
Akatung	1651	99.1	10.5	808±69	33.22±0.15
Eshing/Njimikon	1735	85.3	8.7	2308±184	30.80±0.17
Asoh	1723	72.0	9.2	2204±58	30.36±0.07
Akaagongibo	1693	89.1	8.7	2370±69	29.38±0.11
Uyuei	1538	65.5	7.8	2870±50	29.34±0.06
Uka	1628	94.0	9.5	1725±54	27.07±0.26
Ndek Akorbiri	2042	98.5	14.3	867±79	26.19±0.22
Ekeiyi	1747	76.0	8.9	1918±90	23.27±0.13
Onom	1390	100.0	10.0	2842±52	22.89±0.08
Egunofon	1719	53.8	11.4	1125±221	21.27±0.15
Akaayie	1767	49.8	9.7	1400±52	19.47±0.05
General mean	**1693**	**140.0**	**9.3**	**1820±24**	**27.72±0.04**

streams in the Mountain Pine Ridge Savannah of Belize, Kellman et al. (1998) found 66 tree species and in Muvumba gallery forest in Rwanda, ACNR (2011) identified 70 species. However, the number of trees species found in this study is very low compared to that found in riparian forests of Benin (224 species) by Natta (2003) and of Burkina Faso (196 species) by Sambaré et al. (2011).

The estimation of abundance and richness of plants can vary enormously depending upon whether inventorying included stems of small diameter (dbh < 2.5 cm) or not. In this study, small diameters minimum dbh of

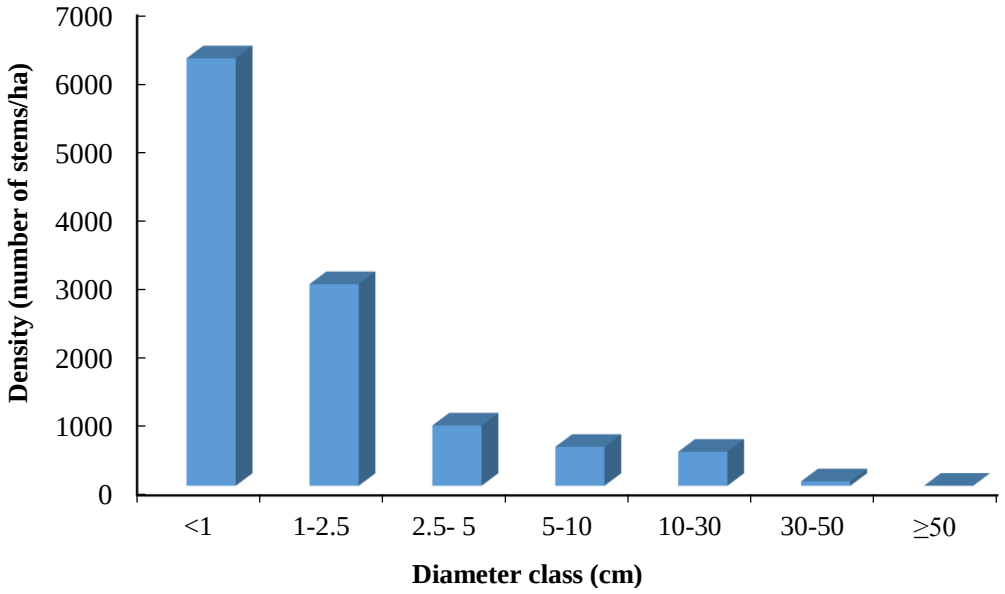

Figure 3. Diameter class distribution of the woody species recorded in Ajei community forest.

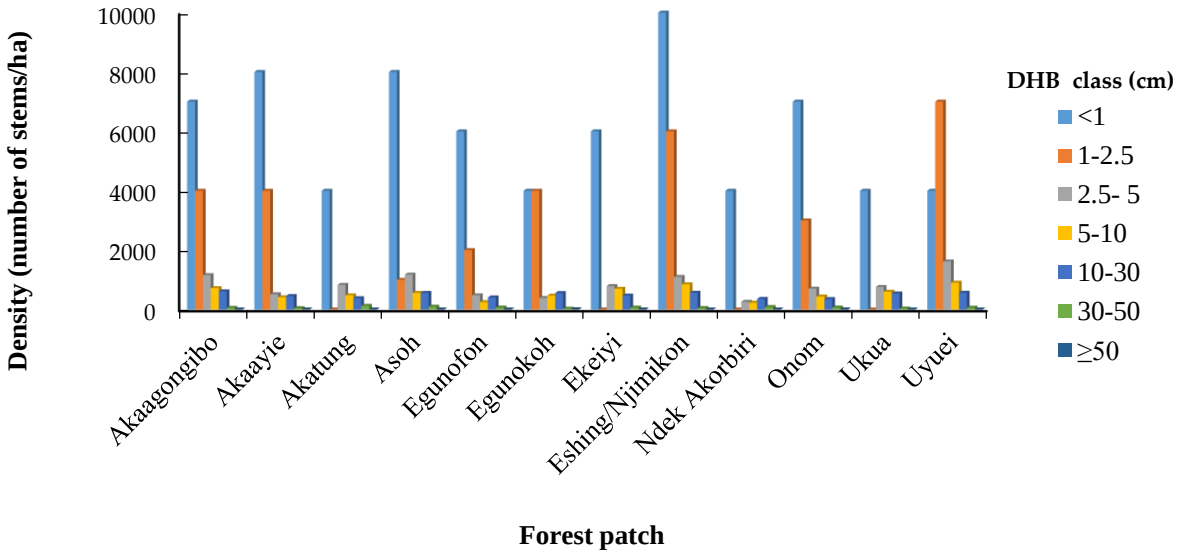

Figure 4. Diameter class distribution of the woody species recorded in each forest patch: <1 cm (seedlings); ≥1 cm to <2.5 cm (small saplings); ≥2.5 cm to <5 cm (medium sized saplings); ≥5 cm to <10 cm (small trees or posts); ≥10 cm to <30 cm (medium sized trees or poles); ≥30 cm to <50 cm (large trees or standards); and ≥50 cm (giant trees or veterans).

1 cm was considered; whereas, in the above cited studies, the authors considered a dbh ≥ 10 cm, except Sambaré et al. (2011) who considered a dbh ≥ 5 cm. The other reasons for the high diversity of woody plants from one location to another may be related to the intensity and frequency of floods, variation in topography, variations in climate and disturbances regimes imposed on the riparian forest by upland environment (Naiman et al., 2008).

The Shannon-Weaver diversity index (H') ranged from 3.88 to 4.89 in different forest patches with a value of 4.34 for the entire forest, reflecting the high diversity within this study site. Forest communities considered rich are characterized by a Shannon diversity value of about

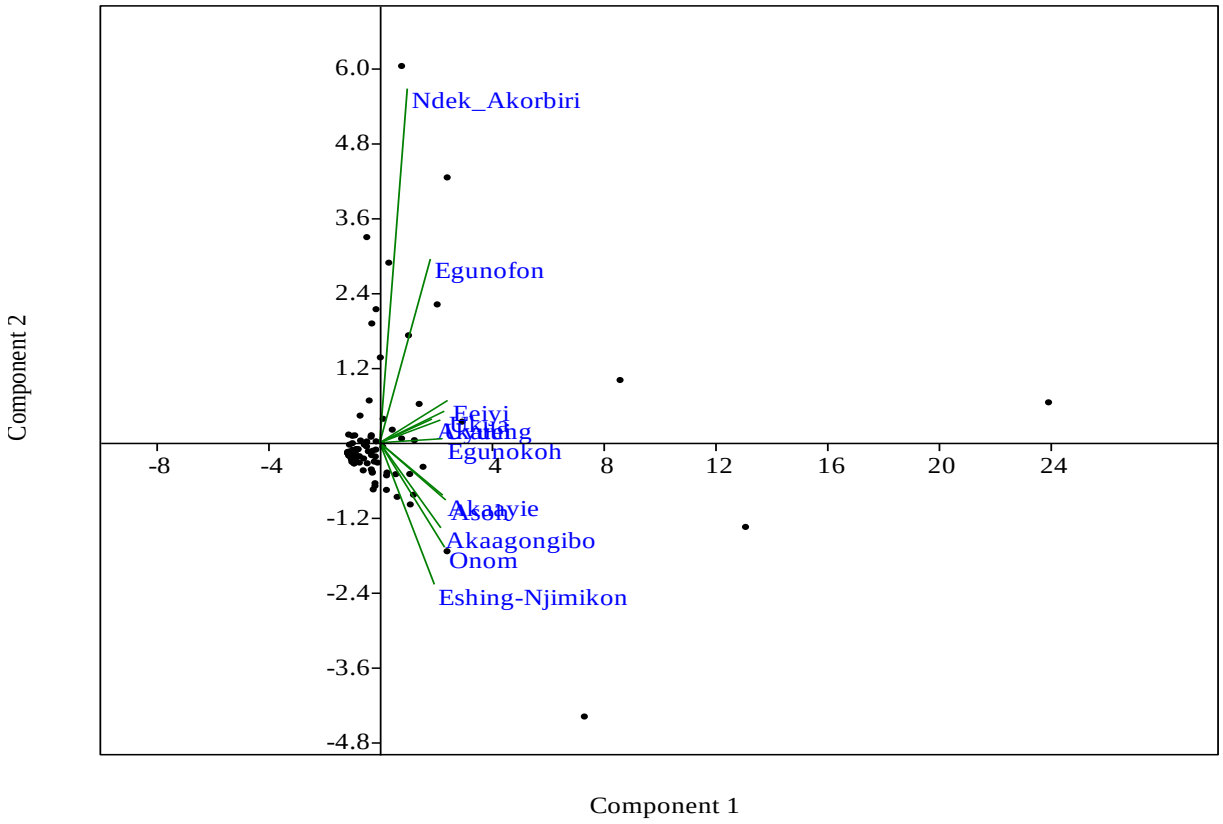

Figure 5. Principal coordinate analysis showing three groups of forest patches.

3.5 or higher (Kent and Coker, 1992). The high diversity is also confirmed by a Simpson's diversity index close to 1.0 (0.94); the low generic diversity (1.32), and the ocurrence of families and genera with a single species. Such high diversity seems also to derive from a great abundance of rare species: 40 species were represented by three or fewer individuals.

Regarding the family importance value, the most important families were Euphorbiaceae, Apocynaceae, Moraceae, Rubiaceae and Meliaceae. In term of diversity (number of species per family), Rubiaceae, Euphorbiaceae, Moraceae, Meliaceae, Malvaceae and Fabaceae were the best represented families. Except for the Meliaceae family, Natta (2003) and Momo Soléfack et al. (2018) have also found these families among the most represented in Benin and in Koupa Matapit gallery forests, respectively. In Burkina-Faso, the Fabaceae and Rubiaceae were the most tree species-rich families in gallery forests of the Hippopotamus Pond Biosphere Reserve (Bélem and Guinko, 1998). According to Gentry (1988) three families (Rubiaceae, Annonaceae and Euphorbiaceae) are always among the ten most species-rich families in Africa, Asia and the Neotropics.

The gallery combined various savannah and forest species. The most important species with an Importance value index (IVI) greater than 10% were *Macaranga occidentalis, X. monospora, R. vomitoria, Tabernaemontana* sp. and *C. acuminate.* IVI is used for prioritizing species conservation, whereby species with low IVI value need high conservation priority compared to the ones with high IVI (Gotelli and Colwell, 2011). In the Ajei upland community forest, 38 species had an IVI less than 0.5%, each. Therefore, conservation priority should be given to those species having low importance value index.

Species frequencies ranged from 8.33 to 100%, and species can be divided into three main groups based on forest patch affinity:

1. Species that occur in all the twelve forest patches and can be described as ubiquitous: There are 6, representing 4.03% of the total species (*Macaranga occidentalis, Croton macrostachyus*, *Ficus sur*, *Psychotria dorotheae*, *Rauvolfia vomitoria* and *Xymalos monospora*).
2. Non-regular species: They are 79 (representing 63.70% of species), each of which is present in at least two different forest patches.
3. Rare, forest patch specific, or occasional species: They are characterized by their belonging to a single

particular patch; they are 39 species (31.45%).

Stand structure of the gallery forest

The overall mean tree density for Ajei upland community forest was 1820 trees ha^{-1}. When considering only individuals with dbh ≥10 cm, the stem density was 693 stems ha^{-1}. This number is comparable to the range of 641 to 715 stems ha^{-1} found by Kellman et al. (1998) in gallery forest in the Mountain pine ridge (Belize). Sambaré et al. (2011) found tree densities ranged from 233 to 727 stems ha^{-1} in gallery forests in Burkina Faso. This density is also within the range of 167 to 1947 individuals per hectare reported by Gentry (1982) for Neotropical forests sampled by different methods.

Values of basal areas found in this study (19.4 to 39.4 m^2 ha^{-1}) are nearly similar to those of riparian forests founnd in Burkina Faso (8.25 to 31.02 m^2 ha^{-1}), but are lower than those found in Benin (35.6 to 45.6 $m^2 \cdot ha^{-1}$). Despite possessing stem densities that are higher than average, the basal areas of gallery forests are lower than average for other tropical forests. This can be explained by the stem sizes that tend to be smaller in gallery forests. It may be a supportive stabilisation adaptation to an unstable upland environment yet to be confirmed by level of shoot-root ratio.

The diameter class exhibited a tendency towards an inverted J-curve distribution, showing an important dynamic of tree species through a high potential of natural regeneration. The high number of individual trees with a small diameter highlights that this ecosystem is dominated by young trees. This gallery forest can be characterized as a low-biomass community with many small-stemmed trees, compared to the continuous upland tropical rain forests. Similar results were found in gallery forests in others parts of Africa (Natta, 2003; Sambaré et al., 2011, Fousseni et al., 2014).

The inverted-J curve distribution in Ajei upland community forest with the presence of more individuals in the diameter classes of ≥2.5 show signs of disturbances and can be explained by three principal causes:

1. The annual transhumance phenomenon in the area by the Bororos and locals accompanied by uncontrolled seasonal bush fires in the savannah in the dry seasons, stretching and consuming the understorey of forest patches;
2. The formation of grazing tracks through the forest patches (common to most patches, but particular to Uka, Egunofon, Akatung and Onom) and;
3. The slash and burn agriculture practice of farmers.

All these challenges restrict the growth and lowers the life span of individuals resulting in a continuous annual regeneration process with fewer individuals having the opportunity to recruit into higher diameter classes. The lack of individuals in the larger size classes cannot really be due to illegal logging of bigger trees by the locals for timber and construction purposes (Temgoua et al., 2018), but by the fact that the forest has limited species that grow larger than these diameters. In all, it could be concluded that that grazing and shifting cultivation activities pose a lot of threats to the sustainability of the forest patches and the entire highland watershed community forest. These phenomena were also described by Fousseni et al. (2014) as major threats in riparian forests of Togo.

Concerning the altitude gradient, the ordination by Principal Coordinate Analysis confirmed the diversity and richness of the lower and middle and lower altitude classes (between 1300 and 1900 m) highest amongst the other elevation classes. This decrease can be explained by changes in biophysical factors, altitude and the combination of other human factors including previous land use. These findings corroborate Wouokoue et al. (2017) who also indicated more species distributed in the lower zones in the Bamboutos Mountain in West region of Cameroon.

Implications for conservation and forest management

In Cameroon the aim of community forestry is to increase the level of involvement and participation of local communities in the conservation and sustainable management of natural resources (Minang et al., 2019). It has a dual objective of improving the standard of living of village populations and conserving biodiversity. Although other resources such as non-timber forest products and wildlife are also important for the populations, the most exploited resource in community forests in Cameroon is timber (Cuny, 2011). From the analysis of the floristic diversity of the community forest of Ajei, it appears that this forest is very poor in commercial timber species. Only four species identified are on the list of potentially commercial forest species established by the Cameroonian forest administration (MINFOF, 2014). These are *Entandrophragma angolense, Carapa grandiflora, Albizia ferruginea* and *Albizia zygia*. From the above species, *E. angolense* is the only one listed among species that are easy to commercialize due to the existence of a large market and demand (MINFOF, 2019). The three other species are among species that can be used, but currently have low commercial value. It is then obvious that the primary objective of the management of the Ajei community forest cannot be the exploitation of timber as is the case for most of the community forests in Cameroon. For example, in Cobaba community forest en Eastern Cameroon, Temgoua et al. (2020) recorded 65 commercial timber species.

One of the options for managing the Ajei community

forest could be payment for ecosystem services through its carbon sequestration and watershed protection potential. The study will therefore need to be complemented by an assessment of carbon stocks. Such payments for ecosystem services initiatives, implemented by World Wide Fund for nature (WWF) in some community forests in eastern Cameroon, have had satisfactory and encouraging results for local development (WWF, 2016; Guechoung, 2018). Conservation efforts of the Ajei community forest should be tilted towards upland watershed forest ecosystems as they constitute an essential resource to the sustainability of endemic highland biodiversity and fresh water systems which supply down slope community with drinking water.

Some tree species of economic value providing non-timber forest products were identified in the Ajei community forest. These include *Cola acuminata*, *Dacryodes edulis*, *Carapa grandiflora*, *Persea americana* and *Cola nitida.* These species must be valued for the improvement of people's livelihoods. It is therefore recommended to encourage and promote the planting of these species around compounds and in farmland. This would support the economic development of the Ajei community, while at the same time supporting water catchment protection, carbon sequestration and climate change mitigation. This could be initiated through small scale agroforestry, woodlots, or tree planting projects by providing seedlings of desired species to the local community. Salami et al. (2002) showed this is quite plausible especially among women folk.

Vegetation disturbances related to slash and burn agriculture, livestock and grazing were noted. These land uses are often conflicting with frequent farmer-grazer conflicts and grazing-water catchment conflicts, especially in the dry season, within the Community Forestry and Family Heritage Zones; given, that the various forests patches have been managed by particular families for decades. Therefore it sounds as though it may be critically difficult to shift the management to new land use policies under Community Forestry - most family settlements around the patches to which they have ancestral attributes and where they are custodians see the community forestry initiative by the government as an attempt to alienate them from their land use rights. Reconciling the rising needs for sustainable exploitation for livelihood security of a local population (coupled with ownership and ancestral rights to the forest patches) on one hand, and biodiversity conservation (with other national environmental benefits as major feeder connecting streams to major hydrological basins) on other hand; have been amongst the challenges faced by the Ajei Forest Community Management Board (AHWaCoFoMB). The Board urgently needs support to address, and successfully implememt, the future participative management plan. The plan should address conservation issues relating to several pressing needs including: Demarcation, fire control, habitat regeneration through viable agroforestry practices, woodlots plantation establishment and continuous environmental education, and finally, sensitization and awareness generation among the population.

Conclusions

This study showed that the gallery forests of Ajei highland community forest have a diversified woody flora. A total of 124 woody plant species were recorded, belonging to 90 genera and 47 families. Despite the high diversity level, the forest is still very poor in commercial timber species. Therefore, this community forest cannot be valorized through timber exploitation as is the case of the majority of community forests in Cameroon. Other options of valorization such as payment for ecosystem services through its carbon sequestration and watershed protection potential need to be explored. A good participative management and monitoring plan for these gallery forests is encouraged as a management tool for the Ajei Forest Community Management Board (AHWaCoFoMB) to help enhance the biodiversity conservation and carbon sink potential of these sites. The study needs to be complemented by an assessment of carbon sequestration potential and the contribution of these gallery forests to climate change mitigation.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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APPENDIX

Table 1. Family and species list of Ajei highland watershed community forest, North West Cameroon (Life forms: Tr-tree, sh-shrub, Li-liana, Pa – palm), * represents the presence in the patch).

Family	Scientific name	Life form	Forest patch											
			Akaagongibo	Akaayie	Akatung	Asoh	Egunofon	Egunokoh	Ekeiyi	Eshing/Njimikon	Ndek Akorbiri	Onom	Uka	Uyuei
Alangiaceae	*Alangium chinense* (Lour.) Harms	Tr	*	*		*	*	*		*		*	*	*
Annonaceae	*Cleistopholis patens (Benth.) Engl. & Diels*	Tr							*			*		
	Uvaria sp.	sh	*	*	*	*			*			*		
	Xylopia acutiflora (Dunal) A.Rich	Tr	*	*	*	*			*			*	*	*
Apocynaceae	*Landolphia* sp	li	*	*	*	*				*	*		*	*
	Rauvolfia vomitoria Afzel.	Tr	*	*	*	*	*	*	*	*	*	*	*	*
	Tabernaemontana pachysiphon Stapf	sh		*										
	Tabernaemontana sp	sh	*	*		*	*		*	*	*	*	*	*
	Voacanga africana Stapf.	Tr			*	*						*		
Aquifoliaceae	*Ilex* sp	Tr												*
Araliaceae	*Polyscias fulva* (Hiern) Harms	Tr	*	*	*	*	*	*		*	*	*	*	*
	Schefflera barteri Harms	sh								*	*			*
	Schefflera mannii (Hook. f.) Harms	Tr					*	*						*
Arecaceae	*Rafia palms* (Rafia) P. Beauv	Pa		*					*					
	Phoenix canariensis Chabaud	Pa						*						
Asteraceae	*Vernonia conferta* Benth.	sh	*	*	*				*			*		
Bignoniaceae	*Kigelia africana* (Lam.) Benth.	Tr			*									
	Markhamia lutea (Benth.) K. Schum.	Tr										*		
	Markhamia sp											*		
Boraginaceae	*Cordia aurantiaca* Baker	Tr		*	*	*						*		
Burseraceae	*Dacryodes edulis* (G. Don.) H. J. Lam.	Tr			*	*						*		
	Santiria trimera (Oliv.) Aubrév.	Tr	*											
Celastraceae	*Salacia erecta (*G. Don) Walp.	sh	*			*							*	*

Appendix 1. Contd.

	Garcinia smeathmannii (Planch. & Triana) Oliv.	Tr													*
Clusiaceae (Guttiferae)	*Psorospermum aurantiacum* Engl.	sh	*	*	*	*		*							*
	Symphonia globulifera Linn.f	Tr								5				3	
	Vismia guineensis (Linn.) Choisy	sh	*	*	*				*				*		
Combretaceae	*Combretum hispidum* Laws	li		*					*						
Commelinaceae	*Palisota barteri* Hook.	sh	*							*					
Cyatheaceae	*Cyathea cameroonianа* Hook.	Tr		*			*							*	
Dracaenaceae	*Dracaena arborea* (Wild.) Link	Tr	*			*	*		*	*					*
Ericaceae	*Agauria salicifolia* G. Don	sh				*									
	Alchornea floribunda Mull.Arg	sh											*		
	Antidesma venosum Tul	sh	*	*	*		*	*					*	*	*
	Antidesma vogelianum Müll.Arg.	sh		*											
	Bridelia ferruginea Benth.	Tr				*									
	Bridelia micrantha (Hochst) Baill	sh	*		*	*	*	*	*	*	*	*	*	*	
	Croton macrostachyus Hochst	Tr	*	*	*	*	*	*	*	*	*	*	*	*	
Euphorbiaceae	*Croton longiracemosu* Hutch	Tr		*		*									
	Drypetes sp	Tr	*		*		*				*	*	*	*	
	Erythrococca hispida (Pax) Prain	sh		*											*
	Macaranga occidentalis (Mull.Arg.)	Tr	*	*	*	*	*	*	*	*	*	*	*	*	
	Mallotus oppositifolius (Geisel) Muill- Arg	sh				*									
	Margariataria discoidea (Baill) G. L. Web	Tr		*					*						*
	Sapium ellipticum (Hochst) Pax	sh			*	*	*						*	*	
	Sapium guineense (J. Lèonard) Kruijt & Roebers.	sh				*									
Fabaceae	*Albizia ferruginea* (Guill. & Perr.) Benth.	Tr	*	*	*	*	*	*	*	*			*	*	*
	Albizia zygia (DC.) J.F. Macbr.	Tr			*		*	*					*		
	Dalbergia lactea Vatke	sh	*	*	*	*	*	*	*		*	*	*	*	
	Millettia conraui Harms	Tr					*				*				
	Adenocarpus mannii (Hook.f.) Hook. F.	sh	*	*		*			*	*		*			*
Flacourtiaceae	*Caloncoba glauca* (P. Beauv.) Gilg	Tr		*											
Hypericaceae	*Harungana madagascariensis* Choisy	Tr	*	*	*	*	*	*		*		*	*	*	
Lamiaceae	*Archboldia* E. Beer & H. J. Lam	sh	*												
Lauraceae	*Beilschmiedia* sp	Tr											*		
	Persea americana Mill	Tr		*	*						*	*			*
Leeaceae	*Leea guineensis* G.Don	sh		*	*	*		*					*		*

Appendix 1. Contd.

Loranthaceae	*Globimetula oreophila* (Oliv.) Tiegh.	**sh**						*****						
Malvaceae	*Cola acuminata* Schott & Endl.	**Tr**		*****	*****	*****		*****	*****	*****		*****	*****	*****
	Cola nitida (Vent.) Schott & Endl.	Tr		*										
	Cola verticillata (Thonn.) Stapf.	Tr				*								*
	Grewia coriacea Mast	Tr												*
	Grewia sp	Tr			*		*							
	Leptonychia echinocarpa K.Schum.	Tr				*								
	Triumfetta cordifolia A. Rich.	sh											*	
Meliaceae	*Carapa grandiflora* Sprague	Tr			*	*	*				*		*	*
	Carapa parvifolia Harms	Tr				*								*
	Entandrophragma angolense (Welw) C. DC.	Tr	*			*				*		*		
	Heckeldora staudtii (Harms) Staner	Tr		*										
	Trichilia welwitschii CDC	Tr	*	*	*	*			*	*		*	*	*
	Turraeanthus africanus (Welw. ex DC.) Pellegr.	Tr	*	*	*	*						*		*
	Turraeanthus mannii Baill.	sh				*								
Melianthaceae	*Bersama abyssinica* Fresen	Tr				*							*	*
Monimiaceae	*Xymalos monospora* (Harv.) Baill ex	sh	*	*	*	*	*	*	*	*	*	*	*	*
Moraceae	*Ficus exasperata* Vahl	Tr	*	*	*	*		*	*	*		*		*
	Ficus sp.1	Tr	*	*				*						
	Ficus kamerunensis Mildbr. & Burret	Tr	*					*						*
	Ficus leprieurii Miq	Tr	*						*	*				
	Ficus ovata Vahl	sh				*								
	Ficus sp. 2	Tr										*		
	Ficus sur Forsak	Tr	*	*	*	*	*	*	*	*	*	*	*	*
	Trilepisium madagascariense DC.	Tr										*		
Myrtaceae	*Eucalyptus globulus* Labill.	sh								*				*
	Eugenia fernandopoana Engl.	sh				*								
	Eugenia gilgii Engl.	sh				*								
	Syzygium staudtii (Engl.) Mildbr.	Tr	*	*		*	*			*		*		*
Myrsinaceae	*Maesa lanceolata* Forsk	sh	*	*	*	*		*		*		*	*	*
Ochnaceae	*Campylospermum flavum* (Schumach. & Thonn.) Farron	sh	*	*		*		*		*			*	*
Olacaceae	*Strombosia scheffleri* Engl	Tr		*	*	*		*		*		*		*
Pittosporaceae	*Pittosporum mannii* Hook .f	sh	*	*		*			*				*	*

Appendix 1. Contd.

	Canthium dunlapii Hutch. & Dalziel	Tr			*	*	*	*						*
	Psilanthus mannii Hook. f.	sh	*											
	Psychothia sp 1	sh												*
	Psychotria camptopus Verdc.	sh		*	*	*	*					*	*	*
	Psychotria capense (Eckl.) Vatke	sh		*	*						*		*	*
	Psychotria dorotheae Wernham	sh	*	*	*	*	*	*	*	*	*	*	*	*
	Psychotria gaboonensis Ruhsam	sh						*					*	
Rubiaceae	*Psychotria peduncularis (*Salisb.) Steyerm.	sh		*				*					*	
	Psychotria sp 2	sh												*
	Psychotria sp 3	sh	*					*						
	Psychotria sp 4	sh	*	*			*			*				*
	Psydrax dunlapii (Hutch. & Daziel) Bridson	sh										*		
	Rothmannia hispida (K Schum.) Fagerlind	Tr	*		*	*				*		*		*
	Unknown	sh			*		*		*		*		*	*
	Shumanniophyton magnificum (K .Schum). Hans	sh				*	*							
Rutaceae	*Fagara macrophylla* Engl.	Tr		*	*	*		*			*		*	*
	Oricia suaveolens (Engl.) Verdoorn	sh				*				*		*		
	Zanthoxylum heitzii (Aubrév. & Pellegr.) P.G.Waterman	Tr	*	*		*	*			*	*	*	*	*
	Allophylus africanus P. Beauv.	Tr	*		*	*	*		*		*		*	*
	Paullinia pinnata Linn.	li												
Sapindaceae	*Chytranthus talbotii* (Baker f.) Keay	Tr		*			*					*		
	Bligha welwitchie Hook.f	Tr	*											
	Unknown	Tr									*			
	Aningeria rubusta (A Chev.) Aubrèv.& Pellegr	Tr			*	*		*					*	
Sapotaceae	*Eriocoelum macrocarpum* Gilg ex Radlk.	Tr	*	*	*	*			*	*			*	*
	Manilkaria obovata (Sabine & G. Dm.) Hemsley	Tr				*								
Simaroubaceae	*Brucea antidysenterica* J.	Tr	*	*								*		
	Hannoa klaineana Pierre ex Engl.	Tr	*			*	*				*		*	*
Thymelaeaceae	*Gnidia glauca* (Fresen) Gilg.	sh	*											
Uknown family 1	Uknown sp. 1	sh		*										
Uknown family 2	Uknown sp. 2	sh		*										
Ulmaceae	*Trema orientalis* (L) Blume	Tr	*		*	*				*		*		*
Verbenaceae	*Clerodendrum violaceum* (Gurk)	sh							*					
Viscaceae	*Cissus* sp	li	*			*				*	*			

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Climate variability, biodiversity dynamics and perceptions of local populations in Waza National Park (Far North Region, Cameroon)

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Climate variability is one of the major ecological challenges of the 21st century in Waza Logone Plain in the Far North region of Cameroon. The physical environment in this area has almost completly deteriorated as a result of declining rainfall and rising temperatures. A study was carried out to understand the dynamics of biodiversity in terms of climate variability in the Waza National Park. This study was based on both the trends of climatic parameters on biodiversity and perceptions of local populations over the last forty years. The adapted approach combines (i) the modeling of climate data through MINITAB 17 Software, (ii) the analysis of wildlife census data and (iii) the digital analysis of satellite images using ENVI 4.5 and QGIS 2.17 Software. The results showed a negative evolution of climatic parameters during the last forty years. The general negative trend of biodiversity evolution of both fauna and flora is a result of the continuous degradation of the Waza National Park. The results of different wildlife census, the spatial analysis and the perceptions of local people confirmed the trend to the degradation of the park and biodiversity losses. Concrete measures of management of the Park should be taken by stakeholders in order to hinder the biodiversity losses, including the construction of water ponds and cartesian wells as well as the enrichment of the park with woody species.

Key words: Climate variability, land degradation, biodiversity dynamics, biodiversity losses, Waza Logone Plain, Cameroon.

INTRODUCTION

Since the United Nations Conference on Environment and Development (UNCED) held in Rio in June 1992, the issues of climate change and variability have become a priority in the protection of the environment, both in industrialized countries historically responsible for these changes, than developing countries. This awareness of the public opinion of the climate issue and the awakening of scientists to these problems were salutary because a wind of protest already blew on the developed world involving companies deemed too subject to the

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technology and industrialization, which are the main sources of greenhouse gas emissions (Merle, 2002).

According to the IPCC Fourth Assessment Report (2007), the current concentration of carbon dioxide is the highest ever seen in the last 420 000 years, and the growth rate recorded in the last century has been unprecedented since at least 20 000 years. Changes in climate have caused impacts on natural and human systems on all continents and across the oceans in recent decades (IPCC, 2014). The rate of global warming observed (more than half a degree Celsius in a century on the globe) and expected (from 1.1°C at best to 6.4°C at worst, on average overall, between 1990 and 2100) is a hundred times higher than the average speed of variations naturally imparted to the Earth's climate (Gnangle et al., 2012). In addition to the rise in average temperatures, the manifestations of global climate change are, among others, the rise in the level of oceans and seas, and rainfall variability. The impacts of these changes will affect all countries of the world, with varying degrees depending on the region (Tarhule, 2011).

Many terrestrial, freshwater and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances, and species interactions in response to ongoing climate change (IPCC, 2014). They pose a significant threat to growth, sustainable development and the achievement of the Millennium Development Goals (MDGs) in Africa (NEPAD, 2007). Africa, in particular, is the continent least responsible for climate change, but it is particularly vulnerable to their effects. Janet (2009) even speaks of an implicit injustice, as the poorest and most vulnerable people, who are the least guilty in the gradual increase of greenhouse gas emissions, are the most affected and the least capable to adapt to the effects of climate change. Additional 75 to 250 million people are expected to suffer from water scarcity aggravated by climate change in sub-Saharan Africa by 2020 according to IPCC report. As climate has a major influence on the global environment, its disruption could have a negative impact on the functioning of both terrestrial and maritime ecosystems. Changes in the frequency, intensity, extent and status of disturbances will affect the risks and the rate of replacement of existing ecosystems by new ecosystems (Ouoba, 2013). These disturbances can accelerate the disappearance of species and create opportunities for the establishment of new species (FAO, 2007), while the ecosystems of arid and semi-arid regions will be strongly affected (Thornton and Herrero, 2009). Studies have shown that changes in temperature and rainfall in the future will often modify and limit the direct effects of CO2 on plants (IPCC, 2007).

The geographical situation of Cameroon, characterized by three main climatic types, makes that certain regions of the country like the Far-North exposed to the effects of the changes and the climatic variability. With increasingly high temperatures and the distribution of increasingly variable and unpredictable rainfall in this part of the country, its biodiversity will be permanently affected. On the other hand, following the droughts of the 1970s and 1980s, the rescue operation Waza launched by the Cameroonian State consisted of the digging of 17 ponds and boreholes in the Park in addition to the 50 existing ones. This palliative is still insufficient given the persistence of the water problem in this Park (Zourmba, 1993). Thus, the Cameroonian Government, under the financial assistance of the Dutch Cooperation and the WWF, set up the Waza Logone Project in 1992, which aims to restore the Waza Logone Plain (Saleh, 2007). The rehabilitation began in 1994 with the opening of two tributaries of the Logone River. These are Logomatya and Aréitékélé in 1994 and 1997, respectively. This double opening has flooded more than 30% of the plain in general and more than 60% of the park (Scholte, 2005) over an area of about 300 km² (Ledauphin, 2006). This has led to positive results on resources with the availability of pastures and watering points for several months in the dry season in the park (Saleh, 2012). In 2002, the project came to an end without any concept of monitoring or learning. Therefore, the great embellishment observed was only of short duration because the situation has changed to its former state. Since the degradation of climatic parameters (rainfall and temperature) is partly responsible for the decline of the biodiversity of the park, it is important to understand how the populations living near this protected area perceive the changes in their immediate environment.

On this background, this study aims to contribute to a better understanding of the dynamics of biodiversity of the park in relation to the perception of local populations.

MATERIALS AND METHODS

Study site

The Waza National Park is located in the Far North Region of Cameroon, between latitude 11° 03 'and 11° 30' N and longitude 14° 20 'and 14° 66' E, close to Nigerian border 10 km (west) and Chadian border 20 km (east) (MINEF, 1997). The Waza National Park is part of the vast Waza Logone Plain covering 8 000 km^2 (Figure 1). The climate is semi-arid and three seasons are distinguished: a rainy season from June to October; a dry and "cold" season from November to February; a dry and hot season from March to June (MINEF, 1997).

The average annual rainfall in Waza varies between 650 and 700 mm. The average annual temperature is around 28°C but can sometimes go down to 18°C in the cold period of November and also reach 45 or 50°C in the shade in March-April. The thermal amplitude is quite high, sometimes reaching 10 to 15°C (Ledauphin, 2006).

Although the park does not contain any permanent watercourse, hydrology is very complex and decisive, particularly with regard to a large part of the vegetation (Vanpraet, 1977). The inflow of water goes through two main ways: the mayos (temporary streams), coming from the Mandara Mountains and the flood waters coming from the overflow of the Logone River and its branches, the Logomatya and the Loromé Mazra.

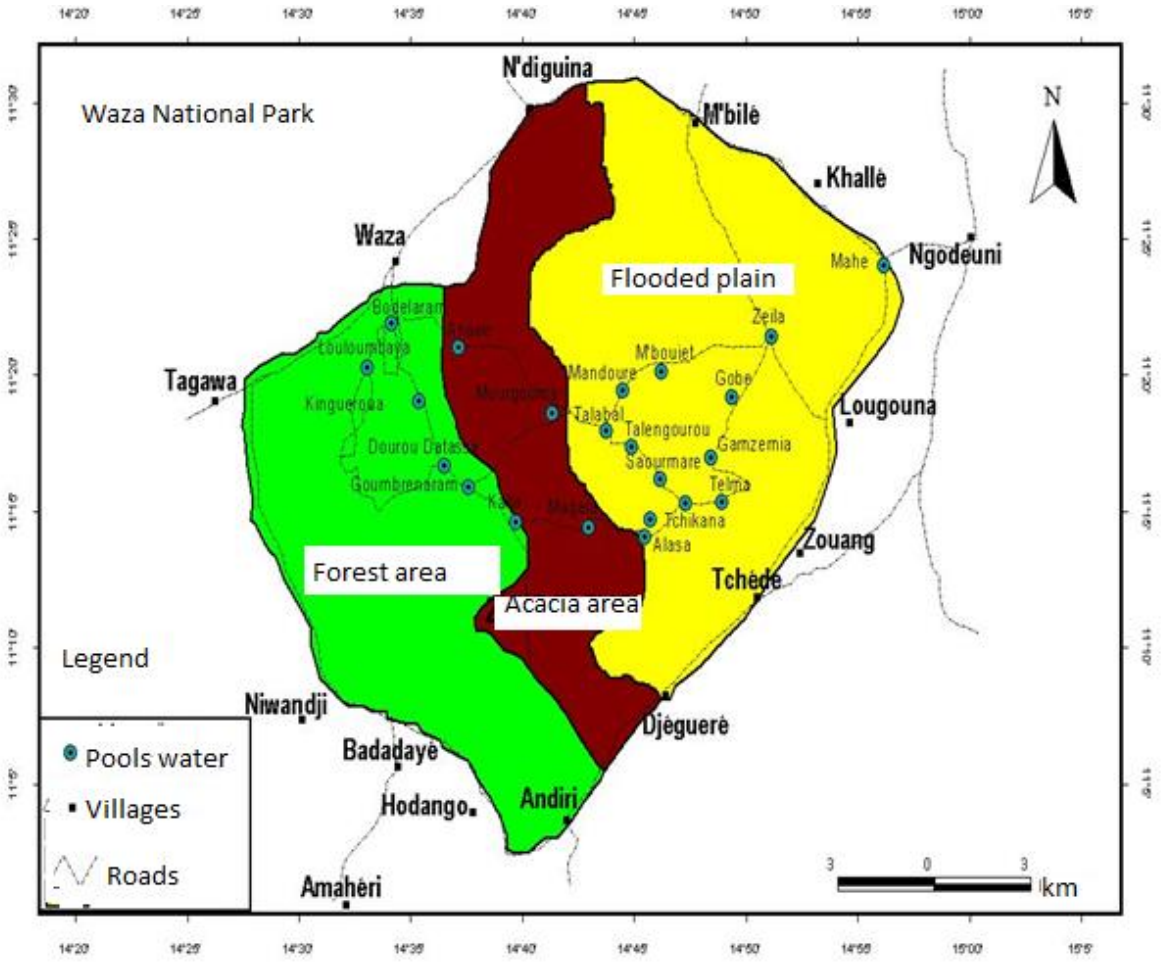

Figure 1. Map of location of the study site.
Source: Ledauphin (2006).

Five types of soil are distinguished in the park from West to East, which are ferruginous soils, planosols, vertisols, hydromorphic soils, anthropogenic soils that are elevated or mounds, signs of an ancient civilization called "Sao Civilization". Soils disturbed by human activity are sandy-clayey on the surface (Vanpraet, 1977).

The park is of the Sudano-Sahelian type characterized by a thorny steppe of *Acacia seyal*, littered with *Balanites aegyptiaca* and rich in annual and perennial grasses (Saleh, 2005). According to White (1986), the Waza National Park is located in the regional center of Sudanese endemism, specifically straddling two vegetation units. The western part of the park is characterized by undifferentiated Sudanian forest (Sudanese forest and savannah with dominant Combretaceae Family), while the eastern part by a mosaic of edaphic grassland and *Acacia* spp. formations. Many authors classify this vegetation in three main types: a wooded vegetation in the western part of the park, whose main species are *Sclerocarya birrea, Anogeisus leiocarpus, Lannea humilis*; shrub vegetation with *Acacia* species located in the center of the Park, the species are *Acacia seyal*, *B. aegyptiaca*, and some *Piliostigma reticulatum* that announce the floodplain; a grassy plain still called " Yaéré " meadow seasonally flooded covering about 55% of the surface of the park and very rich in perennial and annual herbaceous. The main species are *Sorghum arundinaceum, Hyparrhenia rufa, Oryza longistaminata, Ischaemum afrum, Vetiveria nigritana, Panicum anabaptismum, Echinocloa* species, *Aristida adscensionis, Brachiaria ramosa, Brachiaria xantholenca, Chloris pilosa, Echinochloa pyramidalis, Echinochloa stagnina, H. rufa, Jardinea* species, *Oryza barthii, Panicum maximum, Pennisetum pedicellatum, Setaria pallidifusa,* and *Sporobolus pyramidalis*.

The fauna consists of mammals such as *Loxodonta africana, Panthera leo, Hyppotragus equinus, Gazella rufifrons, Kobus kob, Felis sylvestris, Hyena hyena, Canis aureus*, birds, reptiles and fish.

Data collection

The data collection concerned the acquisition of satellite images of the vegetation of the park on LANDSAT, the number of species affected by climate variability and qualitative data.

Acquisition of satellite images on LANDSAT

To evaluate the vegetation dynamics of this protected area, satellite images on LANDSAT were acquired at the same time of the year (December, respectively for the years 1986 and 2016) through the sites http: //earthexplorer.usgs.gov/ and http://glovis.usgs.gov/ to

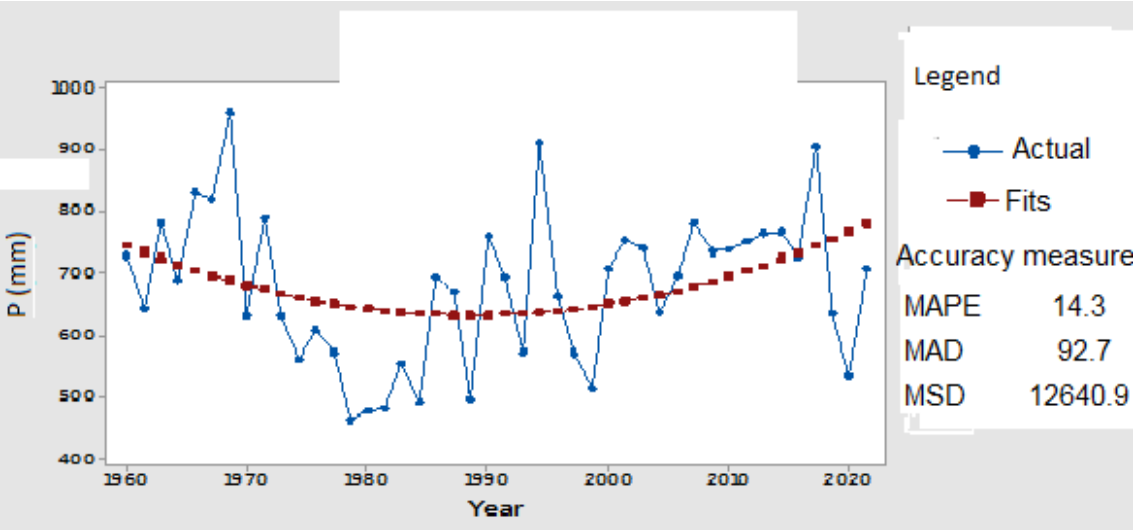

Figure 2. Trend curve of the precipitation of Waza Logone Plain (1960-2020).

reduce problems related to phenological changes in vegetation. Two images were used, namely Landsat 5 TM scenes from 1986 and Landsat 8 OLI scenes from 2016.

Landsat TM scenes from December 1986

The Landsat 5 satellite launched since 1st March 1985 is part of the second generation of Landsat satellites; it is equipped with two multi spectral sensors. This is the MSS sensor whose data acquisition was stopped in 1992 and the TM sensor, tapes were used for the present study. The TM sensor has seven spectral bands and covers an area of 185 km × 185 km. For the 1986 land cover map, the Landsat second grid grid (WRS 2) was used with coordinates 184p52r (Path = 184 and Row = 52) in December 1986. To highlight the theme used here, seven landsat 5 TM strips, bands 2, 3 and 4 which are bands in relation to the canopy were chosen. These tapes allowed us to perform a false color RGB color composition at 4, 3, 2 that is, we assigned band 4 to red, band 3 to green and band 2 to blue.

Landsat 8 scenes from December 2016

This satellite has been launched since 11th February, 2013 and is composed of two instruments namely the OLI instrument (Operational Land Imager) and the TIRS instrument (Thermal Infrared Sensor). The OLI instrument acquires images in nine spectral bands (1 to 9) ranging from visible to infra-red. Seven of these spectral bands were already present on the Landsat 7 ETM + instrument; two additional channels were added, mainly for atmospheric correction (440 nm blue channel) and cloud detection (1380 nm). The TIRS instrument is a two-channel infra-red multi spectral radiometer (Band 10 and 11) that provides data at wavelengths used by older Landsat satellites. For the realization of the 2016 land cover map, the spectral bands of the OLI instrument were chosen. It is mainly a scene from the second landsat grid (WRS 2) with coordinates 184p52r (Path = 184 and Row = 52) from December 2016. For the highlighting of the vegetation cover of the area of interest, bands 3, 4 and 5 were retained in order to make a false RGB color composition at 5, 4, 3 with strip 5 in red, strip 4 in green and strip 3 in blue. It should be noted that these classes were adopted on the basis of the work of Tabopda (2008), which provided for four (4) classes of land occupation: steppe on flooded soil, steppe on clay soil, steppe on sandy soil and steppe on bare soil.

The determination of the number of herbivores affected by climate variability was based on the inventories done by the staff managers of the park.

Qualitative data

The qualitative data were based on questionnaire survey of eighty-four (84) people living near the park, aged at least forty (40) years old. At this age, people might perceive the climate variability for the last forty years. The questions were essentially based on their perceptions concerning the dynamic of biodiversity (flora and fauna) and the variability of the climate in their environment.

RESULTS AND DISCUSSION

Evolution of precipitation

Loth (2004), after an analysis of the pluviometric sequences of the Waza Logone Plain from 1930 to 2000, distinguished five periods: the first period before 1930, characterized by above-average humidity; the second period from 1930 to 1950, characterized by normal humidity, but a little below average; the third period from 1950 to 1969, with above average rainfall; the fourth period from 1970 to 1990, characterized by extreme drought; the fifth period from 1990 to 2000, characterized by a tendency to return to normal with wet years.

Figure 2 shows the trend in precipitation between 1960 and 2020, based on climate data from the study area.

The evolution of the curve indicates two main trends: a decrease in precipitation from the 1970s to the beginning of the 1990s, in line with the results obtained by Loth

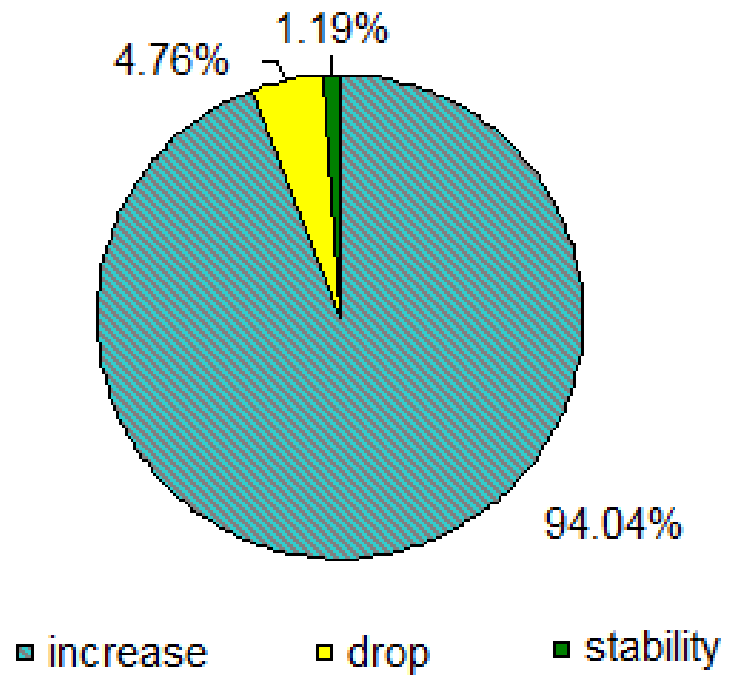

Figure 3. Perceptions of riparian populations of rainfall trends.

(2004); a gradual increase in precipitation from the 1990s to 2013, again in line with the results obtained by Loth (2004).

Abdou (2010) citing Salé (2011) states that this precipitation evolution in the Waza Logone Plain corroborates the results obtained in the other West African Sahelian Sudano regions. According to the same author, the trend in precipitation growth observed in this area since the 1990s is due to a sudden alternation between dry years and wet years. Sighomnou (2002) analyzed the data from 1960 to 2000 in the area and showed that rainfall is steadily declining, and is estimated at around 25%, despite the appearance of the trend of growth indicated by the curve. However, as in all other dry African regions, the main effect is the decrease and the great variability of rainfall, and also the strong evaporation of the waters following the rise in temperatures which drastically reduced the height and duration of floods (Sighomnou, 2002). The same author indicates that it has been shown that in this plain, precipitation fell by about 25%, and floods by about 60% between 1960 and 2000 following the decrease of precipitation in the upper part of the basin.

Overall, the decrease in rainfall and floods, and the increase in temperatures in the area have resulted in the drying of the surface waters of the ponds and rivers.

Perceptions of riparian populations of rainfall trends

The riparian populations mainly perceive the decrease in rainfall which corroborates the precipitation trends in the Waza Logone Plain obtained from the scientific data (Figure 3). Similar studies conducted in Senegal have produced consistent results (Mertz et al., 2009a), where the majority of people (94.04%) perceive a drop in the amount of rain in the last 30 and 40 years, but contrary to the work of Ouoba (2013) conducted in northern Burkina Faso, with contrasting results, with 40% of local populations reporting increased rainfall. The author explains that this contrast can be explained by the fact that on the one hand, the vision of those who mention the decrease of rainfall, can be influenced by the decrease in the number of rainy days especially in August. On the other hand, the vision of those who mention an increase in the quantity of rainfall is in agreement with the analysis of the evolution of the rainfall of the last 30 and 40 years.

Scientific vision of the evolution of temperatures

In the Waza Logone Plain, it is shown from the study carried out by Sighomnou (2002) that temperatures are gradually rising and the high water evaporation estimated by Delclaux (2008) citing Salé (2011) at about 12 km³ (for about 13 km³ of rainfall), would be the cause of the rapid decline in floods (Figure 4).

The trend of this temperature curve, obtained from the zone data, indicates that the temperatures are gradually increasing. These results are consistent with the previous results obtained by Sighomnou (2002) in the area, and the IPCC (2001) shows that this upward trend of

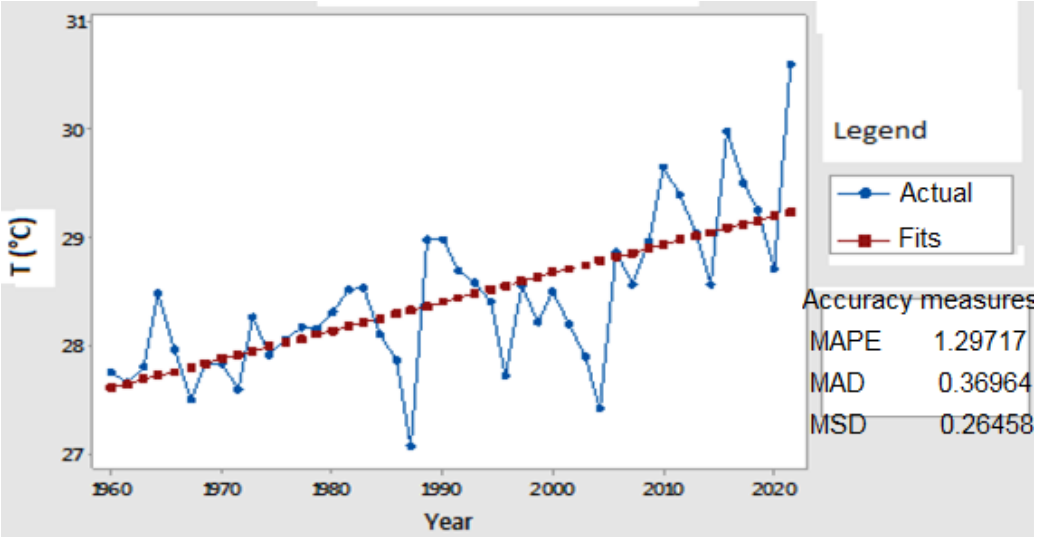

Figure 4. Trend of the evolution of the temperature.

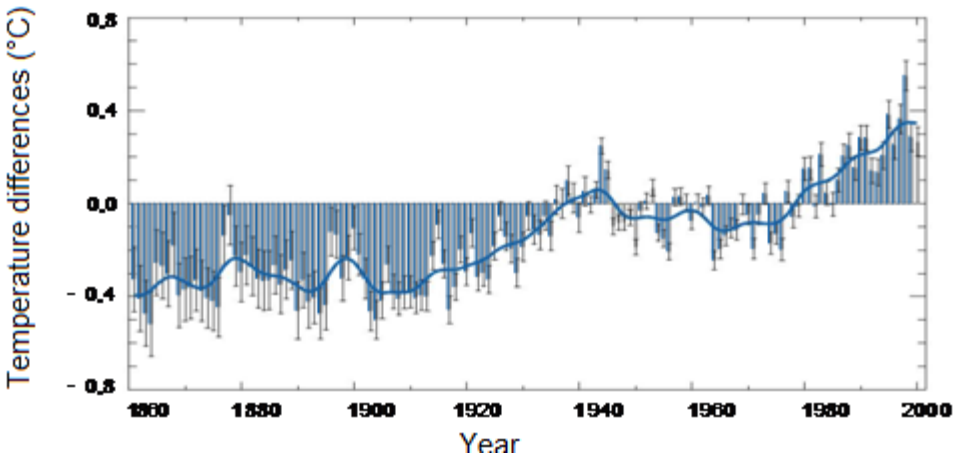

Figure 5. Variation in temperatures at the earth's surface from 1960 to 2000.
Source: IPCC (2001).

temperatures was observed on the whole planet between 1960 and 2000 (Figure 5).

Perceptions of local populations on the evolution of the temperatures

The increase in temperatures in the area is the perception of the majority of local populations (90.47%) (Figure 6), which corroborates the evolution of the temperatures obtained from the scientific data.

The perceptions on the evolution of the temperature reveal that the populations attribute these causes mainly to natural phenomena and to divine wrath. It appears very weakly an implication of the anthropic action. A similar study conducted by Tschakert (2007b) in Senegal showed that populations also mention the mismanagement of the environment and natural phenomena as factors of climate change. In sum, the reasons for the evolution of climatic parameters are generally perceived by the interviewees of the six sample villages as natural causes and divine punishment. A study carried out in the same climatic zone of Burkina Faso leads to the same conclusion (Kabré, 2008).

Scientific vision of the impacts of climate variability on wildlife

Figure 7 shows the evolution of the main herbivorous of

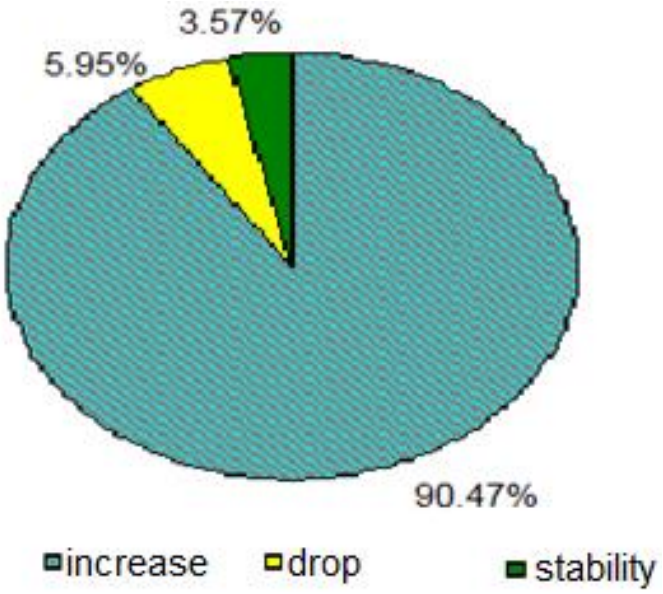

Figure 6. Perceptions of local populations on the evolution of the temperatures.

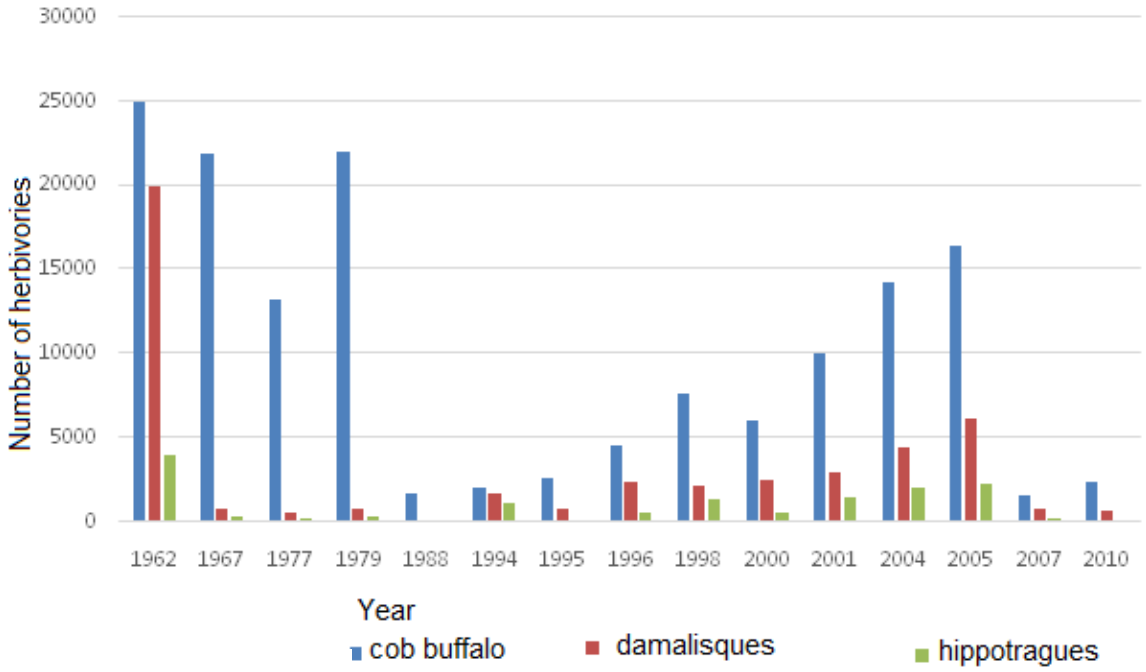

Figure 7. Evolution of three main herbivorous of Waza National Park.

the park. This evolution shows three brutal falls in 1967, 1988 and 2007. The fall in cob buffalo populations is greater than that of the other species because of their vulnerability linked to the high daily watering frequency (3 to 4 times/day) (Saleh, 2012). During the training period, only 4 out of 17 artificial pools still contained water. All natural pools have dried up. Saleh (2012) stated that in 1988, the sharp drop in numbers was caused by the drought where 400 carcasses of Cobs were counted on the edge of dry pools. At this same time, only 1000 Cobs were identified (Vanpraet, 1977). Concerning the other herbivorous that are the Hyppotragues and the

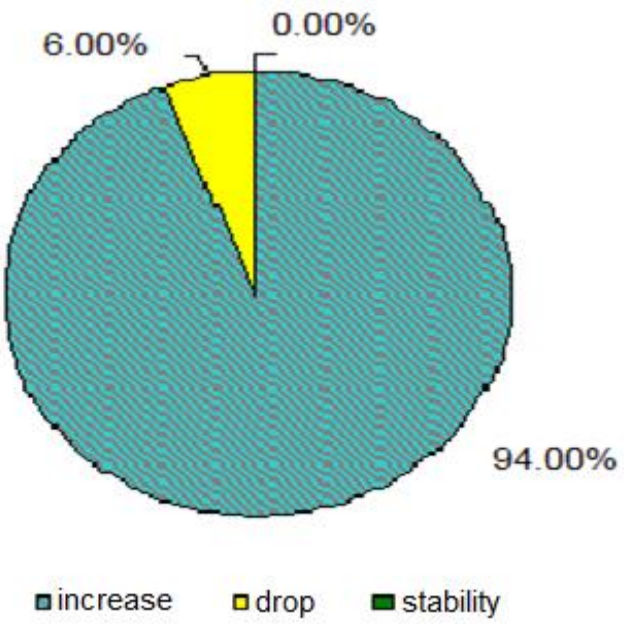

Figure 8. Perception of local populations of the impacts of climate variability on fauna.

Damalisques, the fall in their numbers between the years 1960 and 1970 can be explained according to Scholte (2007) by the first major drought after a decade of heavy rains during which these antelopes left the protected area and became vulnerable through persecution and contact with domestic livestock. He added that contrary to what one thinks, the insufficiency of the flood of the Waza Logone Plain due to the dam of Maga is not the cause of their decline but can be a constraint to their reconstitution.

At the level of the large fauna of the park, the immediate impact of these climatic modifications is the disappearance of species such as the Cobe defassa (*Kobus ellipsiprymnus*), the Bubale (*Alcelaphus buselaphus*), the Buffalo (*Syncerus cafer*), the Panther (*Panthera pardus*), and the Cheetah (*Acinonyx jubatus*) (Saleh, 2012). Going in the same direction, Ndjidda (2012) pointed out that the Redunca (*Redunca redunca*), the Serval (*Leptailurus serval*) have not been seen in the park since 2009. The climatic variability, over time, has negatively impacted on the evolution of the fauna of this protected area. IPCC (2014) stated that increasing magnitude of warming increase the likelihood of severe, pervasive and irreversible impacts on biodiversity, and some risks of climate change are considerable at 1 or 2°C above preindustrial levels.

Perception of local populations of the impacts of climate variability on wildlife

The decline of the fauna in the protected area is the perception of the majority of riparian populations (94.00%) (Figure 8). It appears that wildlife species in the park have all undergone a regressive evolution, but that this trend is to different degrees depending on the vulnerability of each species. This is consistent with the evolution of some species of fauna found in the various counts; in this case the antelopes present an evolution of sawtooth curve (Saleh, 2012). Also, the local populations cite antelopes (Cob buffalo, Damalisques, Hyppotragues) as the species that have undergone great decay. Beside the antelopes, felines like lion and hyena have also seen their number dropped because of the decrease of their main prey indicates the populations. Overall, people have a good perception of the decline of wildlife.

Scientific vision and perceptions of local populations of the impacts of climate variability on the vegetation of Waza National Park

Landsat images from 1986 and 2016 were used to determine four classes of land cover (Figures 9 and 10). The vegetation cover consists mainly of steppes (steppe on flooded soil and steppe on clay soil), soil more or less vegetated and sand or bare soil. The differentiation between the various thematic classes (soil occupation units) is generally significant for the 1986 and 2016 images. The values of the Kappa coefficient are globally high for the images of the two scenes.

State of occupation of soil in 1986

Supervised classification was performed by QGIS 2.17 and ENVI 4.5 software. The result is shown in Table 1.

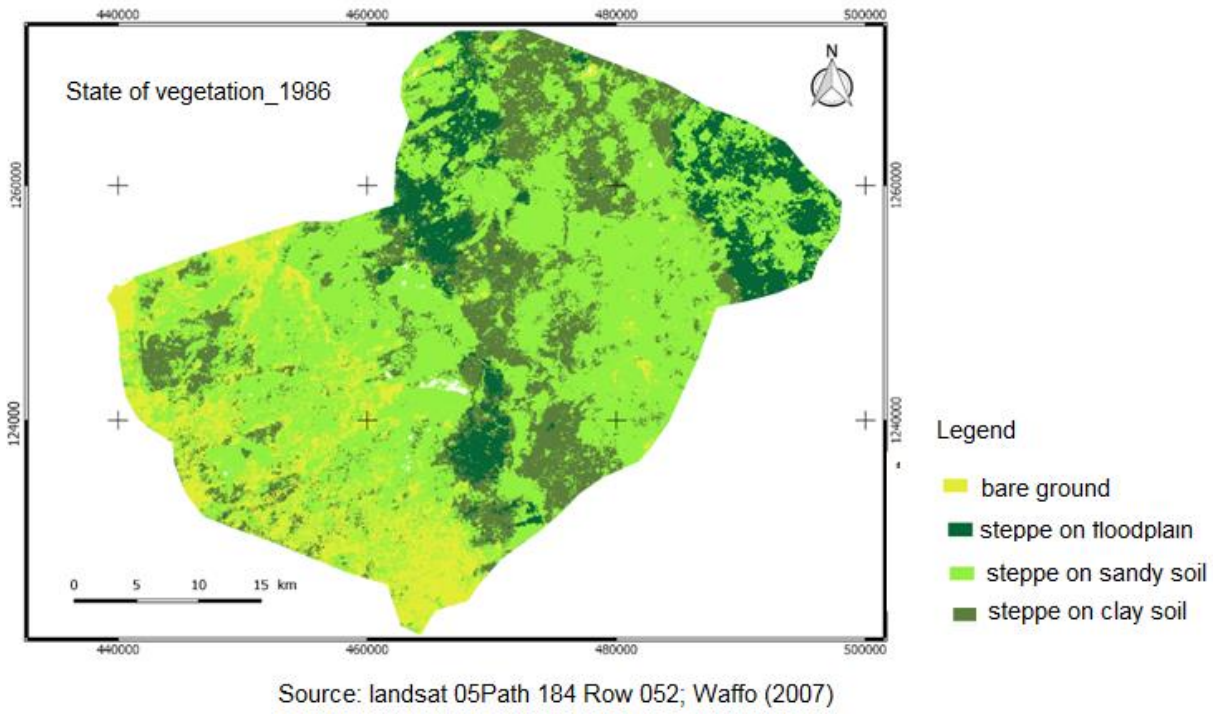

Figure 9. Map of occupation of soil of Waza National Park in 1986.

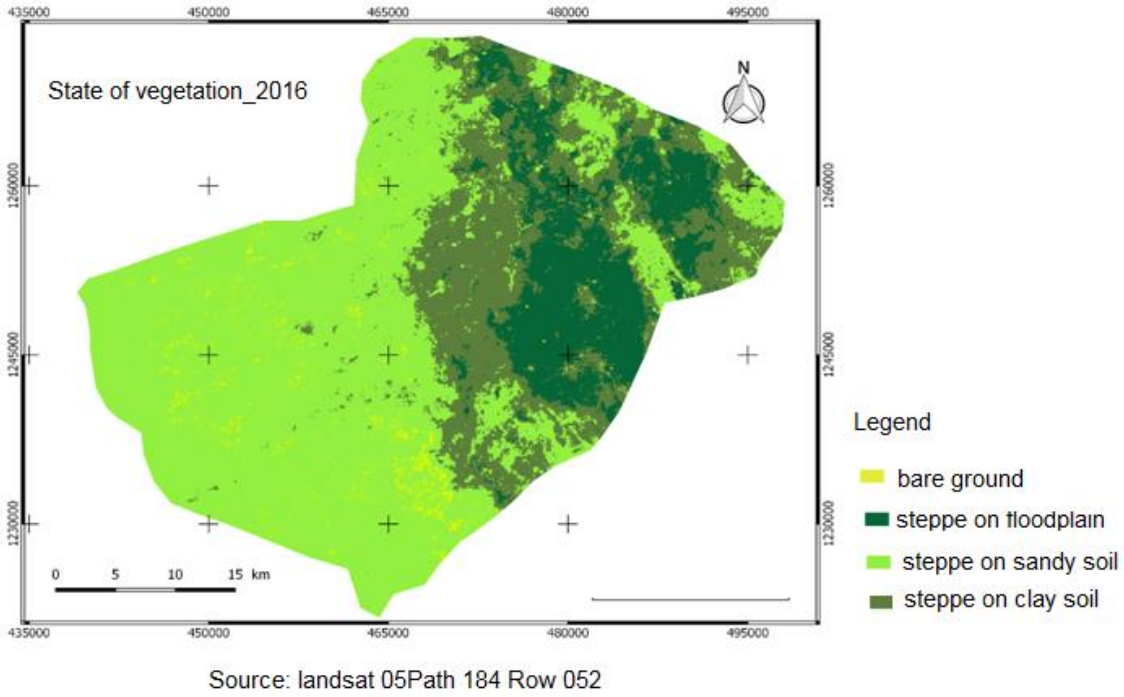

Figure 10. Evolution of soil occupation between 1986 and 2016.

The confusion matrices indicate that there was no confusion between the different classes when classifying the 1986 image. All units of land occupancy were well classified. The pixels are well ranked with percentages

Table 1. Matrix of confusion from the supervised classification of 1986.

Class	Steppe on floodplain	Steppe on clay soil	Steppe on sandy soil	Steppe on bare soil	Badly ranked
Steppe on floodplain	131	3	0	18	0
Steppe on clay soil	1	114	99	92	40
Steppe on sandy soil	0	0	0	0	72
Steppe on bare soil	0	0	2	0	0
Total	132	117	101	110	112

Table 2. Areas of land occupation classes in 1986.

Land cover class	Corresponding area (ha)	Percentage by total park area (%)
Steppe on floodplain	19 170	11.27
Steppe on clay soil	25 560	15.03
Steppe on sandy soil	37 800	22.23
Steppe on bare soil	11 970	7.04
Total	94 500	55.57

Table 3. Confusion matrix from the supervised classification of 2016.

Class	Steppe on floodplain	Steppe on clay soil	Steppe bare soil	steppe on sandy soil	Badly ranked
Steppe on floodplain	213	0	0	0	0
Steppe on clay soil	0	145	139	0	0
Steppe bare soil	0	0	0	147	0
Steppe on sandy soil	0	0	0	0	140
Badly ranked	0	1	0	0	2
Total	213	145	139	147	140

between 92.52 and 100%. However, some errors of commission and omission occurred during the classification. The errors are mainly made in steppe classes on clay soil and bare soil with values of 21.36 and 12.28% respectively.

Area of different classes in 1986

The supervised vegetation classification in 1986 identified four (04) occupancy classes with corresponding areas (Table 2).

The park is covered by very sparse vegetation. The steppe on sandy soil is the most dominant with an area of 37 800 ha and represents 22.23% of the total area of the park. Subsequently, the steppe on clay soil with an area of 25 560 ha for 15.03% of the area; the steppe on flood plain with 19 170 ha for 11.27%; bare soil with little vegetation covers an area of 11 970 ha, for 7.04% (Figure 9).

Overall, the 2016 image confusion matrices indicate that there was no significant confusion between classes during classification. Steppe classes on floodplain, steppe on clay soil and steppe on sandy soil have more than 80% of the well-ranked pixels. Errors of commission and omission occurred during classification. Commission and omission errors are respectively 11.66 and 10% for the bare soil class (Table 3).

In 2016, the steppe class on clay soil is the most dominant vegetation with an area of 29 610 hectares, for 17.41% of the total area of the park. There was a regression of vegetation between the two dates since the class of bare soil with little vegetation comes second with an area of 13 230 hectares, for 7.78% of the park. The steppe on floodplain was 11 880 hectares, for 6.98% and finally the steppe on sandy soil with an area of 10 260 hectares, for 6.03% (Table 4).

The diachronic analysis of land use changes in 1986 and 2016 in Waza National Park reveals that all units experienced increasing or decreasing changes between 1986 and 2016. However, the analysis shows a general trend towards degradation of vegetation between 1986

Table 4. Areas of land occupation classes in 2016.

Classes of land cover	Corresponding area (ha)	Percentage by total park area
Steppe on floodplain	11 880	6.98
Steppe on clay soil	29 610	17.41
Steppe on sandy soil	10 260	6.03
Steppe on bare soil	13 230	7.78
Total	64 980	38.21

Table 5. Evolution of vegetation between 1986 and 2016.

Elements of soil occupation of the park	1986		2016		Evolution 1986-2016	
	Area (ha)	%	area (ha)	%	Area (ha)	%
Steppe on floodplain	19 170	11.27	11 880	6.98	-7 290	-4.29
Steppe on clay soil	25 560	15.03	29 610	17.41	4 050	2.38
Steppe on sandy soil	37 800	22.23	10 260	6.03	-27 540	-16.20
Steppe on bare soil	11 970	7.04	13 230	7.78	1 260	0.74
Total	94 500	55.58	64 900	38.17	-29 600	-17.41

and 2016 (Figure 10).

There are cases of progression and regression of plant formations between 1986 and 2016 (Table 5). The increases observed concern steppe classes on clay soil with a rate of 2.38% and bare soil with little vegetation with growth rates of 0.74%. The increase of the steppe on clay soil, which refers to the Acacia zone of the park, is explained by the adaptation of these species to the arid climatic conditions of the study area and is favored by zoochoria. While the increase of bare soil with little vegetation results from the decline of the original vegetation due to the climatic conditions more and more execrable. The degradation of this plant cover leads to the appearance of bare soils which are thus exposed to bad weather. Adverse effects include multiple consequences such as the formation of shallow crusts, increased runoff and lack of infiltration, leading to a gradual decline in groundwater levels (Ouoba, 2013). Regressions affected steppe classes on floodplain and steppe on sandy soils with regression rates of -4.29 and -16.20%. These results are contrary to those of the work of Tabopda (2008) carried out between 1986 and 2001 in the area which used the scenes of April; then those of December were used, and which showed rather the regression of the classes of steppe on clay soil and bare soil with little vegetation and steppe class progression on floodplain and steppe on sandy soil.

Scientific vision of the impacts of climate variability on vegetation

Predictions from climatologists for the next century indicate global warming, a change in precipitation patterns and climate variability. These adverse effects of climate change and variability can be a major threat to living organisms, directly affecting species or altering their habitats (Chidumayo, 2008; Donfack, 2011). It was noticed by Scholte (2005) an invasion of the park by annual grasses, not palatable by wild animals and decaying rapidly after the end of the flood, at the expense of perennial grasses. The regression of park vegetation is compared by Sighomnou (2002) to increased desertification of this protected area. A similar study in the Sena Oura National Park in Canton Dari in Chad showed that successive droughts have caused the drying up of water sources and drainage of lowland and the destruction of the habitat of fauna species (Bora and Somba, 2014).

Perceptions of local populations on the impacts of climate variability on vegetation

Figure 11 gives the distribution of the different perceptions of the riparian populations on the evolution of the vegetation of the park. The decline of vegetation is the perception of the majority of riparian populations. However, the results of the survey reveal a perception of the improvement of vegetation cover at a proportion of 30.95%. The vast majority of responses in favor of vegetation improvement come from village populations on the plain side. In fact, in the face of the receding floods from year to year, a few feet of woody species are growing in the grassy carpet of the plain. This situation makes these populations believe in an increase in vegetation. But the spatial analysis shows the opposite with a regression of 7 290 ha.

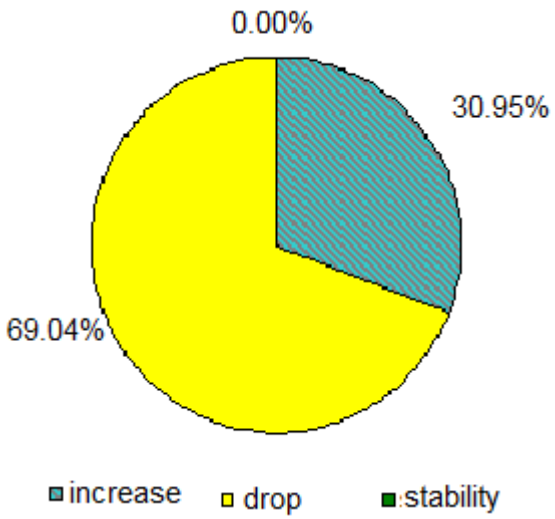

Figure 11. Perceptions of local populations on the evolution of vegetation.

Overall, the perceptions of local populations show that they have a good perception of the evolution of vegetation cover. This is consistent with the results of the diachronic analysis of land use by satellite images. These results show that vegetation of Waza National Park decreased by 17.41% from 94 500 to 64 900 ha, or 29 600 ha for cover land use units. The riparian populations mention as major causes of the decline of the vegetation cover: the irregularity of the rains, the increase of the heat and the receding of the floods with 96.42, 79.76 and 66.66%, respectively. The other cause cited by riparian populations is bush fires (25%). Added to this is the strong wind which, according to 22.61% of the populations in the six sampled villages, uproots the trees. The majority of the interviewees in the six villages said that there was a trend of decreasing vegetation cover due mainly to irregular rainfall, increased heat and reduced flooding. This same observation is noted in the works of Wezel et al. (2006) as cited by Ouoba (2013).

The decline in vegetation cover highlighted by the interpretation of satellite images is confirmed by the local populations living in this area. Populations have even pointed out that climatic variability has favored the simple disappearance of certain woody species such as *Diospyros mespiliformis, Acacia polyacantha, Borassus aethiopum* and *Ficus rubiginosa*. The analysis of the evolution of land use in the park between 1986 and 2016 shows a general tendency towards degradation. The main causes of degradation include: irregular rainfall, increased heat, receding floods, bush fires and strong winds. The assessment of the perception of local populations on the evolution of biodiversity shows they have a good perception of the evolution of different components of the biophysical environment, especially the vegetation cover. This is in agreement with the results of the analysis of the ground occupation by the satellite images.

Conclusion

Climate change and variability is one of the major ecological challenges of the 21st century in the Waza Logone Plain of the Far North Region in Cameroon. The physical environment in this area has almost completely deteriorated as a result of declining rainfall and rising temperatures. The overall objective of the study was to show the dynamics of biodiversity in relation to the climatic variability of the Waza National Park located in the heart of the Waza Logone plain. The approach taken to conduct the study combines the use of survey and field observation data, modeling of climate data through MINITAB 17 software, analysis of wildlife census data, and digital analysis of satellite images using ENVI 4.5 and QGIS 2.17 software.

The results showed a regressive trend of precipitation between 1970 and 1990, then a gradual trend from 1990 to 2004. The vast majority, that's 79% of the populations perceive a negative evolution of the various climatic parameters, which is consistent in the majority of case with meteorological data analyzes. The temperatures are gradually increasing according to the scientific vision and the perceptions of the populations. The general trend of biodiversity evolution (fauna and vegetation) over the last forty years is to the continued degradation of Waza National Park. Landsat images from 1986 and 2016 were used to determine four classes of land cover. The vegetation cover consists mainly of steppes (steppe on flooded soil and steppe on clay soil), soil more or less vegetated and sand or bare soil. The differentiation

between the various thematic classes (soil occupancy units) is generally significant for the 1986 and 2016 images ($P<0.05$). The values of the Kappa coefficient are globally high for the images of the two scenes.

Recommendations were made for the restoration of the park's biodiversity, including the construction of water ponds and Cartesian wells, the improvement of the load capacity of the park in fodder, the enrichment of the park with woody species.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Ethnobotanical study of indigenous knowledge on medicinal plant uses and threatening factors around the Malga District, Southern Ethiopia

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The study conducted in Malga district in 2019 aimed at documenting indigenous medicinal plants use among the Kebeles community, and the factors threatening local knowledge on medicinal plants before suggesting ways to overcome such threats. A total of 100 informants were selected and snowball sampling techniques were used. Ethnobotanical data were collected using semi-structured interviews, field observations, guided field walk, and group discussion with traditional medicine practitioners. The ethnobotanical study reveals that 60 medicinal plant species are inventoried and are distributed across 55 genera and 37 families while they are used as a cure for 40 ailments. Of these, 36 medicinal plants were reported for human ailments treatment, 7 for livestock, and 17 for both human and livestock ailment treatment. Leave were reported as most frequently utilized plant part with 45.78%. Intestinal parasite ailments were reported as one of the common problems along with oral administration. Informant consensus analysis showed that ailments like rabies, poisoning, and snakebite scored the highest value (0.98), while and pneumonia and jaundice scored the lowest values (0.63). Agricultural expansion, firewood, deforestation, and cash crop expansions were reported as driving factors for the loss of medicinal plants. Here the Wereda administration, as well as concerned governmental and non-governmental bodies should interven to minimize the loss of medicinal plant and associated knowledge.

Key words: Malga Wereda, medicinal plant, Indigenous knowledge, Informant, consensus.

INTRODUCTION

Ethiopian has used traditional and veterinary medicine to treat diseases for generations (Anteneh et al., 2012) and majority of the population relies on traditional medicine as their primary form of health care (Elizabeth et al., 2014). Owing to its long period of practice and existence, traditional medicine has become an integral part of the culture of Ethiopian people (Mirgissa, 1998). In Ethiopia, approximately 80% of humans and 90% of the livestock population rely on traditional medicinal plants to cure different ailments (Dawit, 2001) as a result of difficulties

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in accessing modern health facilities, the cultural acceptability of healers and low cost of traditional medicine invited local communities to dwell traditional healers (Nguta et al., 2010).

Besides the importance, Ethiopia's traditional medicine and indigenous knowledge as elsewhere in Africa is faced with the problems of continuity and sustainability (Ensermu et al., 1992; Elizabeth et al., 2014). Nowadays herbal practitioners have to walk greater distances for collection of herbal medicine that once grew in the vicinity of their homes. Bizuneh et al. (2018) in their ethnobotanical study reported that, valuable indigenous knowledge associated with medicinal plants was under risk and need to be properly documented. Those studies so far conducted on medicinal plants in Ethiopia also reported that, the existing medicinal plants were on conservation risk (Belachew and Behailu, 2018; Muluken et al., 2018). Bizuneh et al. (2018) also stated that the problem is further compounded by the fact that traditional knowledge on traditional medicine is also being lost at an alarming rate.

Additionally, According to Gonfa et al. (2015), Solomon et al. (2016), Banchiamlak and Young (2019) reports those medicinal plants available in the study region (Sidama Zone) are becoming extinct through human induced factors or in the verge of disappearance and the associated knowledge held by elders has received less attention in the past. Furthermore, the rich ethnomedicinal knowledge held by the Sidama community at large and traditional medicine practitioners in particular needs an in-depth study and documentation (Nigatu et al., 2018) and medicinal plants are exposed to various destructive anthropogenic activities. Thus, this study aimed at inventorying the medicinal plants used and documenting the associated indigenous knowledge while raising awareness about the drivers threatening both knowledge and the sustainability of the resource around the Malga district of Southern Ethiopia before suggesting ways to overcome such threats.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Malga district Southern Ethiopia. The district is bordered by Wondo Genet Wereda in the north, by Goriche and Shebedino Wereda in the South, to the west by Tula Administration and the east by Kokosa Wereda in Oromia Regional State. The Wereda geographically extends from 7° 0' N to 7° 00' 0.00" N Latitude and 38° 29' 59.99" to 38° 49' 99" E Longitude (Figure 1). The Malga district is divided into 23 Kebele Administrations (the smallest administrative unit in Ethiopia) and has three rural towns. The capital town of Malga district is Manicho which is located 26 km from the regional state capital, Hawassa town. Based on the data from the Wereda/district, the total land area is 32,651 hectares (ha) of which an estimated 18,177 ha are under cultivated land, 6,988 ha are used for cereal and *Enset venticosum* production and the rest are covered by forest, water, and grazing land. Cereal crops are grown in the highland part consisting of wheat, barley and beans, vegetables are also grown seasonally and continuously through irrigation at some distance of the rivers. Out of agricultural crops, scattered tree species were also observed in their homegardens including: *Croton macrostachyus Del., Juniperus Procera* Hochst. ex.Engl., *Erythrina brucei* Schweinf. emend. Gillett*, Eucalyptus species, Arundinaria alpina* K. Schum*., Cupressus lusitanica* Mill*., Ficus species* and *Euphorbia species.* During field observation and discussion session's local elders raised that previously, traditional homes of Sidama were constructed using timber from Juniperus species, but now days these tree species are becoming increasingly scarce and it is now common to use timber from eucalyptus as well. The rainfall and the temperature condition of the area were described based on the data collected from 1998-2009 by the National Meteorological Service Agency (NMSA) from Hawassa Station. The result of the analysis of data from NMSA showed that the range of mean monthly minimum and maximum temperature of the study area is 12.6 and 20°C and average annual rainfall will vary from 1,201-1,600 mm. The elevation of the area ranges from between 1,501–3,000 m above sea level. The agro-ecology of the Wereda has a 78% humid and 22% sub-humid tropical climate. Wereda had an estimated population of 127,844 in 2010, based on the 2007 census projections (Central Statistical Agency, 2007): having 50.6% male and 49.4% female.

Sample size and sampling techniques

The study was conducted in six Kebeles in the Malga Wereda/district from July to August of 2019. Kebeles were purposively selected based on reconnaissance surveys and recommendations from local society (knowledgeable elders, religious leaders, and development agents). The selected Kebeles were 'Mellow,' 'Haro,''Haru merisa,''Elula chirariso,''Weteraresu, and 'Sintaro' (Figure 1). A total of 100 informants were selected. Based on Martin (1995) from a total 100 informant, 24 key informants were purposively selected based on recommendations from local authorities (Kebele administrator, knowledgeable elders, religious leaders, development agent and local guides). Appointments were made before visiting the key informants and the informants except for the key informants were selected through the Snowball method (Bailey, 1994) which consists in the search for new interviewees by the indication of people already interviewed. They were asked to give their knowledge about the plants they use against a disease, plant parts harvested methods, preparation of the remedy, details of administrations and the dosage (Banchiamlak and Young, 2019). The ages of the informants were between 18 to 93 years.

Ethnobotanical data collection

Following techniques described in Martin (1995) and Cotton (1996), ethnobotanical data were collected from July to August 2019. The techniques employed for data collection were group discussions; field observations, guided field walks and observation, and a semi-structured questionnaire pre-prepared in the Sidama language and finally translated into English (Appendix 1). Besides, four focus group discussions each of which consists of 6 members of traditional healers, religious leaders and knowledgeable elders were carried out. During this discussion session, questionnaires that were employed for informants were brought to discussion and validation of the information that was previously given by respondents. Floristic voucher specimens were collected with the help of traditional healers, knowledgeable elders, and development agents. The collected specimen was properly identified by comparing with already identified specimens in National Herbarium of Ethiopian using taxonomic literature such as Edwards et al. (1995,

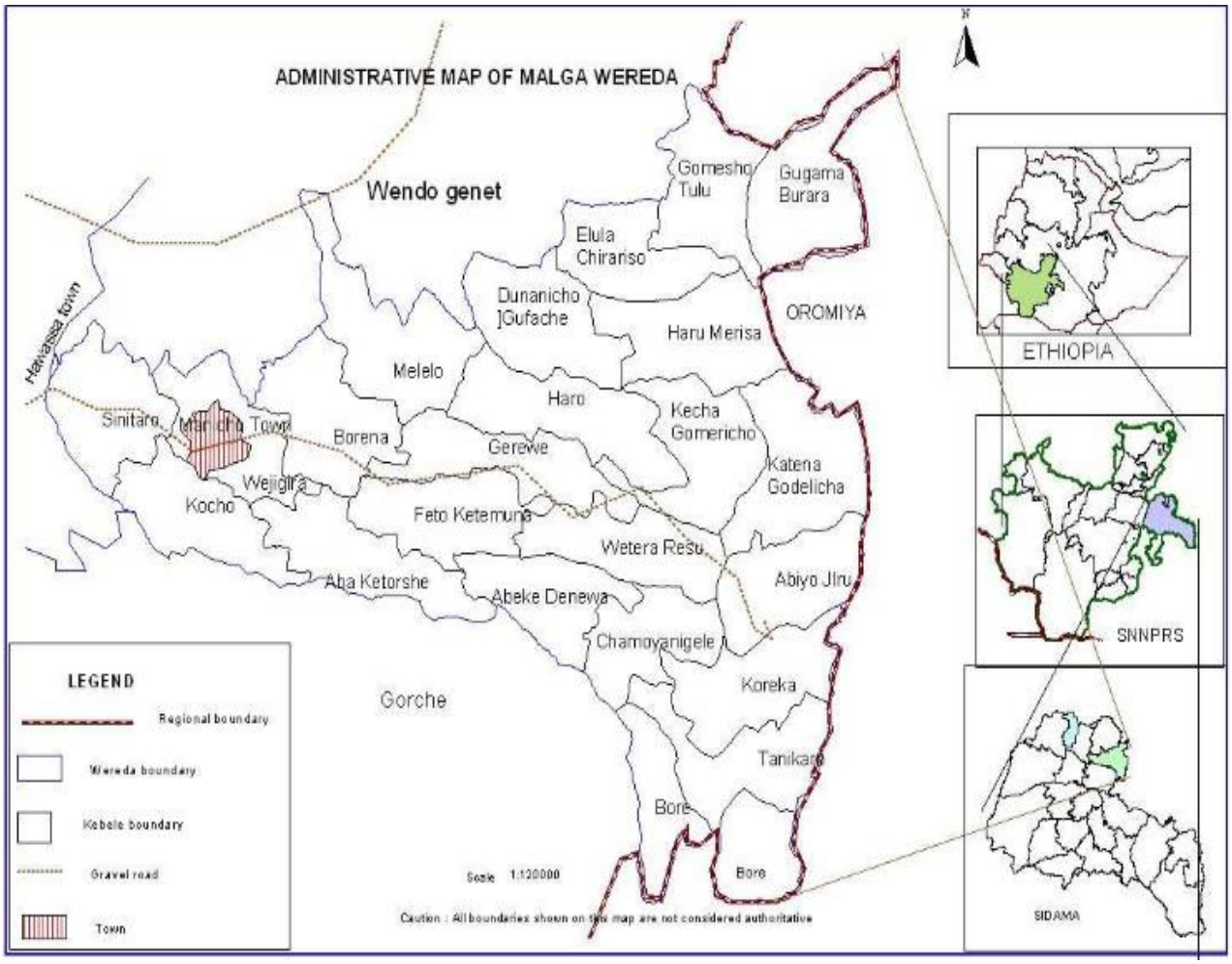

Figure 1. Map of Malaga District, Southern Ethiopia. Study areas were Kebeles: Melelo' Haro, Haru merisa, Elula chirariso, Weteraresu and Sintaro.

1997, 2000); Hedberg and Edwards (1989, 1995), and Hedberg et al. (2003, 2004, 2006).

Data analysis

In this section, both qualitative and quantitative approaches to data analysis were used. Qualitative methods used were based on percentages and frequency to summarize the data on medicinal plants (Martin, 1995; Cotton, 1996). The most useful qualitative information gathered on medicinal plants reported by local people included: medicinal value, application, methods of preparation, routes of administration, disease treated, and parts used, and the habit was analyzed through descriptive statistics. To make a simple calculation, to determine proportions and to draw bar graphs, MS Excel spread sheet was also utilized. Regarding quantitative data analysis, the Informant Consensus Factor (Fic) was used to measure the total usage of plant species according to culture applicability. Health disorders were categorized into eight groups like plants with high FIC versus low FIC value to compare its pharmacological active. The FIC values will be high if maximum respondents acknowledge one or a few plants to treat a specific disease. The FIC value can be calculated by the formula FIC = nur – nt/nur – 1; Where FIC = informants consensus factor, nur = number of use citation, nt = number used species (Canales et al., 2005).

Ethical considerations

Participants gave their informed consent (EPIC) before commencing with the interview schedules as required by the University of Hawassa University ethics committee. Approval for the study was obtained from the Hawassa University, approval number: VPRTT/027/2019.

RESULTS AND DISCUSSION

The results of the ethnobotanical survey contributed to the inventory and document of 60 plant species divided into 55 genera and 37 families (Table 1). The dominant family was Fabaceae with five species, followed by Cucurbitaceae, Euphorbiaceae, Rutaceae, and Solanaceae each with four species and Asteraceae with three species. Different scholars in their study also

Table 1. Medicinal plants reported for the treatment of different ailments in Malga District, Southern Ethiopia.

Scientific name	Family	Folk name	Ha	Parts used	Preparation	Application	Diseases treated	Uses
Acokanthera schimperi (A.DC.) Schweinf.	Apocynaceae	Qararo	Sh	Fresh leaves/stem barks or seed	Crushing and pounding	Oral or dermal	Gonorrhea, Amoeba and evil eye	Human
Achyranthes aspera L.	Amaranthaceae	Nole	H	Fresh leaves/ fresh root	Pounding	Oral	Intestinal parasites and lung infection	Livestock
Albizia gummifera Oliv.	Fabaceae	Galcaca	T	Bulbs	Crushing, pounding and boiling	Oral	Lung infection, Cough, Jaundice	Human and livestock
Aloe sp.	Aloaceae	Argissa	H	Fresh leaf	No need	Oral	Intestinal parasites	Human
Antiaris toxicaria Lesch.	Moraceae	Dimbicho	T	Dry/fresh stem bark	Pounded/powdered	Oral	Rabies	Livestock
Artemisia abyssinica Sch.Bip. ex A.Rich.	Asteraceae	Sunado hayiso	H	Fresh leaf	Crushing and pounding	Oral	Malaria	Human
Argemone mexicana L.	Papaveraceae	Wajo uta	H	Dry/fresh leaves	Crushing and pounding	Oral	Diabetes	Human
Calpurnia aurea (Ait.) Benth	Fabaceae	Cekata	Sh	Dry/fresh leaves	Pounding	Dermal	Head and skin infection	Human
Carica papaya L.	Caricaceae	Papaya	T	Fresh leaves or dry/ fresh seeds or fruits	Cocking or pounding	Oral	Intestinal parasites, Malaria, Gastric illness	Human
Catha edulis (Vahl.) Forssk.ex Endl.	Celastraceae	Cate	Sh	Dry/fresh roots	Crushing	Oral	Amoeba	Human
Citrus limon (L.) Burm.F.	Rutaceae	Lomee	Sh	Fresh fruits	No need	Oral	Blood pressure	Human
Citrus sinensis (L.) Osbeck	Rutaceae	Burtukane	Sh	Fresh fruits	No need	Oral	Gastric illness, common cold	Human
Coffea arabica L.	Rubiaceae	Bunna	Sh	Fresh stem bark	Crushing ,pounding and boiling	Oral	Malaria, gastric illness, sudden sickness	Human and livestock
Commelina benghalensis L.	Commelinaceae	Lalunxe	H	Leaf/stemLatex	Extraction	Dermal	Skin infection	Human
Cordia africana Lam.	Boraginaceae	Wadicho	T	Freshstem bark	Chewing	Oral	sudden sickness	Human
Cucurbita pepo L.	Cucurbitaceae	Baqula	Cl	Dry seeds	Cocking	Oral	Tape worm	Human
Cucumis prophetarum L.	Cucurbitaceae	Basu baqula	Cl	Dry seed/whole	Pounding/chewing/ burning	Oral/nasal	Intestinal parasites, lung, infection, gonorrhea, glandular swelling	Human and livestock
Clematis hirsuta Guill. & Perr.	Rununculaceae	Fide	H	Dry fruits/seed/ whole	Pounding/powdering	Oral	Breast cancer , Tonsillitis	Human and livestock
Croton macrostachyus Del.	Euphorbiaceae	Masinna	T	Leaves/stem bark	Pounding/chewing/ rubbing	Oral /dermal	Wound cancer, tetanus, acute blooding, lung infection, gonorrhea, intestinal parasites	Human and livestock
Datura stramonium L.	Solanaceae	Banje	H	Fresh leaves	Pounding	Dermal	Head infection	Human
Delonix regia (Hook.) Raf.	Fabaceae	Mimi	T	Dry/fresh leaves	Crushing, pounding and boiling	Oral or dermal	Diabetes, acute bleeding, wound	Human
Dodonaea viscosa subsp. *angustifolia* (L.f.) J.G.West	Sapindaceae	Itancha	T	Fresh leaves	Crushed and pounded	Oral/dermal	Ecto-parasites	Livestock
Dovyalis caffra (Hook.f. & Harv.) Sim	Flacourtiaceae	Faranjete shisho	Sh	Fresh roots	Chewing	Dermal	Snake bite	Human
Ekebergia capensis Sparrm.	Melianthaceae	Godicho	T	Dry/fresh leaves/stem bark	Crushing and pounding	Oral	Intestinal parasites and Cough	Human and livestock
Ehretia cymosa Thonn.	Boraginaceae	Gidicho	T	Fresh stem bark	Crushing and pounding	Oral	Intestinal parasites	Livestock

Table 1. Contd.

Eucalyptus citriodora Hook.	Myrtaceae	Shitote barzafe	T	Fresh leaves	Rubbing	Nasal	headache	Human
Euphorbia ampliphylla Pox.	Euphorbiaceae	Care	Sh	Fresh tem latex	No need	Oral	Intestinal parasites	Human
Euphorbia tirucalli L.	Euphorbiaceae	Shuramo care	Sh	Freshstem latex	No need	Dermal	Skin cancer	Human
Ficus sur Forssk.	Moraceae	Odako	T	Dry fruits or fresh stem bark	Crushing, pounding and powdering	Oral and dermal	Malaria, Wound, Acute bleeding and Vomiting	Human
Hypoestes forskaolii (Vahl)R.Br	Acanthaceae	Xexxe	H	Fresh root	Pounding	Oral	Intestinal parasites	Livestock
Juniperus procera Hochst. ex.Engl.	Cuppressaceae	Honcho	T	Fresh leaf	Crushing and pounding	Oral	Pneumonia/Lung infection	Human and livestock
Kalanchoe petitiana A. Rich	Crassulaceae	Hancululee	H	Fresh leaves	Heating	Dermal	Leg swelling, skin infection	Human
Lactuca inermis Forssk.	Asteraceae	Amessa	H	Fresh leaf/whole plant	Crushing and pounding	Oral	Anemia	Human
Lagenaria siceraria (Molina) Standl.	Cucurbitaceae	Surupha	Cl	Fresh seeds or dry seeds	Pounding	Oral	Jaundice, Intestinal parasites	Human
Measa lanceolata Forssk.	Myrsinaceae	Gowacho	Sh	Dry seed	Chewing/sniffed	Oral/nasal	Nasal problem, asthma and Skin infection	Human and livestock
Melia azedarach Forssk.	Meliaceae	Kiniin	Sh	Fresh/dry leaves	Pounding or chewing	Oral or dermal	Malaria, Intestinal parasites, Wound and Tetanus	Human
Millettia ferruginea (Hochst.) Bak.	Fabaceae	Hengedicho	T	Fresh stem bark	Crushing and pounding	Oral/dermal	Ecto-parasites	Human and Livestock
Momordica foetida Schumach.	Cucurbitaceae	Herase	Cl	Whole part	Crushing and pounding	Oral	Glandular swelling	Human
Moringa stenopetala L.	Moringaceae	Shiferaw	Sh	Fresh leaves	Cocking	Oral	Diabetes	Human
Nicotiana tabacum L.	Solanaceae	Arado	Sh	Dry seeds /fresh leaves	Crushing and pounding	Nasal /oral	Common cold, Headache	Human and livestock
Nuxia congesta R.Br.ex Fresen.	Loganiaceae	Burcanna	T	Fresh leaves	Pounding	Oral	Intestinal parasites	Livestock
Olea europaea subsp. cuspidata (Wall. ex G.Don.) Cif	Oleaceae	Ejerssa	T	Dry/fresh branches/ Fresh leaves	Chewing or cocking	Oral	Teeth problem, Intestinal parasites	Human
Pittosporum abyssinicum Del	Pittosporaceae	Bobanticho	T	Fresh stembark	Sniffed	Nasal	Headache	Human
Phytolacca dodecandra L'Herit.	Phytolaccaceae	Haranjicho	Sh	Fresh/dry leaves	Pounding and powdering/rubbing	Oral/dermal	Intestinal parasites, Lung infection, Rabies Stop pregnancy	Human and livestock
Ricinus communis L.	Euphorbiaceae	Qomboho	T	Fresh/dry stem bark/ Dry/fresh root	Crushing, pounding/chewing	Oral and dermal	Pneumonia (Lung infection), Body swelling	Human and livestock
Rhamnus prinoides L'Herit.	Rhamnaceae	Xaddo	Sh	Fresh leaves	Rubbing	Dermal	Skin infection	Human
Ranunculus multifidus Forssk.	Rununculaceae	Umixagicho	H	Dry leaves	Pounding/powdering	Oral/nasal	Pneumonia/Lung infection Headache	Human and livestock
Rhus glutinosa A. Rich	Anacardiaceae	Oloncho	T	Dry/fresh stem bark	Boiling	Oral	Vitamin shortage	Human
Rubus apetalus Poir.	Rosaceae	Gora	Sh	Fresh leaves	Chewing	Dermal	Body swelling, Wound	Human
Ruta chalepensis L.	Rutaceae	Sunkurtaa	H	Fresh leaves	Pounding/rubbing	Oral/nasal	Vomiting, evil eye, pneumonia, Intestinal parasite	Human and livestock

Table 1. Contd.

Senna occidentalis (L.) Link	Fabaceae	Hamash haqa	Sh	Fresh/dry leaves	Pounding	Dermal	Poisoning	Human
Sesbania sesban (L.) Merr.	Fabaceae	Arbeti	Sh	Fresh leaves	Pounding	Dermal	Body swelling	Human
Solanum incanum L.	Solanaceae	Borbodho	Sh	Fresh/dry roots	Chewing	Oral/ dermal	Intestinal parasites, Nasal blooding and Snake bite	Human
Solanum nigrum L.	Solanaceae	Xunayee	H	Fresh root/leaf/fruit	Chewing and swallowing	Oral	Intestinal parasites	Human
Toddolia asiatica (L.) Lam.	Rutaceae	Harangama	Sh	Fresh leaf/root	Cocking and rubbing	Oral	Glandular swelling, body swelling	Human
Urtica dioica L.	Urticaceae	Lalesa	Cl	Fresh/dry roots	Crushing, pounding/chewing	Oral/dermal	Gonorrhea , Fever, Evil eye	Human and livestock
Vernonia amygdalina Del.	Asteraceae	Hecho	Sh	Fresh/dry leaves	Pounding/powdering or chewing or cocking	Oral	Intestinal parasites, Jaundice, Malaria	Human and livestock
Vernonia auriculifera Hiern	Asteraceae	Reejje	Sh	Dry/fresh leaves or fresh root	Crushing and pounding or chewing	Oral and dermal	Body swelling, Wound, Head infection	Human
Zingiber officinale Rosc.	Zingiberaceae	Jaanjiiweello	H	Dry/fresh rhizome	Crushing/pounding/ chewing	Oral	Common cold	Human and livestock

Ha, Habit; T, Tree, Sh, Shrub; H, Herb; Cl, Climber.

reported similar findings such as Balcha (2014), Mekonen et al. (2015), Banchiamlak and Young (2019). Of these 36 plant species, 60% were used as human medicines, seven plant species (11.67%) as livestock medicines and 17 plant species (28.33%) were used for treating both human and livestock diseases (Table 1). Regarding habit diversity, 18 plant species (30%) were trees, 22 (36.67%) shrubs, 15 (25%) herbs and 5 (8.33%) were climbers (Table 1). Alemayehu (2010), Kefyalew (2015) and Abiyot et al. (2018) reported that shrubs were the most harvested forms as source of medicines.

Socioeconomic characteristics of the interviewed respondents

As can be seen in Table 2, 100 informants participated in the ethnobotanical survey of the Malga district. Of these, 77% were men, 23% women, and 24 were key informants. The majority of respondents were more than 50 years old (37%). Eleven informants were between 20 and 30 years old, 19 informants were between 31 and 40 years old, 33 informants were between 41 and 50 years old and 37 informants were above 50 years old. Majority of the informants had attended different level school (53%) (Table 2).

Common ailments and plant species used in the study area

As shown in Table 1, traditional healers had amazing and surprising indigenous knowledge on diagnosis, treatment, and determination of ailments. The medicinal plant species recorded in the Malga are also used as remedies in other parts of Ethiopia. Among a total of 60 medicinal plants, 11 in Gonfa et al. (2015); 21 in Nigatu et al. (2018) and 26 species in Banchiamlak and Young (2019). Hence, this widespread report on the use of these medicinal plants by different groups of the societies in different localities could be attributed to different cultural groups, which could validate the medicinal properties of these species. People of Ethiopia over a wide area therefore may tend to use the same medicinal species as a result of the wider distribution of medicinal plants in the country and to a certain extent their usefulness (Gonfa et al., 2015).

The practitioners commonly diagnose each health problem by interviewing and visual inspection of the patient. The patients are commonly interviewed for symptoms observed and the duration of the diseases. Such as changes in eye color, tongue color, throats are all visually inspected by the practitioner. For diseases like fibril illness, evil eye, and Jaundice, the local people prefer traditional healers for treatment (Figure 2). Some of the medicinal plants in this study were also reported to cure specific diseases (Miruts, 2010; Banchiamlak and Young, 2019). *Vernonia amygdalina*, *Solanum incanum*,

Table 2. Distribution of respondents according to socio-economic characteristics.

Socio-economic characteristics	Number of respondents	Percentage
Gender		
Male	77	77
Female	23	23
Age (years)		
20-30	11	0.11
31-40	19	0.19
41-50	33	0.33
>50	37	0.37
Education		
Non formal education	47	0.47
Primary education	31	0.31
Secondary education	13	0.13
Post-secondary education	9	0.09

Croton macrostachyus, Carica papaya, Arundo donax, and *Momordica boivinii* were reported to cure intestinal parasites and associated illness. *Datura stramonium* and *Vernonia auriculifera* were also reported to cure head infection (Fungal disease) and *Allium sativum*, *Vernonia amygdalina*, *Zingiber officinale, Artemisia abyssinica,* and *Melia azedarach* were claimed as the treatment for malaria.

Similarly, the medicinal value of *Commelina benghalensis*, Croton macrostachyus, *Hypoestes forskaoli*i, Phytolacca dodecandra, Ruta chalepensis, and *V. amygdalina* as a treatment for intestinal parasite and skin infection was reported by (Gonfa et al., 2015; Nigatu et.al, 2018). In Nepal, Shandesh et al. (2009) in their ethnobotanical study reported that Achyranthes aspera and Urtica dioica are the most effective medicinal plants to cure intestinal parasite and fever-related ailments.

Importance of medicinal plants

Informant consensus factors

Based on the conditions of the disease and treatment resemblance, diseases in the study area have been grouped into different categories as described by Canales et al. (2005). As shown by Table 3, the medicinal plants that were presumed to be effective in treating a certain disease had higher ICF values, which indicated that these diseases were more common than those with low ICF. Based on the used citations of the key informants, plant species were clustered into eight different categories) to calculate the ICF values. The ICF values range between 0.63 (Pneumonia and jaundice) and 0.98 (Rabies, poisoning, and snake bite). Thus, all clusters had an ICF value greater than 0.5 showing that all of them could be considered for validation in support of its traditional use.

Nineteen plant species were reported to be used for the treatment of intestinal parasite alone and wound and body swelling together followed by a lung infection and liver problem (15 species); malaria, vomiting, and typhoid (11 species); common cold, asthma, nasal blooding, fibril illness (10 species); skin and head infections (10 species); rabies, poisoning, and snake bite (5 species); evil spirit and the evil eye (4 species). The ailments rabies, poisoning, and snake-bite scored the highest value (0.98) with 166 use-reports for 5 plant species. The species responsible for this high consensus were *Antiaris toxicaria, Dovyalis caffra, Senna occidentalis, Solanum incanum and Phytolacca dodecandra* with 166 of the 60 reported medicinal plants, followed by the evil spirit and evil eye were scored the second highest value (0.97) with 122 use-reports for 4 plant species. The species responsible for this high consensus was *Acokanthera schimperi, Olea europea* subsp*. Cuspidata, Ruta chalepensis and Urtica dioeca* with 122 of the 60 reported medicinal plants. Skin and head infections scored the third highest value (0.93) with 121 use reports for 10 plant species were as *Calpurnia aurea, Commelina benghalensis, Datura stramonium, Dodonaea angustifolia, Kalanchoe petitiana, Measa lanceolata, Mill ettia ferruginea, Rhamnus prinoides, Ranunculus multifid us* and *Vernonia auriculifera.* This indicates that informants use relatively few taxa to treat specific disease conditions and they tend to have consistency in the use of plant species.

Medicinal plants used to treat those ailments were more popular and effective to cure the ailments and the ailments are more common than the others in the area.

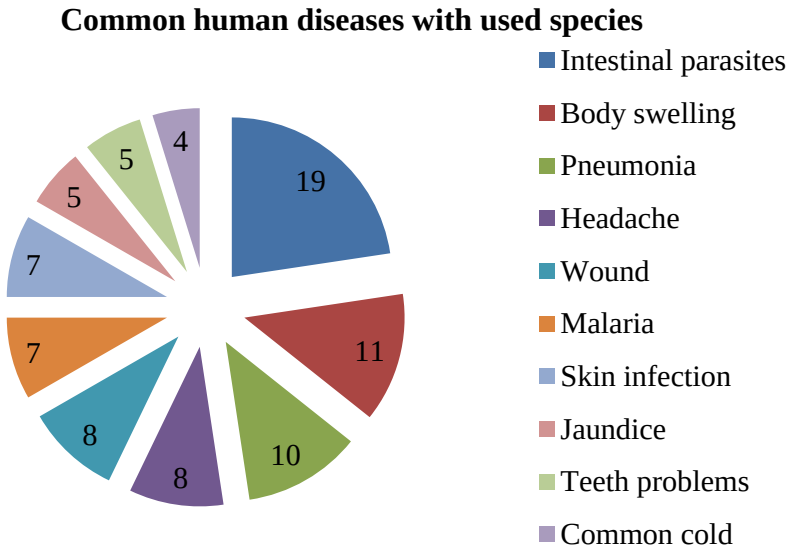

Figure 2. Common human ailments and medicinal plants used in Malga district

Table 3. Informant consensus factor by categories of diseases in the study area.

Category	Species	Use citations	ICF
Rabies, poisoning and snake bite	5	166	0.98
Evil spirit and evil eye	4	112	0.97
Skin and head infections	10	121	0.93
Common cold, asthma, nasal blooding and fibril illness	10	119	0.92
Malaria, vomiting and typhoid	11	82	0.88
Wound and body swelling	19	109	0.83
Intestinal parasite	19	72	0.75
Pneumonia (Lung Infection) and jaundice	15	39	0.63

Informants reported that they would not need modern medicine for those diseases treatment rather they used traditional medicinal plants. The low value of ICF indicates that the informants disagree on taxa to be used in the treatment within a category of illness. In this study, the lower ICF value scored for the category of diseases like Pneumonia (Lung Infection) and jaundice (Liver problem) scored the lowest value (0.63).

Parts of medicinal plants used

Leaves were reported as the most frequently utilized plant part with (45.78%) (Figure 3A). A large proportion of herbal preparation from leafs was also reported by Gonfa et al. (2015), Bizuneh et al. (2018), Abiyot et al. (2018), Nigatu et al. (2018); Banchiamlak and Yound (2019). Those from root sources were reported by Alemayehu (2010), Lulekal et al. (2014), Melesse et al. (2015). Similarly, leaf are claimed as the dominant plant parts used in the remedy preparations for livestock ailment treatment (Gonfa et al., 2015; Banchiamlak and Yound, 2019). Both leaf and stem bark accounts for 75% (Figure 3B) from the total remedy preparation followed by whole plant parts and root (12.5%) each respectively. Like human remedy preparation, the leaf is the most harvested form in remedy preparation for livestock ailment treatment. But, remedy preparations from stem bark, roots, and whole plants are risk to plant survival. So, in this work, the researcher suggested that, the local people must adopt alternative ways of conservations of medicinal plants in their home gardens to minimize losing of the floral diversity. In both human and livestock treatments, leaves are more harvested parts of the plants which covered 38.71% followed by bark (20.97%), seed (16.13%); root (14.52%); whole plant (4.84%); fruits (3.23%) and latex (1.61%) (Figure 3C). The preference of leaves to other plant parts may be due to the easy preparations compared to remedy preparations from other plant parts. Furthermore, leaves carry copious amounts of plant secondary metabolites that have medicinal properties as reported (Bhattarai et al., 2006).

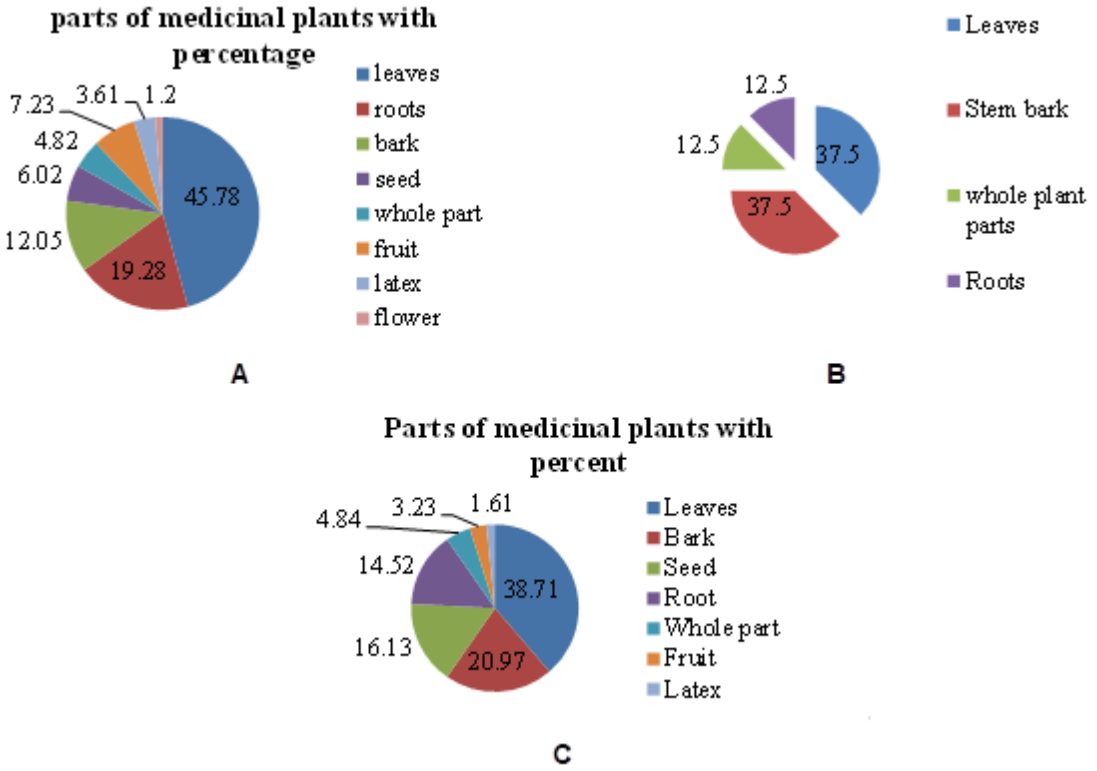

Figure 3. Medicinal plants of Malga district. **A.** Plant parts used only for human ailments treatment; **B.** Plant parts used only for livestock ailments treatment; **C.** Plant parts used for both human and livestock ailments treatments.

Methods of preparation

The principal methods of remedy preparation are chewing (24.69%), followed by pounding (19.75%), crushing and pounding (14.81%) and rubbing (12.35). Among those, crushing, pounding, and powdering are common ones. Crushing and pounding cover 50%, pounding 37.5%, and powdering (12.5%). This result is in agreement with the earlier founding (Emiru et al., 2011; Gonfa et al., 2015; Bizuneh et al., 2018) who noted that the principal method of remedy preparation was through crushing. The highest medicinal plant knowledge acquisition by the healers in this study area was from parents or close relatives. They have the only oral-based transmission of knowledge. The healers have very high intentions to keep their traditional knowledge secret. These limits the knowledge transfer from generation to generation and lead to destruction of the indigenous knowledge which held by local communities. Some informants argue that mixing and using some medicinal plants taken with foods is better than taking alone. For instance, dry fruit of *F. sur* mixed with honey and taken orally as food is used to treat malaria. Leaf of *V. amygdalina* and *Croton macrostachyus* mixed with salt and honey used as medicine to treat intestinal parasites and *M. lanceolata, Croton macrostachyus* and *V. amygdalina* powdered and mixed to treat milk production shortages of the livestock.

Forms used

Informants claimed that fresh forms of the preparations were considered more powerful than dried ones; to treat humans and livestock ailments. Similar results were reported in earlier studies (Belachew and Behailu, 2018; Abiyot et al., 2018 and Nigatu et al., 2018). This could be associated with the components and activities of active principles of fresh preparations. They also claimed that the application of remedy in fresh forms is more relevant than a dry one because it is easy to prepare and handle. This account for 74.52% of the total plants and 25.48% were used in dry forms (Figure 4). Similar results were reported earlier (Belachew and Behailu, 2018, Abiyot et al., 2018; Nigatu et al., 2018) which could be associated to the components and activities of active principles of fresh preparations. Here harvesting of the fresh plant parts minimizes the chances of preservation for later use and affects the sustainable utilization of medicinal plants. In this study, remedy preparation from single plant parts accounted for 88.77% and preparations from combined plant species were about 11.23%. This consensus was in

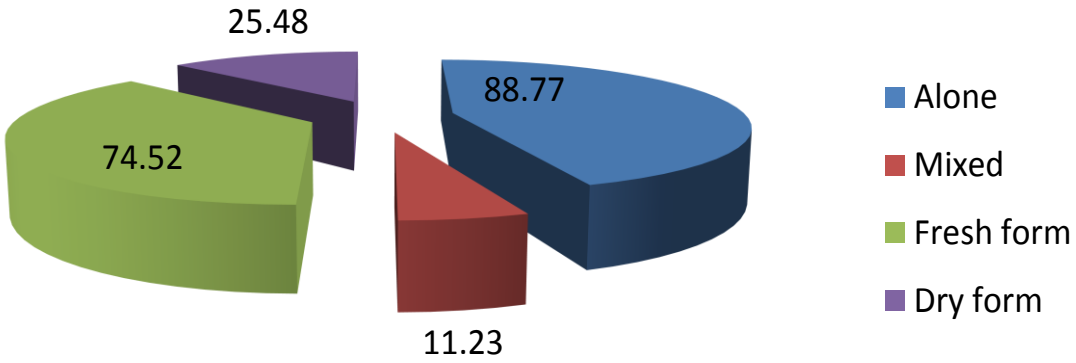

Figure 4. Forms used and composition of remedy preparation.

agreement with those of Bizuneh et al. (2018).

Routes of administration and dosage used

Internal ailments were commonly treated by drinking, chewing and swallowing. Skin infections like snake bite were treated by rubbing and painting on the infected parts. Ailments like jaundice and pneumonia were treated by crushing and pounding, decoction and infusion applied through oral administration. Headache was treated through nasal smell and evil eye through oral administration and different methods were used to the other ailments (Table 1). The choice of oral administration is related to the use of some solvents or additives (honey, milk, butter and food) that are commonly believed to serve as a vehicle to transport the remedies (Tolosa et al., 2013; Balcha, 2014; Nazim et al., 2017; Abiyot et al., 2018, Belachew and Behailu, 2018; Nigatu et al., 2018; Banchiamlak and Young, 2019). For example, stems and roots of *Bersama abyssinica* are chewed or powders and drunk against intestinal parasites. There was not a proper dosage observed like modern medicines but were taken according to disorder and need. Ethno medicines were used with tea-spoons and finger-tips which passing from generation to generation. Such as finger length for root and stem bark, pinch for powdered plant parts, numbers for leaves, seeds, fruits and flowers, cup for decoction and infusion for plant parts, were used to estimate and fix the dosage of the medicine (Nazim et al., 2017). The healers believe the effectiveness of the traditional medicines but the measurements used to determine the dosages are not standardized and doses are given depend on the age, physical fitness, stage of illness, pregnancy, and the presence or absence of any disease other than the disease to be treated. The absence of adverse effects of traditional medicines was frequently mentioned by the healers. If the dosage is more than the treated person can handle milk is added to minimize the power of the medicine.

Threats to medicinal plants and opportunity to overturn the threats

In the study area, human induced factors were recorded as the main threats to plant species in general and medicinal plants in particular. As shown in Figure 5, the most important threatening factors include in descending order the agricultural expansions (25%), firewood (20%), deforestation (18%), cash crop expansions (16%) and charcoal production (7%) reflected a threat on medicinal plants. According to elder local informants, most of Malga area was covered with forests until about the 1940s. However, high deforestation rates over the years have left only highly disturbed remnant forests which are now confined to the mountain slopes.

Conclusion

The results of the study has revealed that about 60 medicinal plant species used by the local community were inventoried reflecting the richness and the diversity of the medicinal plant resource of the Malga District Southern Ethiopia. The associated knowledge of the local people is deep-rooted in the time-honored use practices of herbal medicine as illustrated by the end use of the medicinal plants: 36 species were noted to treat human ailments, 7 species for livestock ailment treatment, and 17 species for both human and livestock health treatments. In addition, 28 different human and 12 livestock ailments were recorded. Shrubs were found to be dominant as traditional medicinal plant remedy sources in the study area followed by trees, herbs, and climbers. Leaves were also found to be the most harvested plant parts for the preparation of the remedies followed by bark and roots. In the preparation of medicines, single plants were used to prepare the medicines to cure the diseases rather than mixing. The routes of administration are mainly internal in which oral administration is the common one. However, both the plant resources and the indigenous knowledge of herbal

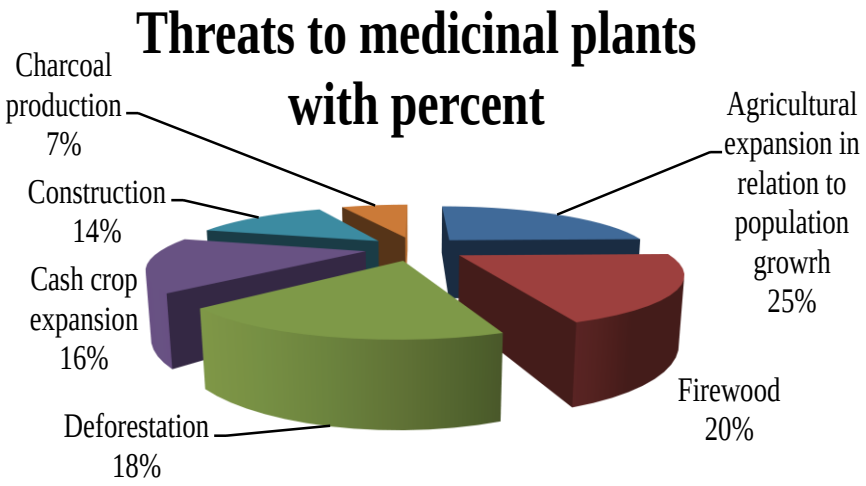

Figure 5. Threats for medicinal plants.

medicine are under threat. The main factors leading to the loss of plant species in the study area are agricultural expansion driven by population growth and cash crop expansion (*Catha edulis* and *Coffee Arabica*). The study site had rich medicinal plant diversity. But, the knowledge on medicinal plants is shrinking due to its secrecy, and oral-based knowledge transfer to close relatives. The medicinal plant resources, the associated traditional knowledge, and medical practices are in great need of protection through the implementation of appropriate conservation strategies.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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Attitudes of local leaders towards wildlife conservation in village areas in southern Ngorongoro Conservation Area, Karatu District, Tanzania

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Understanding attitudes of local leaders towards conservation issues in village areas surrounding protected areas is vital for the success of sustainable biodiversity conservation. This is because of the need of designing effective conservation programs outside protected areas and to reduce resource-based conflicts involving local communities and protected areas. Twenty villages in Karatu district located between Ngorongoro Conservation Area (NCA) and Lake Manyara National Park (LMNP) were chosen for this study. The data were collected using semi-structured questionnaires administered to 133 local leaders in 20 villages. Findings indicated that attitudes of local leaders towards conservation in the village areas were positive. We observed that 90.3% of the village government members and 50% of the chairpersons considered charcoal making as detrimental to the environment and insignificant to the development of their villages. Majority of the respondents (80.0%) rated that village environmental conservation bylaws are having inadequate penalties for offenders in dealing with the current state of rapid environmental deterioration in village lands. The position of a leader was an important predictor as 87.4% of village chairpersons and 70.0% of the village government members were positive towards conservation in village lands. The implication of the results could be linked to conservation initiatives outside protected areas and understanding the attitudes and securing the support of local leaders.

Key words: Environmental conservation, Ngorongoro Conservation Area, wildlife conservation, local communities, protected areas.

INTRODUCTION

The term “attitudes” has been used in relation to positive or negative responses towards an entity or object (Karanth and Nepal, 2012), and is defined as a mental evaluation of a particular entity with some degree of favor or disfavor (Gebregziabher and Soltani, 2019). Attitudes are formed through an individuals’ experience and perceptions (Infield and Namara, 2001). Attitudes of local people can provide insights on how they will behave, how they comply with wildlife protection regulations, how they respond to economic losses caused by wildlife, and the

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degree to which they are willing to coexist with wildlife (Balakrishnan and Belay, 2017). People's perceptions reflect the beliefs that they derive from their experiences and interactions with a particular phenomenon (Mulrennan et al., 2012; Gebregziabher and Soltani, 2019). The sustainability of biodiversity management programs relies on the nexus of the community's perceptions, knowledge and awareness of the problems of biodiversity deterioration and mitigation measures (Mengistu and Assefa, 2020). Biodiversity awareness campaigns were reported to raise the knowledge and hence the higher level of community participation towards conservation of biodiversity (Montana and Mlambo, 2019). Biodiversity conservation outside protected areas entails the presence of local authorities which form the basic units of community organizations at the grassroots levels (Spenceley et al., 2019). For these local units to realize sustainable conservation issues such as financial and technical requirements, incentives through income and other benefits and commitments of local communities through participation need to be addressed at the outset (Keane et al., 2019).

The Community Based Conservation (CBC) approach was established after the failure of the fences-and-fines approach in delivering conservation goals (Mulrennan et al., 2012; Keane et al., 2019). Fences-and-fines approach disregarded the interests of local inhabitants and excluded them from the management and use of natural resources located in their areas (Aryal et al., 2020; Weldemichel, 2020). The exclusion and other factors such as wildlife induced damages to crops, livestock and humans as well as evictions of people without compensation during establishment of protected areas altogether converged and promoted human-conservation conflicts which derailed trust between various conservation stakeholders (Keane et al., 2019). This thwarted supports of local people for conservation programs in village lands and the surrounding protected areas. The failures in achieving conservation objectives, lack of support of local people for conservation initiatives and the growing hostilities between local people and management of protected areas necessitated the development of CBC with the main purpose of reversing the situations above (Hill et al., 2010; Brown et al., 2018; Keane et al., 2019). In doing so, the CBC approach intended to change local peoples' attitudes and practices and use them as means to reach the desired conservation outcomes (Root-Bernstein, 2020). This considered the fact that when local people felt deceived, they tend to sabotage conservation efforts through for instance burning forests and facilitating poachers (Nilsson et al., 2016; Kaeser and Willcox, 2018). Therefore, the future success of CBC requires collaborative planning that takes into account CBC in a multi-scale and multi-actors' approach (Hill et al., 2010; Balakrishnan and Belay, 2017; Kaaya and Chapman, 2017).

As in many other parts of the world, the main purpose of biodiversity conservation in Tanzania is attached to protected areas while little or no attention is given to areas outside protected areas. These areas provide corridors which are crucial for the movement of wild animals between various habitats. However, human activities in unprotected areas continue to block these corridors which in turn indicate the likely collapse of protected areas in the long term due to the negative effects of the isolation and habitat fragmentations (Newmark, 2008; Caro et al., 2009). Tanzania has set aside more than 35% of its land as protected areas and this contributes to 17.5% of the Gross Domestic Product (Kaaya and Chapman, 2017). These areas are therefore a good representation of the situation where biodiversity is treasured excluding conservation programs in village and general public lands. But resources in areas outside protected areas are getting depleted faster than in protected areas because of unsustainable practices associated with socio-economic activities. Depleted resources in unprotected areas combined with rapidly increasing human population in Tanzania which for the last ten years (2002-2017) has increased by 30% from 34.4 million to approximately 54 million (URT, 2017), exerts huge pressure on the resources of the surrounding protected areas.

Despite the realization of some conservation successes, especially in integrating government and society in living sustainably, biodiversity continues to decline (Rands et al., 2010; Pringle, 2017). The National Biodiversity Strategy and Action Plan (NBSAP) for Tanzania towards Convention on Biological Diversity (CBD) 2010 targets identified inadequate awareness of the public and poverty as the main challenges to improving biodiversity conservation in the country as well as insufficient finances allocated to conservation activities resulting in incapacity to information dissemination (Rush and Solandt, 2017; Johnson et al., 2019). As a way of improving biodiversity conservation, the plan proposed provision of biodiversity education and information to related sectors outside protected areas. However, there exists gaps between biodiversity conservation strategies and the practices of sectors such as agriculture, and thus, the need to be aligned to policies of natural resources managements that consider sustainable healthy ecosystems in the country (Rockström et al., 2010; Brown et al., 2018).

Therefore, the study aimed at assessing and documenting the awareness and attitudes of local leaders towards conservation issues in village areas surrounding protected areas. Understanding the findings could contribute not only in designing effective conservation programs outside protected areas but also in reduction and possible elimination of resource-based conflicts involving local communities and park officers. The main objective of the study was to examine the attitudes, perceptions, knowledge and awareness of local

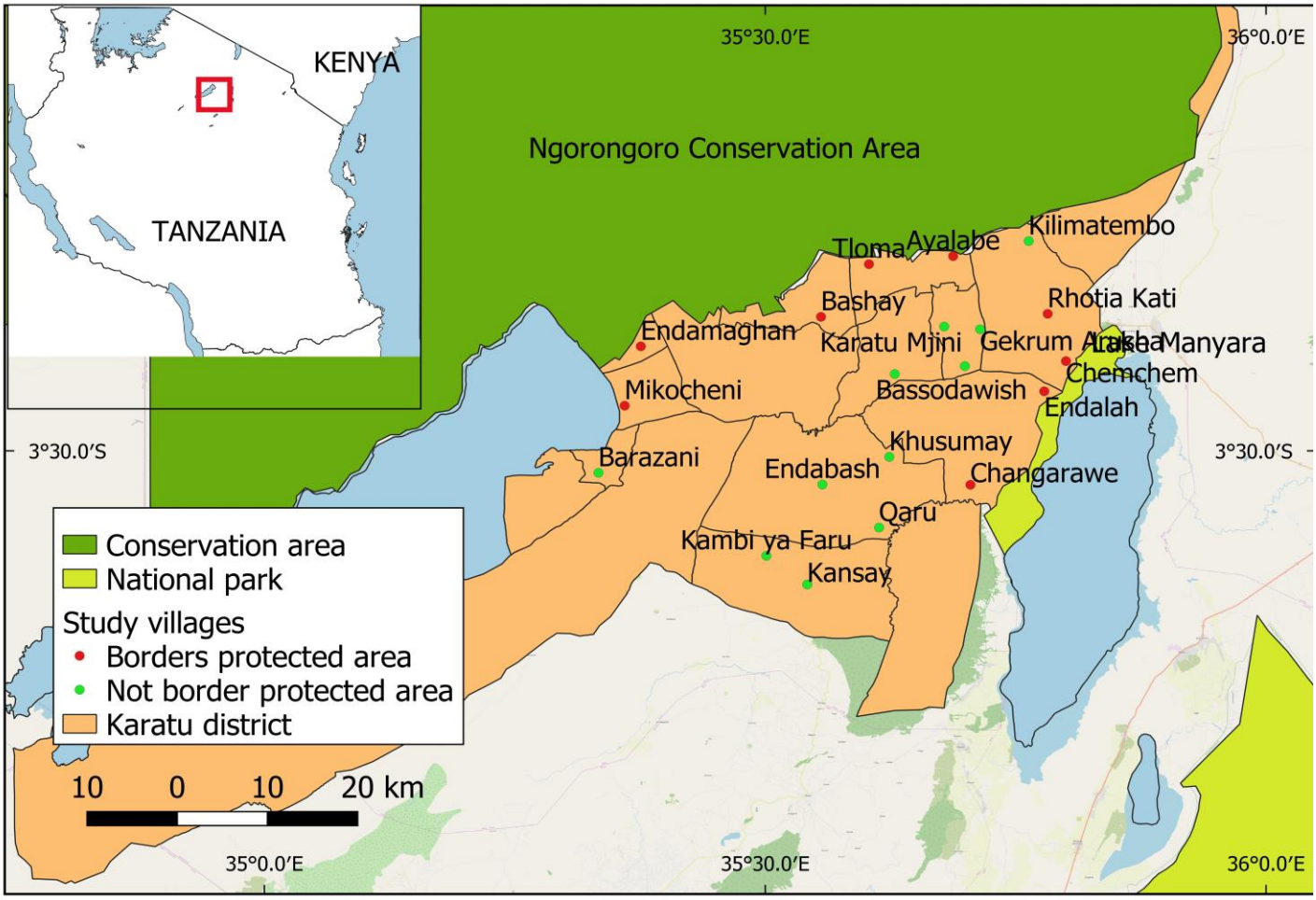

Figure 1. Study villages bordering (red dot) and villages not bordering (green dots) NCA and LMNP in Karatu district, northern Tanzania.

community leaders towards conservation issues in Karatu villages and the neighboring Ngorongoro Conservation Area (NCA) and Lake Manyara National Park (LMNP). Specific objectives were 1) to assess the knowledge and awareness of local leaders on issues related to conservation (water, wildlife presence, cultivation lands, livelihoods and soil erosion). 2) To determine attitudes of local community leaders towards conservation activities in village areas. 3) To determine the attitudes of local community leaders towards the roles of protected areas in the development of surrounding villages.

MATERIALS AND METHODS

Study area

Karatu is one of the five districts in Arusha Region and is located in the northern part of Tanzania (Figure 1) between latitudes 3°10'-4°00'S and longitude 34°47'-35°56'E. Karatu borders Mbulu district to the south, NCA (established 1959) to the north, LMNP (established 1960) to the east and Meatu district to the west. It is the traditional home to the Iraqw tribe who are agro-pastoralists, Barbaig tribe who are pastoralists, and the Hadzabe tribe, noted mainly as hunters and gatherers. The district has total land area of 3,300 km^2 and roughly divided into three zones; uplands, midlands and lowlands with altitude ranging from 1,000 to 1,900 m. Rainfall is bimodal and ranges from 300-1200 mm/year. The uplands consist mainly of agriculture while lowlands are woodlands used for grazing, charcoal production and wildlife. The district has 15 administrative wards and more than 45 registered villages with total population of 230,166 people growing at an annual rate of 3.2% and aggregated into 34,000 households (NBS 2012). Locations of study wards are indicated in Figure 1. The average population density is 7-10 person/km^2 and most people live in the uplands mainly around Ngorongoro Northern Highland Forest Reserve of Karatu (Owenya et al., 2011; URT, 2017). The African elephant (*Loxodanta africana*) happen to be the most frequently encountered species, others include dik-dik (*Madoqua kirkii)*, spotted hyena (*Crocuta crocuta)*, African buffalo (*Syncerus caffer)*, yellow boboons (*Papio cynocephalus).*

The major economic activities in Karatu district are crop farming and livestock keeping which lack sustainable practices and continue to create soil degradation (Owenya et al., 2011). The rapidly increasing population and the rate at which natural resources are being degraded, not only negatively affects livelihoods but extends conservation problems such as siltation to the surrounding protected areas such as Lake Manyara, which is

part of LMNP that provides crucial biological habitats (Raphael, 2018).

Data collection

The data were collected using semi-structured questionnaires with both closed and open-ended questions (Appendix 1). The questionnaire was designed by researchers purposely for this study and pilot tested before conducting the real data collection. The questionnaire survey was conducted form 1st June to 10th August 2013. Prior to the interview, the main purpose of the study was explained to the village executive officer or chairman. Permission for conducting interviews was then granted. Sensitive questions such as their ideology or religion were avoided and each questionnaire was given a number instead of the name of a respondent. The first part of the questionnaire focused on social demographic information of respondents. The second part focused on knowledge, awareness, attitudes, wild animal species and corridors and the interactions of conservation stakeholders at the village levels. For the purpose of this study three main stakeholders were identified; the management of the surrounding protected areas, NGOs and central government. In general respondents were asked to use the scale provided to tick against statements they agreed with based on four response categories namely: 1=Strongly Disagree, 2=Disagree, 3=Agree and 4=Strongly Agree. Open ended questions enquired answers about resources gotten from the surrounding protected areas.

Sample selection

Sample study villages were selected by first grouping all villages in Karatu district into two categories based on whether they bordered or did not border the surrounding protected areas. The list for each category was arranged alphabetically and correspondingly assigned numbers in an ascending order. Ten numbers were randomly picked from each category giving a total of twenty study villages from which data was collected.

The random selection of respondents considered the position and gender of the local leaders. Position identification process was done through the ward leader and respondents in various positions were identified. For the purpose of this study two groups were formed. Group one who constituted chairperson included the village chairpersons, sub-village chairpersons and village executive officers. They run the day to day activities of the village government. Group two which was composed of members was made up of members of the village government council. They plan and formulate policies of the village government and play overall supervisorial roles of group one above. Village councils are constituted of between 15 and 25 people depending on the village area and population sizes. For Karatu district the average population size per village was twenty people. Gender proportion considered local government regulations where women must account for at least 25% of all the members of the council. In all the selected villages lists with names of all the local leaders were obtained and sorted into two position groups alphabetically followed by allocation of numbers in ascending order. In each selected village eight numbers were randomly picked. In total, one hundred and sixty respondents (n=160) were selected. However, only one hundred and thirty-three respondents (n=133) were reached for interview (Table 1).

Data analysis

Data analyses were done using the Statistical Package for Social Sciences (SPSS version 24, NY, USA). Descriptive statistics were used to summarize the questionnaire response data. Since most of the data were categorical, Pearson's chi-square analyses were performed to determine the differences in the independent variables that explain the attitude of the community about conservation issues in their areas and surrounding protected areas. Furthermore, linear regression analysis was used to determine the factors that contributed most to statistical significance in relation to independent variables such as age, level of education (primary vs secondary), village location (bordering vs not bordering protected area), gender (male vs female) and position of leader (chairpersons group vs members group). The explanatory variables included charcoal making, village conservation bylaws, role and performance of neighbouring protected areas to village development programs, availability of water, cultivation land. The significance level was set at $P < 0.05$.

RESULTS

General characteristics of the respondents

Socio-demographic characteristics of the respondents included gender (males 76%, n=133), age intervals in years with age group 40-49 having more respondents (43%, n=133), followed by age group 29-39 (29%) and ≥50 (28%). Most of the respondents were married (94%, n=133) and few were single (6%). Majority of the respondents had attained primary education level (71%, n=133) and secondary education (29%). 51% (n=133) of respondents comes from villages that border with NCA and LMNP and 49% of respondents comes from villages that do not share border surrounding protected areas of NCA and LMNP. Out of 133 respondents, 30 were village chairpersons and 103 were members in the village government.

Knowledge and awareness on conservation related issues

The issue of water supply was assessed in the sampled village areas. Respondents were asked to describe water availability as either normal or difficult. The majority of respondents (76.5%, n = 68) who came from further away villages and 61.5% (n = 65) of respondents from closest villages to PA described water availability as difficult (χ^2 = 0.12, df = 1 P = 0.062). Most of the chairpersons (96.7%, n = 30) described water availability as difficult while 61.2% (n = 103) of the members group described water availability as difficult; a statistically significant difference (χ^2 = 13.73, df = 1 P< 0.001). The linear regression analysis conducted between water availability assessment as a dependent variable and village location and position of leader as predictors was statistically significant. The two significant variables explain 12.1% of the variation (r^2 = 0.12, P < 0.001). However, the most important variable in predicting the variations is position of a leader (t = -4.04, P< 0.001) followed by the village location (t = 2.17, P = 0.032).

The results on the presence of wild animals showed

Table 1. Village leaders from each respective village bordering and villages not bordering PA.

Villages bordering PA	Number of respondents	Villages not bordering PA	Number of respondents	Total respondents
Ayalabe	8	Karatu Mjini	8	
Tloma	8	Gekrum Arusha	8	
Endamaghan	8	Barazani	8	
Kambi ya Faru	5	Mikocheni	7	
Rhotia Kati	6	Bassodawish	6	
Bashay	6	Khusumay	7	
Chemchem	6	Qaru	6	
Kansay	7	Endabash	6	
Endalah	6	Kilimatembo	5	
Changarawe	5	Gekrum Lambo	7	
Total	65		68	133

that wild animal species exist in village areas. Most respondents (78.5% n = 65) in villages bordering the protected areas compared to 60.2% (n = 68) of respondents from villages not bordering the protected area indicated the presence of wild animals in their village areas. The difference between village locations was statistically significant (χ^2 = 17.78, df = 1, P< 0.001). Four other issues presented to respondents were shortages of cultivation lands, relationship between conservation and livelihoods, soil erosion and water source location. The linear regression analysis of the four issues as dependent variables against gender, level of education, position of leader and village location as independent predictors gave the following results; For shortages of cultivation lands, the level of education and position of leader were statistically significant explaining 10.3% of the variation (r^2 = 0.10, P < 0.001). However, the most important variable in predicting the variation was level of education (t = 2.56, P = 0.012) followed by the position of leader (t = 2.18, P = 0.031). Gender was not statistically significant (t = 0.59, P = 0.557). For the relationship between conservation and livelihoods, only the position of leader was a significant predictor and explained 29.7% of the variation (r^2 = 0.29, P< 0.001, t = -7.25, P < 0.001). The level of education (t = -0.24, P = 0.808) was not statistically significant. For soil erosion, the position of a leader explained 54.5% of the variations (r^2 = 0.55, P < 0.001, t = 11.97, P < 0.001) while level of education was not statistically significant (t = 0.21, P = 0.837). For the location of water sources, the village location differed significantly (r^2 = 0.06, P = 0.003, t = -3.01, P = 0.003).

Attitudes of local leaders towards conservation in village areas

In determining attitudes towards conservation in village lands three key statements were used in obtaining the views of respondents in the study areas. These included variables are charcoal production, village conservation by-laws and village environmental conservation committees. Most of the respondents from the members group (90.3%, n = 103) and 50% (n = 30) from the chairperson group considered charcoal making as detrimental to the environment; a statistically significantly difference (χ^2 = 33.01, df = 1 P< 0.001). 84.6% (n = 65) of the respondents from villages bordering the protected areas, and 77.9% (n = 68) of respondents from villages not bordering protected areas stated that charcoal making is detrimental to the environment; a statistically significantly difference (χ^2 = 13.31, df = 1 P< 0.001). The linear regression analyses of three activities as dependent variables against with age, level of education, village location and position of leader were all statistically significant. For charcoal activities, position of leader, age of respondent and village location were all statistically significant explaining 27.9% of existing variations while level of education was not significant (Table 2).

For village conservation by-laws most of the respondents from the chairperson group (80%, n = 30) agreed with the statement that village conservation bylaws have inadequate penalties for offenders while only 36% (n = 103) of the members group agreed to the statement; a statistically significantly difference (χ^2 = 54.77, df = 1 P< 0.001). Age of the respondent was the only statistically significant variable in explaining the observed 16.8% of variation while position of leader, village location and education level were not statistically significant (Table 3). For village environmental committee, again the position of leader was the most statistically significant variable in explaining the observed 7.7% of variations while education level, village location and age of respondents were not significant (Table 4).

Attitudes of local leaders towards the roles of surrounding protected areas to village developments

Two issues were used to assess the attitudes of local

Table 2. Linear regression analysis results with charcoal production activities as dependent variable and age, level of education, village location and position of leader as independent variables.

Independent variable	Unstandardized coefficient		Standardized coefficient	Statistics	
	B	Std. error	Beta	t	P
(Constant)	-0.74	1.90		-3.39	0.009
Village location	-0.19	0.34	-0.05	-6.23	0.001
Position of leader	1.29	0.44	0.25	2.90	0.004
Age	0.44	0.30	0.13	2.617	0.010
Education level	0.46	0.49	0.08	0.93	0.354

[a]Dependent variable: Charcoal production activities in the village

Table 3. The linear regression analysis model with village bylaws to environmental conservation as dependent variable versus four independent variables age, level of education, village location and position of leader.

Independent variable	Unstandardized coefficient		Standardized coefficient	Statistics	
	B	Std. error	Beta	t	P
(Constant)	2.41	2.05		1.18	0.242
Position of leader	0.39	0.37	0.10	1.07	0.288
Village location	-0.42	0.48	-0.08	-0.88	0.379
Education level	0.09	0.53	0.02	0.18	0.86
Age	1.01	0.32	0.28	3.14	**0.002**

[a]Dependent variable: Village bylaws to environmental conservation do not provide adequate penalties for offenders.

Table 4. Linear regression analysis results with environmental committee as a dependent variable against age, level of education, village location and position of leader as independent variables.

Independent variable	Unstandardized coefficient		Standardized coefficient	Statistics	
	B	Std. Error	Beta	t	P
(Constant)	4.07	1.63		2.50	0.014
Position of leader	-0.54	0.29	-0.17	-3.323	**0.001**
Village location	0.63	0.38	0.14	1.65	0.102
Education level	0.24	0.42	0.05	0.56	0.578
Age	0.09	0.26	0.03	0.36	0.716

aDependent Variable: The environmental committee in your village is doing a good job in environmental protection.

leaders towards protected areas. These were “the roles of protected areas contribute to village developments” and the “performance in supporting social services projects at the village level”. 56.7% (n = 30) of the chairperson group agreed with the statement that protected areas considerably contributed to the development of the village while only 13.6% (n = 103) of the respondents from the members group agreed with this statement; a statistically significantly difference (χ^2 = 38.21, df = 1 P< 0.001). However, both the members (87.4%, n = 103) and the chairperson groups (70.0%, n = 30) agreed with the statement that protected areas are not doing enough to support social services in villages (χ^2 = 6.69, df = 1, P< 0.073). The majority of respondents (56.9%, n = 65) from villages bordering protected area agreed with the statement that protected areas considerably contributed to the development of the village whereas only 38.2% (n = 68) of the respondents from villages not bordering protected area agreed with the statement; a statistically significantly difference (χ^2 = 10.68, df = 1 P = 0.014). 90.8% (n = 65) of respondents from villages bordering protected area and 76.5% (n = 68) of respondents from villages not bordering protected areas agreed with the statement that protected areas are not doing enough to support social services in villages; a statistically significantly difference (χ^2 = 8.82, df = 1 P< 0.032).

A linear regression of the roles and performance as

Table 5. Linear regression results on the roles of protected areas to village developments as dependent variable and level of education, position of leader and village location as independent predictors.

Independent variable	Unstandardized coefficient		Standardized coefficient	Statistics	
	B	Std. error	Beta	t	P
(Constant)	3.31	1.01		3.28	0.001
Village location	1.02	0.34	0.26	3.03	**0.003**
Position of leader	-0.25	0.25	-0.09	-1.00	0.322
Education Level	-0.02	0.36	-0.01	-0.05	0.957

aDependent Variable: The surrounding protected areas played significant role for the development of your village.

Table 6. Linear regression results on the performance of protected areas support to village social service projects as dependent variable and level of education, position of leader and village location as independent predictors.

Independent variable	Unstandardized coefficient		Standardized coefficient	Statistics	
	B	Std. error	Beta	t	P
(Constant)	9.16	0.89		10.26	<0.0001
Village location	-0.70	0.30	-0.21	-2.37	**0.019**
Position of leader	0.18	0.22	0.07	0.79	0.429
Education Level	-0.17	0.32	-0.05	-0.52	0.606

[a]Dependent variable: The surrounding protected areas are not doing enough to support social services in your village.

dependent variables and level of education, position of leader and village location as independent predictors was done, and results are shown in Table 5. For the case of roles of protected areas to village developments village location was statistically significant in explaining the variation by 15% while the village location and education level of respondents were not significant (Table 5). In the case of performance of protected areas support to village social service projects only the village location was statistically significant explaining 26.5% of the variation while level of education and position of leader were not significant (Table 6).

DISCUSSION

Knowledge and awareness on conservation related issues

Five factors related to conservation issues were used to evaluate the knowledge and awareness. These are water availability, presence of wild animals in village areas, shortage of cultivation land, local community livelihoods and soil erosion. The responses on the description of water availability showed that most of the leaders were aware of the current status of water availability in Karatu district areas and described its availability as difficult. For leaders from villages bordering protected areas they were more likely to indicate the availability as normal. The difference could be explained by the short distances to water sources located in the nearby protected area. The other reason could be the impact of community conservation programs by the adjacent protected areas that support social service projects which include water supply to local communities (Kaltenborn et al., 2008; Balakrishnan and Belay, 2017). The descriptions of leaders reflected varied water availability among the villages with different locations. This corresponds to the location of water sources for the villages where majority of respondents indicated to be in the surrounding protected areas. The closer the village to protected area the more likely the indication that the water source is in the adjacent protected area. The position of a leader significantly influenced the response patterns. The chairperson of a group was more likely to indicate difficult availability than the member group. This could be connected to their roles in the village, and therefore they might have presented the views on behalf of the whole village as opposed to the member groups. Generally, the views were that protected areas are currently the main source of water for many villages in Karatu district. The availability status was described as becoming insufficient due to climate variability characterized with long-term droughts, degradation of the forests and increasing number of human population (Chaligha et al., 2007; Malley et al., 2009; Nyembo et al., 2020).

Majority of leaders pointed out to the presence of wild animals in the village areas and the crosstab with village location as a predictor was significantly important. Leaders from villages bordering protected areas were more likely to admit the presence of wild animals in their village areas than those from villages not bordering

protected areas. This was expected considering the nature of human-wildlife interactions between local people and the surrounding wildlife species (Matseketsa et al., 2019). The movements of wildlife into human settlements might indicate possible declining resources in the nearby wildlife areas. Some wild animal species such as elephant tend to have wide ranging habitats and migrate between these habitats (Kumar et al., 2018; Neupane et al., 2019).

The increased socio-economic activities of local people cause the encroachments to wildlife areas. If these trends are allowed to continue, then more wildlife species would continue to be seen in village areas and this in turn would heighten the human-wildlife conflicts (Kumar et al., 2018; Hariohay et al., 2019; Matseketsa et al., 2019). The shortage of cultivation lands was highly attributed to increased human population in the village areas by most local leaders. The variables level of education and position of leader were significant predictors. The leaders with higher level of education and chairperson positions were less likely to attribute shortages of cultivation lands to increased human population in village lands. This was expected given the other reasons that could cause shortages of land resources. Higher level of education could be associated to be of those more informed about the other causes. Based on their functions, the leaders in the chairperson category happen to be more involved in the course of addressing development challenges in their respective villages. In this way, they might have encountered related information on other possible reasons for shortages. These could include intensification and inadequate agricultural practices which lead to underutilization of the existing cultivated lands depicted in persistent food insecurity (Pretty and Smith, 2004; MacKenzie, 2018).

The chairperson category was more likely to suggest that conservation programs improve livelihoods than the member category. Again, given their functions these leaders play the frontlines roles in all development initiatives in the villages. This provided more opportunities for them to participate in various conservation programs. Through participation and involvement, they were likely to be more informed on the connections between conservation programs and better community livelihoods (Infield and Namara, 2001; Mariki, 2013; Abebe et al., 2020). Lack of significant relationship was not expected between the villages with different locations. This is because NCA and LMNP community conservation service policies with local community development projects focused on the neighboring villages that share direct boundary with them. Consequently, leaders from villages bordering protected areas had more interactions in terms of contacts and participations in these community conservation projects which received substantial amount of money from the respective protected area (Kaaya and Chapman, 2017).

Soil erosion from the villages causes siltation of Lakes Manyara and Eyasi (Raphael, 2018). Chairperson category totally opposed the statement compared to member category which supported that soil erosion generated from their areas cause siltation and possible disappearance of the surrounding lakes. Lake Manyara in particular had been continuously subjected to massive degradation as a result of socio-economic activities in the surrounding areas (Yanda and Madulu, 2005; Janssens de Bisthoven et al., 2020). Soil materials deposited into the lake basin make it shallow and susceptible to high evaporation (Nyembo et al., 2020). The volume of water gets reduced and if the current trend is not reversed there are possibilities of converting the lake into a seasonal one and completely disappearing in the long term. Though there was no evidence gathered that shows local leaders were involved in soil erosion initiatives by adjacent protected areas, there was evidence that conservation agriculture projects were being conducted in Karatu district (Owenya et al., 2011). Among other issues, the approach critically addresses the problems of soil erosion. Concisely, the leaders were expected to be highly aware on challenges associated with the problems of soil erosion. However, they showed basic understandings and most of their descriptions were evident during focused group discussions with key informants working in different departments at the Karatu district council.

Attitudes of local leaders towards conservation in village areas

Local leaders' attitudes were examined using three activities connected to environmental conservation goals in village areas. The activities were charcoal making, village environmental conservation bylaws and village environmental conservation committees. The attitudes of local leaders towards conservation activities in village areas were positive, with 87% of respondents indicating that charcoal making activities were destructive and the village environmental conservation bylaws and committees were not adequately addressing the current situation of rapidly deteriorating resources in the village lands. The results indicated that four independent variables, age, level of education, village location and position of leader were important predictors.

For the charcoal issues the variation was explained by three variables of age, village location and position of leader. The activities were viewed less negatively by the older leaders than the younger ones. This could be linked to the level of education of the respondents and their tradition of high dependence on charcoal and firewood for energy source for domestic cooking. There were many younger leaders with higher level of education compared to the older group. As indicated previously higher level of education entails more understanding of the importance of conservation. Leaders from villages not bordering

protected areas were less negative to charcoal activities than those from villages bordering protected areas. Hence there could be two possible explanations for this variation. First, the activities are carried out in villages not bordering protected areas. The leaders from these villages were beneficiaries of the activities either as individuals or as an institution of the village government. Second, apart from benefits sharing, these programs facilitate training and participation of local leaders in conservation activities involving adjacent villages that share direct boundaries with protected areas. These interactions between local people and protected area management not only improve the attitudes towards protected areas but also towards conservation issues generally (Moreto et al., 2016). With the improved conservational attitudes, people were more negative towards charcoal activities which in most cases were conducted using unsustainable methods. This finding supports our first hypothesis that leaders from villages bordering protected areas will be more positive towards conservation in village areas. The disparity supports other findings which indicated enhanced conservational attitudes resulting from the interactions between local people and protected area managements (Kideghesho et al., 2007; Jagger et al., 2018).

In the case of village environmental conservation bylaws and committees, and position of leader showed significance difference. With the position of a leader as an important predictor, the chairperson group was more likely to rate both bylaws and committees as more inefficient than the member group. This could be associated with bigger responsibilities and roles of the group chairperson in running the village governments and also to a higher level of education where the majority of the group chairpersons had secondary level of education (MacKenzie, 2018). Higher level of education involves more understanding of the linkages of conservation issues (McClanahan et al., 2005; Kideghesho et al., 2007; Jagger et al., 2018). The desires of local leaders were to see more actions towards addressing the current challenges facing resources management in the village areas. For instance, the penalty for defaulting one bylaw was set at TZS 5,000 (about US$ 3) which according to the village leaders was far below the value of trees that were illegally harvested. In the case of committee underperformance, the reasons indicated were financial constraints and some of the members collude with the defaulters through corruption practices. These suggestions explain the dissatisfaction of local leaders on the ongoing situations. Consequently, they need to promote sustainable practices that enhance the health of the environment in their village areas.

Attitudes of local leaders towards surrounding protected areas

Generally local leaders held negative attitudes towards surrounding protected areas in terms of the two issues used to assess them. These were roles they played in the development of villages and performances in supporting social service projects at the village government level. Important predictors were level of education, village location and position of leader. During linear regression analysis the effect of level of education did not appear. Those from villages bordering protected areas were more negative towards the protected areas than the other group from villages located further from protected areas (Mariki, 2013; Kirumira et al., 2019). This supported our second hypothesis that local leaders from villages bordering protected areas will be more negative towards them given the higher conservation-induced costs experienced in these areas. Historically, the costs experienced tend to increase with decreasing distance from the protected areas. For the variable position of leader, the category of chairperson group was less negative than the member group. There can be two possible explanations for the divergence in the given responses. One is the possible influence of level of education where majority of respondents in this group hold higher level of education. Two is on their roles where they have more direct involvement and participation than the other group in community conservation initiatives. Apart from the impact of participation on their attitudes, benefits received could be another reason for the more positive. They form the first contact group for any community conservation programs in village areas. In the process of involvement and participation they are likely to have received more benefits from extra assignments resulting from the conservation programs activities. Consequently, the information and benefits gained through the involvement explain their attitudes towards protected areas. This finding corroborates with that of a similar study conducted in western Serengeti (Kideghesho et al., 2007) in Tanzania where wildlife-related benefits or rather conservation-related benefits had a positive impact on local people's attitudes towards protected areas.

Conclusions

Our results revealed that village leaders close to protected areas were more positive towards conservation of village areas. Given the indicated positive attitudes of local leaders towards conservation in village areas, conservation initiatives outside protected areas would likely receive the support of local leaders. Currently, one of the big threats facing the existence of protected areas is the huge demands of local communities that depend on natural resources for their daily survival. Among other factors the access to resources in protected areas has been central to conflicts between the local communities and the protected areas. The present study identified the resources that were scarce or not existing in village areas

but highly needed by the local people. These include trees and land for cultivation. The increasing population and unsustainable practices of socio-economic activities in village areas hugely contribute to depletion of these resources. The study villages were in rural areas with no electricity power whereby the major source of energy used is firewood which is now scarce.

We recommend strategies in designing participation of local leaders need to consider their roles and position in community organizations. Another factor that is crucial to bring on board is village location from protected area boundary. Knowing the resources needed by the local people and exploring the possibilities of developing these resources in their areas would be vital for the surrounding protected areas. One of the possible projects that could address several goals is agroforestry and greener energy sources such as biogas and solar power. Establishing trees in these human dominated areas would relieve protected areas of the pressure resulting from the demand of local people for the resources. The conflicts arising from access to resources also would be tackled.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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APPENDIX

Questionnaire survey for 20 villages in Karatu district, Tanzania: June-August 2013

I. Socio-demographic characteristic

a. The village office

1. Questionnaire No……
2. Date ……
3. Village name……
4. GPS reading: S……E……
5. Village population……
6. Village boundary: Border PA☐ Not border PA☐
7. Village main economic activities……

b. The Respondent

1. Name of Respondent……
2. Position of leader: Chairperson ☐ Member ☐
3. Gender: Female ☐ Male ☐
4. Age of respondent: 20-29 ☐ 30-39 ☐ 40-49 ☐ 50-on ☐
5. Level of education: Primary☐ Secondary☐
6. Marital status: Single ☐ Married ☐

II. Knowledge and awareness on conservation related issues

1. How do you describe in one word water availability in your village?

   Normal ☐ Difficult ☐

2. Are there wild animals currently found in your village/district?

   Yes ☐ No ☐

3. Shortage of cultivation land is due to increase in human population

   1 ☐ 2 ☐ 3 ☐ 4 ☐

4. There is relationship between conservation and better livelihoods

   1 ☐ 2 ☐ 3 ☐ 4 ☐

5. Soil erosion from your village is cause siltation of Lakes Manyara and Eyasi

   1 ☐ 2 ☐ 3 ☐ 4 ☐

6. The water source for your village is located in the nearby protected area

   1 ☐ 2 ☐ 3 ☐ 4 ☐

III. Attitudes towards of conservation village areas

1. Charcoal making activities are important for your village development

   1 ☐ 2 ☐ 3 ☐ 4 ☐

2. Village conservation bylaws have inadequate penalties for offenders

   1 ☐ 2 ☐ 3 ☐ 4 ☐

3. The performance village environmental conservation committee is satisfactory

   1 ☐ 2 ☐ 3 ☐ 4 ☐

IV. Attitudes towards the roles of surrounding protected areas

1. Protected areas considerably contributed to the development of your village

   1 ☐ 2 ☐ 3 ☐ 4 ☐

2. Protected areas are not doing enough to support social services in village

   1 ☐ 2 ☐ 3 ☐ 4 ☐

V. Wild animal species and their corridors in village areas

1. Mention wildlife species most frequently encountered in village areas.....
2. Is there any wildlife corridor in your village/district areas?

   Yes ☐ No ☐

VI. Conservation stakeholders at the village levels

1. Which is the main source of information for conservation activities in your areas?

   PA ☐ District council ☐ Central government ☐ NGOs ☐

2. Mention one thing found in PA that you wish to be available in your village.....
3. The central government does not provide support for conservation in your village

   1 ☐ 2 ☐ 3 ☐ 4 ☐

Thank you for your time and participating to fill in this questionnaire

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