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Full Length Research Paper

Raid range selection by elephants around Kakum Conservation Area: Implications for the identification of suitable mitigating measures

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The factors that influenced elephants raiding in some spatial ranges around Kakum Conservation Area (KCA), Ghana were investigated. Crops were the basis for range selection by the elephants and the most commonly raided crops were plantain, cocoa and cassava. However, oil palm (*Elaeis guineensis)* plantations, bushes, crops at seedling and growing stages, or farms with active pepper fence never suffered any raid. It was observed that the presence of pawpaw (*Carica papaya*) and bako (*Tieghemella heckelii)* exposed nearby farms to risk. Since elephants do not raid oil palm plantations around KCA, we recommend that only oil palm groves should border the KCA to mitigate human-elephant conflict around KCA and that the pepper-fence method currently in use could also be effective if its accompanying financial burden is taken away from the farmers and funded by the government.

Key words: Raided zone, oil palm plantation, pepper-fence, human-elephant conflict, protected areas.

INTRODUCTION

West Africa is the only region where a higher proportion of elephant range (about 60%) is found inside designated protected areas than outside. Many of these protected areas, however, are forest reserves, which only afford limited protection (Blanc et al., 2007) but as expanding human populations compete with elephants for habitat (Blanc et al., 2007) and resources (Conover, 2002), the future of forest elephant populations may soon depend entirely on protected areas (Barnes, 1999). The protected range of elephants in Ghana is about 22.8% (Blanc et al., 2007), and elephants in Ghana continue to be under pressure from habitat fragmentation and high human population densities (Barnes, 2002). Shifting cultivation up to the boundaries of protected areas exacerbates the problem of crop raiding by elephants, which is severe wherever elephants occur (Barnes, 2002).

In their position as keystone species that play a major role in stabilizing plant and animal communities (Campos-Arceiz and Blake, 2011; Beaune et al., 2013), or charismatic icons of conservation (Dublin and Hoare, 2004), elephants should enjoy adequate security in protected areas. However, a severe conflict has

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developed between elephants and humans, sometimes leading to serious fatalities on either side (Kiiru, 1995; Nelson et al., 2003; Omondi et al., 2004; Malima et al., 2005; Campfire, 2007; Kioko et al., 2008).

Farmers around protected areas rely on subsistence agriculture as well as cash crops for their food security and livelihoods. However, these crops are also an attractive, accessible, and predictable source of food for elephants (Monney et al., 2010). As a result, elephants may raid crops for food and inflict considerable damage with corresponding impacts on farmer livelihoods. It cannot be overemphasized that wherever agriculturists and elephants (*Loxodonta* spp. and *Elephas maximus*) share the same landscape, conflict develops (Lahm, 1994; Barnes, 1996; Naughton-Treves, 1998; Whyte et al., 1998; Hoare, 1999; Mubalama, 2000; Seneviratne and Rossel, 2001; Sitati et al., 2003; Sukumar, 2003). Ensuring farmers livelihoods and food security through reduction of HEC is an internationally agreed goal (Parker et al., 2007) and conservation managers today are required to tackle this complex issue in collaboration with communities in order to achieve conservation objectives (Parker et al., 2007). If solutions to alleviate crop raids by elephants are not found, persistent raiding of crops may compromise elephant conservation (Chiyo and Cochrane, 2005).

For over a decade, the African Elephant Specialist Group (AfESG) has been actively concerned with trying to help unravel the dynamics of HEC with a view to mitigating the problem (Dublin and Hoare, 2004). It is therefore recognized that a long term solution to elephant crop raids can be devised based on the outcome of proper investigations of the behavioral dynamics and pattern of raids by the elephants (Monney et al., 2010). The farming landscape outside protected area has not been completely unraveled and the actual raid ranges have not been mapped. Mapping and the use of spatial data for forest resource management and planning have been recognized worldwide, especially if they are transformable to readily-analyzed formats. The application of integrated GPS/GIS technology to habitat utilization models has enabled the identification of those areas most at risk from elephant raids (Breininger et al., 1991; 1995; Duncan et al., 1995). A map of this nature is expected to give a clear picture of the elephant raid situation around KCA.

The current problem around KCA is that about 52 communities are located at the fringes of the protected area and farm at its edge sometimes to the immediate boundaries. The farms attract elephants that wander off the reserve (Boafo et al., 2004; Monney et al., 2010), and this coupled with lack of appropriate mechanisms to ward off the elephants have resulted in crop raiding incidences with consequent HEC. Apart from feeding on farm crops, the forest elephant is also noted for uprooting, breaking, trampling and plucking crops without eating them (Monney et al., 2010). The factors that influence raid zone selection by the elephants by mapping the range raided by the animals around the KCA were investigated. This is expected to enable the identification of raid range preferences and rejections by elephants around the KCA. It is hoped that the results will inform the management towards appropriate ways to control raids by the elephants and hence find lasting solutions to HEC.

MATERIALS AND METHODS

Study area

The study was undertaken around the Kakum Conservation Area (KCA), Central Region, Ghana, lying between longitude 1° 30 ' W - 1°51' W and 5° 20 ' N – 5° 40 ' N (Figures 1 and 2) from October, 2011 to September, 2012. The KCA consists of the Kakum National Park (KNP) and the Assin Attandanso Resource Reserve (AARR) and is managed as a national park by the Wildlife Division of Forestry Commission. Towards the end of the 19th century, the Kakum forest was among the various reserves set aside as the "*Celtis-Lophira* hardwood Ghana's Production Resource Reserve"; but the boundaries were not clearly demarcated until 1925. In 1940, the Assin Attandanso forest was added to form a 366 km^2 contiguous block in the moist evergreen forest zone (Hall and Swaine, 1976). Timber exploitation especially of *Khaya ivorensis* (mahogany) escalated from the 1950s until 1989 when the reserve was placed under the then Ghana Wildlife Department (GWD). Over the years, many laws (e.g. 1961 Wild Animals Preservation Act and the Legislative Amendments of 1971) had to be passed to make the existence of the park a reality. The KCA was finally gazetted as a national park and resource reserve by Legislative Instrument 1525 of 1992 under the administrative jurisdiction of the GWD.

The dominant vegetation type is moist forest, with other vegetation types being swamp forest (permanent and periodic) and riverine forest. The canopy coverage is closed or open, with irregular distribution of about 105 species of vascular plants (Wiafe et al., 2010). A small elephant population of about 160 (Dudley et al., 1992; IUCN, 2004) exists within the Kakum Conservation Area among populations of other mammals. KCA is surrounded by agricultural farms and about 52 communities with an estimated total population of 50,000 people. The main source of income of the indigenes is agriculture, supported by logging, hunting, trading, small-scale mining, charcoal burning and domestic animal rearing.

Range mapping

The study area was divided into nine sites, namely Kruwa, Briscoe II, Adiembra, Ahomaho, Aboabo, Afiaso, Antwikwaa, Mfuom and Abrafo (Figures 2 and 3). These sites were named after the nearest fringe communities or staff camps. GPS readings were taken along the boundaries of the ranges raided or visited by elephants, each at about 400 m intervals or less where necessary. GPS readings were also taken at the centre of each nearby community or staff camp. Range around KCA found to have been raided or visited by the elephants were investigated over the study period. Factors that attracted the elephants to the range, the vegetation type and the general habitat features at raided ranges were recorded.

Raid behaviour

A distance of about 50 m from the elephants was maintained to walk behind them to investigate their activities and raid behavior

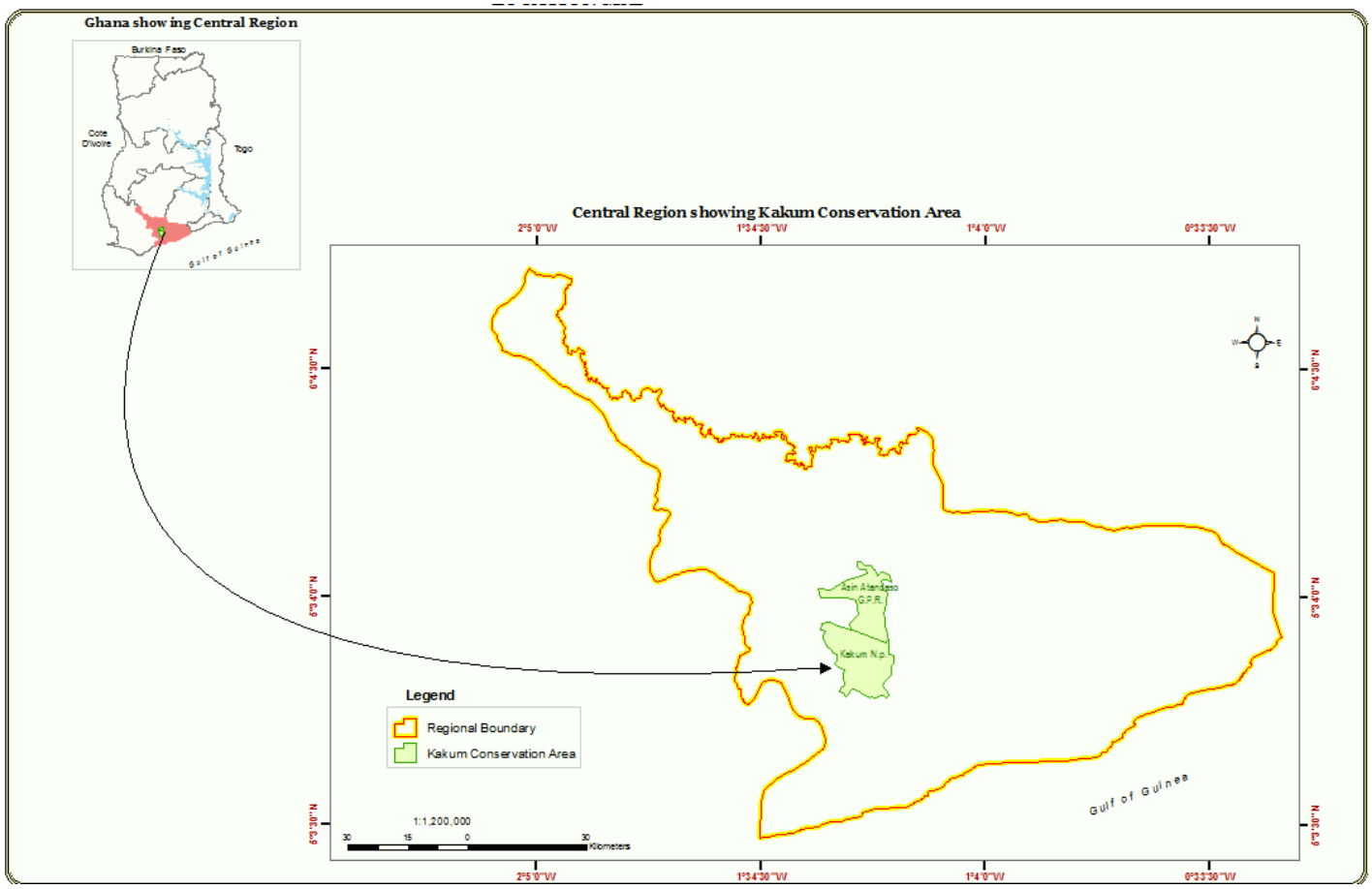

Figure 1. Central Region of Ghana showing the location of KCA.

and determine the herd sizes and raid frequency of herd sizes in such raid ranges.

Seasonal raids

The study period covered both rainy and dry seasons in order to investigate raid occurrences in these two seasons: The two rainy seasons from April to July and from September to November, and the dry seasons from December to March and in August. Data were collected in each season.

Data processing and analysis

GIS (v9.3) remote sensing was used to interpret GPS readings. Spatial data of GPS were downloaded onto a computer, converted to a database file and exported to Arc Map to be projected into a Geographical Coordinate System plotted as individual points and joined together to form maps. All statistical analyses involved the use of Microsoft Excel® software (2007) and PAST (Paleontological Statistics Software Package for Education and Data analysis) software (Hammer et al., 2001). Ordinary least square was used to regress herd size against frequency of raid to evaluate the hypothesis that smaller herd sizes raid more frequently than larger herd sizes or smaller herd sizes raid less frequently than larger herd sizes. Chi-square test was also used to evaluate the hypothesis that raids were more frequent during the dry season than the rainy season.

RESULTS

Range mapping

Sixty-three elephant raid ranges were mapped around KCA during the one-year study and these covered a total land area of 289,447.30 m^2 (Table 1). Afiaso site recorded the highest number of 15 raided ranges covering a total land area of 86,698.40 m^2 representing 30% of the total land area raided, while Briscoe II site recorded the lowest of the two raided ranges covering 1,625.60 m^2 (0.6% of total land area) (Table 1). It was observed that people farmed to the immediate boundaries of the park (Figure 3) as pointed out by previous studies (Barnes et al., 2003; Monney et al., 2010). Crops raided were cocoa (*Theobroma cacao*), cassava (*Manihot esculentus*), plantain (*Musa paradisiaca*), cocoyam (*Xanthosoma* sp.), banana (*Musa*

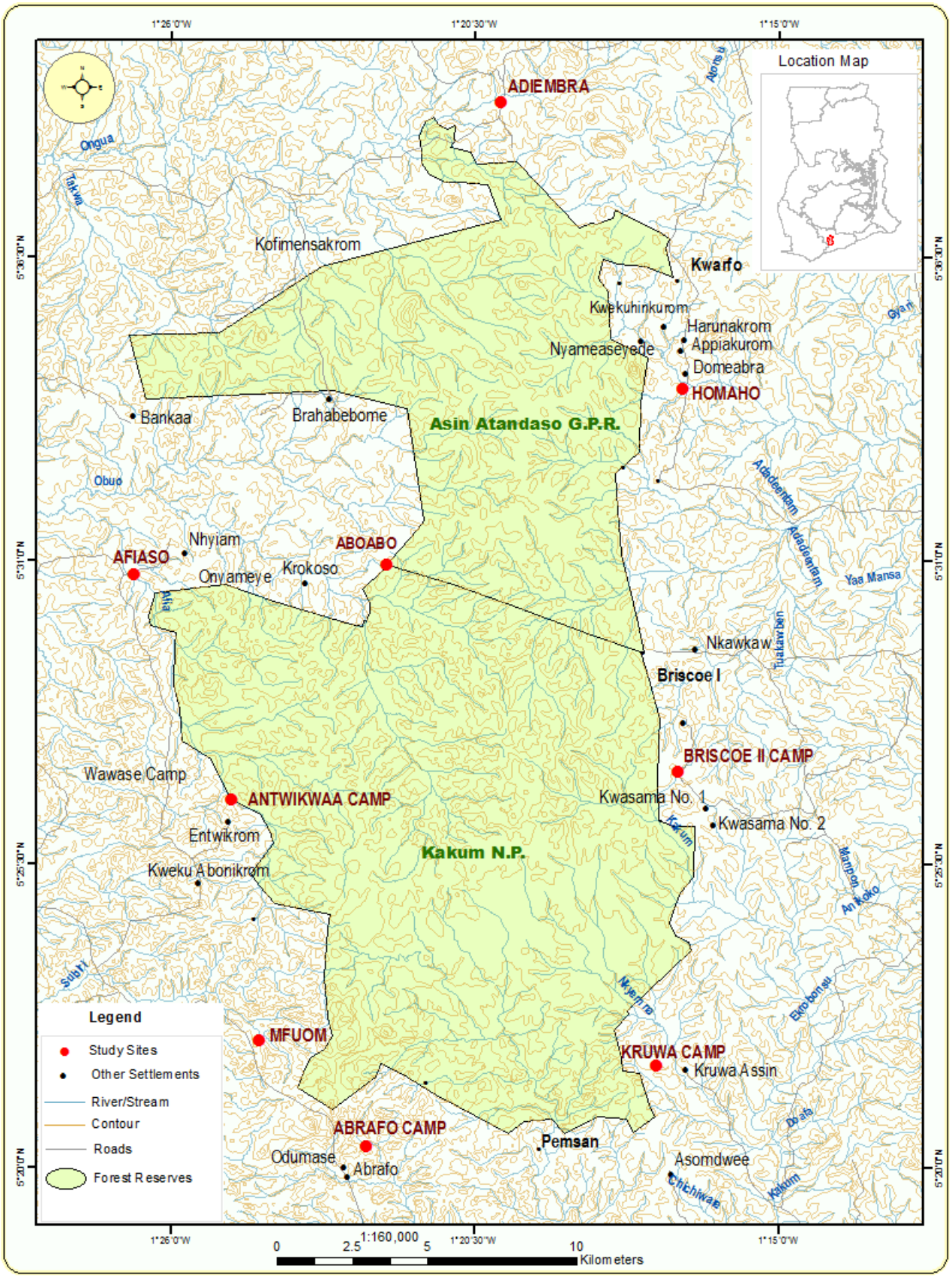

Figure 2. Map of KCA showing surrounding communities.

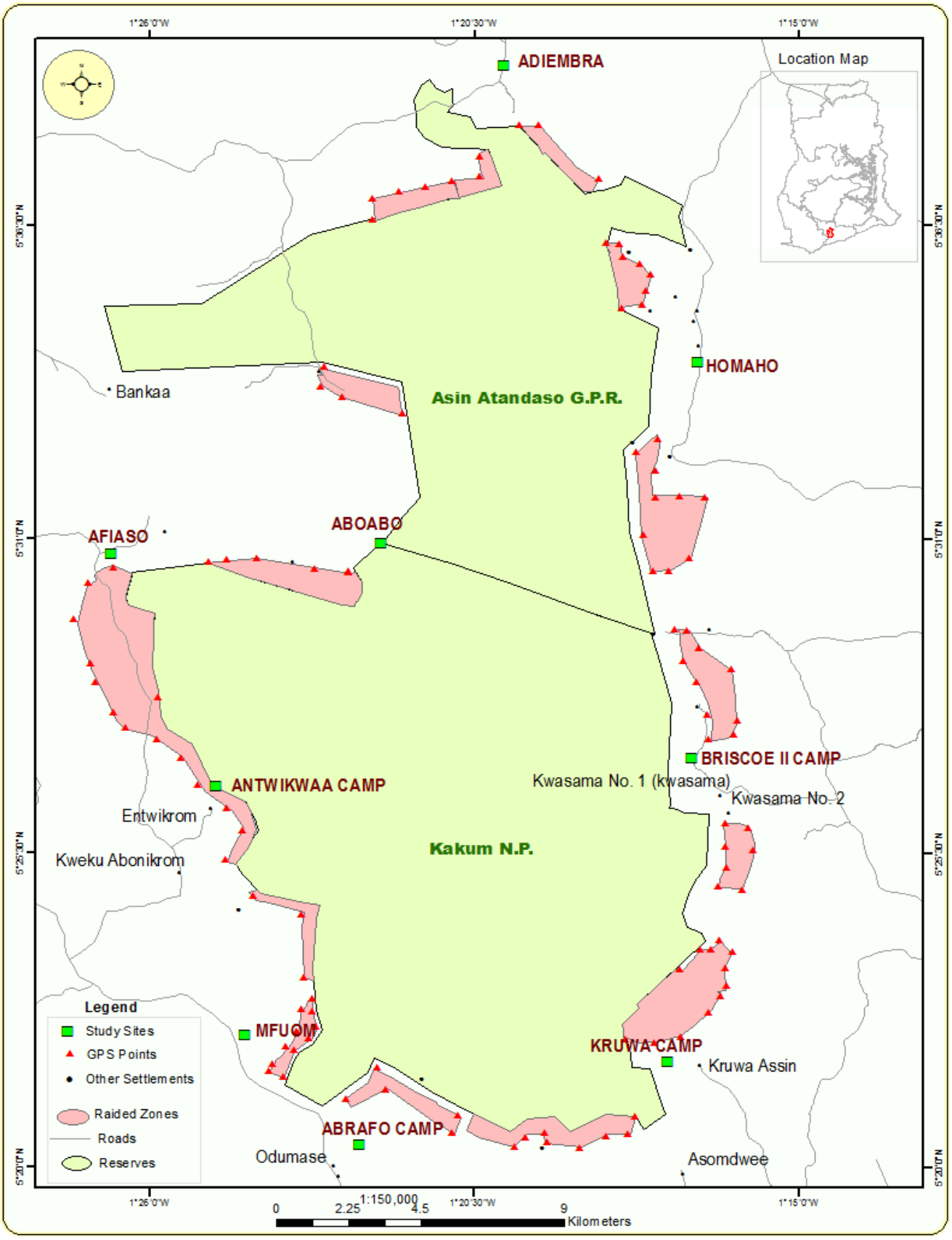

Figure 3. Map of KCA showing raided ranges around it.

Table 1. Activities of elephants in raid ranges in each study site.

Study site	Number of raid ranges	Total area raided (m^2)	Dominant plant/crop	Activities of elephants
Kruwa	7	18,223.20 (6.30%)	Cocoa, cassava, plantain, banana, maize	Eating, breaking, uprooting and trampling
Briscoe II	2	1,625.60 (0.56%)	Cassava, plantain, maize	Eating, breaking, uprooting and trampling
Adiembra	5	16,241.20 (5.61%)	Cocoa, cassava, plantain, maize	Eating, breaking, uprooting, and trampling
Ahomaho	8	39,649.60 (13.70%)	Cocoa and plantain	Eating, breaking and trampling
Aboabo	8	13,004.80 (4.49%)	Cocoa, cassava, plantain,	Eating, uprooting, breaking and trampling
Afiaso	15	86,698.40 (29.95%)	Cocoa, cassava, plantain, maize, cocoyam, yam	Eating, uprooting, breaking and trampling
Antwikwaa	9	17,068.80 (5.90%)	Cocoa, cassava, plantain, yam	Eating, breaking, uprooting, and trampling
Mfuom	5	54,186.5 (18.72%)	Cocoa, cassava, plantain	Eating, uprooting, breaking and trampling
Abrafo	4	43,349.2 (14.98%)	Cocoa, cassava, plantain,	Eating, uprooting, breaking and trampling
Total	63	289,447.3 (100%)		

sapientum), yam (*Dioscorea* sp.) and pawpaw (*Carica papaya*) (Table 1).

Raid behaviour

Though the elephants fed mostly on mature plants, not all raids recorded in this study were accompanied by feeding. There were some examples of raids without consumption at four sites, namely Kruwa, Adiembra, Antwikwaa and Aboabo (Table 3). Some ranges occupied by oil palm (*Elaeis guineensis)* or bushes including *Chromolaena odorata, Securinega virosa, Aspilia africana, Mallotus oppsitifolius and Mimosa pudica,* never suffered any elephant raids (Table 2). There were no records of oil palm raids by the elephants around KCA throughout the study period. It was observed that elephants walked through palm plantations to consume pawpaw plants on 13 occasions (Table 2). Other farms which were also not raided were those in which crops were at the seedling and growing stages or with active pepper fences (fences still smelling of pepper). Farms with inactive pepper fences (no pepper smell) were however raided. Pepper fencing involves soaking rags in a mixture of ground pepper and grease and hanging the rags on fences around each farm. Four farm ranges covering a total land area of 6,268.30 m^2 (Table 2) were never raided by the elephants due to the pepper fences at the boundaries of those farms. The elephants were observed attempting to raid such farms on many occasions but were repelled by the scent of pepper. However, at some sites such as Mfuom (Figure 4) and Abrafo, because pepper scent waned, elephant raids were detected. Visits to farms by the elephants did not always result in crop raiding. For example, four times at Kruwa and two at Mfuom, the elephants walked through farms with only young growing crops such as seedlings without raiding.

We observed that the elephants showed special preference for some plants, notably pawpaw (*Carica papaya)* and bako (*Tieghemella heckelii*). This was evidenced by the frequency at which bako or pawpaw was selected from non-raided ranges after walking past other plants intact except for the obvious trampling as the elephants moved through them. For a mature pawpaw, almost the entire plant is taken as food, while in the case of the bako, only the fruit was of interest to the elephants.

It was observed that elephants raided in herds of two to eight individuals (Table 5) though the field staff used to see herd sizes up to 15. Results of regression analysis indicated a non-significant negative relationship between herd size and frequency of raids with a probability of less than 50% of the raid events ($Y = -0.975x + 9.04$, $r = -.607$, $R^2 = 0.37$, $t = -1.708$, $p = 0.148$). Therefore, the hypothesis that the frequency of raid events is influenced by the size of a herd was rejected.

Seasonal raiding

Raids were recorded in both rainy and dry seasons, even though figures recorded for the rainy season were higher than those in the dry season (Table 4). Chi-square tests however indicated no significant differences ($\chi^2 = 15.48$,

Table 2. Activities of elephants in non-raided ranges in each study site.

Study site	Number of non-raided ranges	Total land area of non-raided ranges (m^2)	Nature of land	Dominant plant/crop	Activities of elephants (no. of times)
Kruwa	6	24,232.30	Bushes, pepper - fenced farm	*Chromolaena odorata,* oil palm	NIL
Briscoe II	5	70,124.40	Abandoned farm	*Securinega virosa*	Consumed pawpaw plants (3x) and bako fruits (3x)
Adiembra	6	18,243.20	Bushes, pepper - fenced farm	*Chromolaena odorata,*	NIL
Homaho	7	43,694.60	Bushes, pepper - fenced farm, belled farm	*Mallotus oppsitifolius, Mimosa pudica*	Consumed pawpaw plants only (2x)
Aboabo	9	47,364.30	Bushes	*Chromolaena odorata,* and oil palm	NIL
Afiaso	10	1,725.60	Bushes	oil palm *Chromolaena odorata,*	Consumed pawpaw plant only (6x)
Antwikwaa	12	20,068.80	Bushes, pepper - fenced farm	*Chromolaena odorata,*	NIL
Mfuom	4	63,186.5	Bushes	*Aspilia africana, Mallotus oppsitifolius*	NIL, consumed pawpaw plants only (2x)
Abrafo	5	51,342.2	Bushes, pepper fenced farm	*Mimosa pudica Securinega virosa,* oil palm	NIL
Total	64	339,981.9			

Table 3. Frequency of raids by elephants at each study site during the study period.

Study site	Frequency of raids by elephants at the various sites observed by our team (and by field staff)			
	Dry season	Total	Rainy season	Total
Kruwa	1 (10)	11	3(16)	19
Briscoe II	0 (2)	2	1 (4)	5
Adiembra	2 (11)	13	5 (12)	17
Ahomaho	2 (13)	15	3 (13)	16
Antwikwaa	1 (0)	1	2(16)	18
Afiaso	3 (3)	6	4 (13)	17
Aboabo	2 (3)	5	4(8)	12
Mfuom	0 (8)	8	0(6)	6
Abrafo	0 (8)	8	4 (5)	9
Total	11 (56)	67	26 (93)	119

df = 8, p = 0.059), and thus the hypothesis that raids were more prevalent in the rainy season than the dry season around KCA was rejected.

DISCUSSION

The results of this study are consistent with the expectation by Monney et al. (2010). For crop raiding to escalate around KCA, indeed,crop raiding by elephants has doubled in less than two years, with 63 raided farms covering a total land area of 289,447.30 m^2 as compared to 33 raids covering 103,496.20 m^2 land area (Monney et al., 2010). This is probably because the elephants became adapted to some deterrent measures that

Figure 4. Inactive pepper-fenced farm.

Table 4. Composition of elephants in raids during the study period.

Herd size recorded	Frequency	Study site(s) and (number of times herds were encountered at site)
1	3	Afiaso (3)
2	10	Afiaso (2), Aboabo (2), Abrafo (2), Kruwa (2), Adiembra (2)
3	9	Kruwa (2), Adiembra (2), Homaho (2), Aboabo (3)
4	8	Homaho (2), Adiembra (2), Afiaso (2), Antikwaa (1), Aboabo (1)
5	3	Briscoe II (1), Antikwaa (1), Adiembra (1)
6	1	Antwikwaa (1)
8	1	Homaho(1)

restrained them previously. For example, it was showed that pepper fencing had been ignored by some of the farmers (Monney et al., 2010; Wiafe and Sam, 2014) and it appeared that the elephants tool advanture from lapses in this deterrent measure and raided when the effect of the pepper had waned (Monney et al., 2010; Wiafe and Sam, 2014).

Field staff confirmed that the elephants could smell the pepper application and stayed far away from the source though no estimates of how far they stay away had been made so far. The implication of this observation is that pepper fencing to protect farms far away from the reserve boundary may be unnecessary and may rather elicit raids by the elephants when the scent of pepper wanes. Also, bako and pawpaw plants were found to trigger crop raiding as the adventure the animals took towards these plants linked them to some nearby farms. Even though this study has inadequate data in the case of the bako tree, this has been confirmed by the field staff. Thus, farmers far away from the park's boundary would be better advised to get rid of pawpaw trees from their farms. In previous studies, plantain, cassava and cocoa farms were found to be the most commonly raided and sources of great risk to farmers around KCA (Barnes et al., 1995; Barnes et al., 2005) and around Bia National Park, Ghana (Sam et al., 2005). Other studies reported banana as the most preferred, for example around the Kibale National Park, Uganda (Naughton-Treves, 1998)

Table 5. Composition of elephants in raids during the study period.

Herd size recorded	Frequency	Length x width of foot print (cm) for herd size	Study site(s) and (number of times encountered at site)	Mode of encounter
1	3	40 x 39	Afiaso (3)	Sight (1), footprint (2)
2	10	50 x 47, 42 x 40	Afiaso (2), Aboabo (2), Abrafo (2), Kruwa (2), Adiembra (2)	Footprint
3	9	50 x 47, 42 x 40, 35 x 32	Kruwa (2), Adiembra (2), Homaho (2), Aboabo (3)	Footprint
4	8	42 x 40, 35 x 32, 36 x 33, 32 x 29	Homaho (2), Adiembra (2), Afiaso (2), Antikwaa (1), Aboabo (1)	Footprint
5	3	51 x 47, 48 x 44, 49 x 47, 42 x 40, 39 x 37	Briscoe II (1), Antikwaa (1), Adiembra (1)	Footprint
6	1	50 x 46, 46 x 43, 35 x 32, 30 x 28, 25 x 22, 21 x 19	Antwikwaa (1)	Sight
8	1	50 x 47, 42 x 40, 49 x 47, 42 x 39, 39 x 36, 35 x 32, 25 x 22, 20 x 18	Homaho(1)	By footprint

and across Gabon (Lahm, 1994).

The elephant is one of the wild species that cause very severe damage to crops and jeopardize entire families' livelihoods. The complex situation currently is that while the feeding behavior of elephants constitutes crop raiding to humans because they cause damage to their crops, this study supports Monney et al. (2010) that the elephants around KCA also raided without feeding. It seems that stringent monitoring of crops by elephants has resulted in the phenomenon of raiding without feeding and that any mechanism used to elude the elephant apart from quitting farming and using the appropriate deterrent method will rather induce the elephants to cause more damage.

Current deterrent methods including pepper fencing, guarding farms in the night and scaring elephants with noise and bells have their own disadvantages which make them ineffective. For example, guarding farms at night involves sacrificing economic ventures during the daytime with compensatory rest. Also, the otherwise most effective deterrent pepper fencing method has not been well patronized due to the cost and effort involved in fencing large farms. Even in the presence of the pepper fence, elephants may still attempt to visit farms looking for lapses in the construction. New ways of the application of pepper as elephant repellent have been tested in Zimbabwe (Le Bel et al., 2010) involving dispensers and projectiles propelling small balls (40–50 mm diameter) filled with either chilli-pepper powder or oil extract but Niskanen (2006), Osborn and Rasmussen (1995), Osborn FV (2002) found lapses in this method. There have been experiments with beehives and elephants elsewhere (Vollrath and Douglas-Hamilton, 2002; King et al., 2009) but this option has not been explored in KCA because it has been proven that bees alone will not stop elephants from raiding crops (Karidozo and Osborn, 2005). Also, electric fences found to be the best solution according to Thouless and Sakwa (1995) have been found to be expensive to maintain (Kioko et al., 2008) while the use of aspirin is traceable in the food web to have adverse consequences on other fauna.

One important finding of this study is that oil palm plantations were never raided at the fringes of the park by the elephants no matter how close the oil palm occurred to the boundary. It has been recommended for management to seek collaboration with farmers and chiefs of fringe communities and with government assent to allow only oil palm plantations around the park as a long term solution to HEC. It is believed that the proximity of the Twifo Oil Palm Plantation (TOPP), about 3.5 km away from the Reserve, will offer a ready market to boost palm oil production in the country, and also offer a more reliable means of income to the communities. This, however, requires great effort initially until the palm seedlings mature to gain immunity from elephant raids. Establishment of oil palm plantations has usually been a controversial issue as forests are sacrificed for them. However, areas around the KCA are already destroyed forest and farmlands, and therefore present a different scenario from the general biodiversity concerns.

In conclusion, this study perceives the problem of farm crop raiding by elephants from KCA as becoming increasingly complex. The mitigating measures used so far offer no lasting solution and HEC continues to escalate. The KCA elephants have evolved to show special preference for a variety of farm crops as food and it seems that they try to access every area possible in their search for food and so preventive measures used should be sustainable. The recommended oil palm plantation, if considered, may offer a more effective

solution than all the previous and currently existing mitigating measures, and others adopted elsewhere, especially combined with the application of pepper-fence method currently used. But the pepper-fence method can be effective if the financial burden is taken away from the farmers.

Conflict of Interests

The author(s) have not declared any conflict on interests.

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Woody plant species diversity in the last wild habitat of the Derby Eland (*Taurotragus derbianus derbianus* Gray, 1847) in Niokolo Koba National Park, Senegal, West Africa

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The Niokolo Koba National Park (NKNP) in Senegal is the last refuge of the critically endangered antelope of the subspecies Derby Eland (*Taurotragus derbianus derbianus* Gray, 1847). Woody plants, that provide shelters and forage for the Eland in NKNP, were assessed for their floristic diversity to characterize its confined habitat. Hence, 156 square plots of 20m x 20m were established randomly in the confined area of the Derby Eland. In each plot, list of plants species, their number of individuals, and the environmental factors (soil hardness and type, altitude, percentages of vegetation cover and fire occurrence) were noted. Fifty (50) trees species belonging to 40 genera and 29 families were recorded. The most represented families were *Combretaceae* (13.92%), *Leguminosae-mimosoideae* (12.66 %), *Leguminosae-caesalpinioideae* (11.39 %), *Leguminosae-papilionoideae* (7.59 %), *Rubiaceae* (7.59 %) and *Tiliaceae* (6.33 %). The most abundant species were *Combretum glutinosum* Perr. ex DC., (28.79%), *Pterocarpus erinaceus* Poir. (12.42%), *Crossopteryx febrifuga* (Afzel. ex G. Don) (7.30%), *Strychnos spinosa* Lam. (7.18%) and *Hexalobus monopetalus* (A. Rich.) Engl. & Diels (7.06 %). Altitude, fire occurrence and vegetation cover were the most important environmental factors influencing the distribution of plants species. Results suggest conservation defenders of Eland, for a sustainable management plan, to invest in in-*situ* fencing in order to increase possibilities of conservation of this critically endangered species in its native area.

Key words: Plant inventory, specie composition, confined habitat, wild, sustainable management.

INTRODUCTION

For millennia the earth's greatest diversity of ungulates has been carried by African savannahs that extend from

Senegal in the west to Ethiopia in the east. These biomes include tropical ecosystems characterized by a continuous grass layer occurring together with trees under a different climatic regime (Justice et al., 1994). These ecosystems provide shelters and food for wildlife. Unfortunately during these last decades, researches have shown that savannahs are undergoing degradation and fragmentation due to combined effects of fire, human activities and climate variation (Riggio et al., 2013). Consequently, some species are highly endangered and at risk of extinction among which the large mammals like ungulates are the most threatened (Baskaran et al., 2011). In West Africa particularly in Senegal, the Derby Eland (*Taurotragus derbianus derbianus* Gray, 1847) is one of the mammalian species on the International Union for Conservation of Nature (IUCN) red list of critically endangered species and even close to extinction (UICN, 2008).

The Derby Eland was widespread to West African savannah and its historical range covered Cameroon – Gambian's axis (Dorst and Dandelot, 1970). Nowadays owing to natural and human pressures its wild habitat is solely restricted to the Niokolo Koba National Park (NKNP) and its neighbouring Faleme Hunting Zone both (East, 1998; IUCN, 2008). NKNP is Senegal's largest and oldest national park set on Sudano-Guinean savannah (Madsen et al., 1996; Mbow, 2000). Despite its already shrunk location, the Eland's natural habitat in the national park is currently undergoing degradation emphasizing its shrinking and the number of Eland individuals is decreasing (IUCN, 2008). In 1990, the population of Eland was estimated at 1000 individuals (Sournia and Dupuy, 1990) but its later estimation set between 400 to 800 individuals (East, 1998) and has been decreased to approximately 170 individuals in wildlife in the NKNP (Hájek and Verne, 2000; Renaud et al., 2006).

This continuous decreasing population puts Eland on the UICN critical list of endangered species (IUCN, 2008). In the light of this, some preservative measures were taken with the establishment of the first breeding ex-situ herd in Bandia reserve (Antoninova et al., 2004). Till recent date, little is known on the wild habitat of the Derby Eland in its last natural refuge. Researches had been done on the Western Derby Eland in wild but they had a narrow-scope, mainly oriented on aerial and ground survey in the NKNP (Galat et al., 1992; Hájek and Verne, 2000; Renaud et al, 2006) and on the diet constituents (Hejcmanová et al., 2010). There is lack of ecological information on its habitat which deserves to be filled. In contrast to the habitat of its relative, the Eastern Derby Eland (*Taurotragus derbianus gigas* Heuglin, 1863) which is dwelling in savannah vegetation is dominated by *Isoberlinia doka* (Bro-Jorgensen, 1997; East, 1998; Grazian and d'AlessiSilvio, 2004) is more documented.

Therefore it becomes urgent for a better conservation strategy and a sustainable management in the wild habitat to describe its last habitat. Hence this study aims to improve knowledge and information on the last worldwide wild habitat of the Western Derby Eland for its better ecological management and for decision making. Research focused on the species' composition and diversity in relation with the environmental factors in order to provide basic knowledge for the sustainable management of the Western Derby Eland population in NKNP. As the Derby Eland is a browser (Grazian and d'AlessiSilvio, 2004), the study hypothesized that it lives in habitat with a similar floristic composition.

MATERIALS AND METHODS

Study area

Stretching on 2485 km^2 the study area is located roughly at the centre-east of the NKNP between -13°23' and -12°51' W and 13°23' and 12°69' N (Figure 1). The rainfall regime is single modal from June to September with a mean annual rainfall of 900 to1100 mm. The average monthly temperature is 25°C from November to January and 33°C from April to May, and the relative humidity is between 69 and 97%. In NKNP anthropogenic, activities are strictly prohibited. Therefore vegetation in the park is supposed to be well protected from the anthropogenic factor but it has been strongly affected by the early fire's management (Mbow, 2000; Sonko, 2000). The confined habitat of the Derby Eland identified through a survey with the elder evicted villagers, the researchers and the retired elder and current park rangers, were divided in zone of medium probability of Eland occurrence (ZMPEO) and in zone of high probability of Eland occurrence (ZHPEO) (Figure 1).

Sampling design and data collection

Plant Inventory was made using a stratified random scheme at 2 levels. Stratification was based on a land cover map derived from a supervised classification of Landsat 8/OLI (Operational Land Imager) and a ground truth for validation. Landsat images were acquired in December, 2013 from Glovis (http://glovis.usgs.gov/). Squares plots of 250 m x 250 m size were randomly set on a net grid map of the study area. Within each selected plot, four square sub-plots of 20 m x 20 m size (400 m^2) were established using a random distance from the centre in compass directions (Figure 2). Plots size was justified by the fact that they were used successfully during previous studies (Hejcmanovā and Hejcman, 2006; Sambou et al., 2007; Sambou et al., 2008; Mbow, 2013). The sample size

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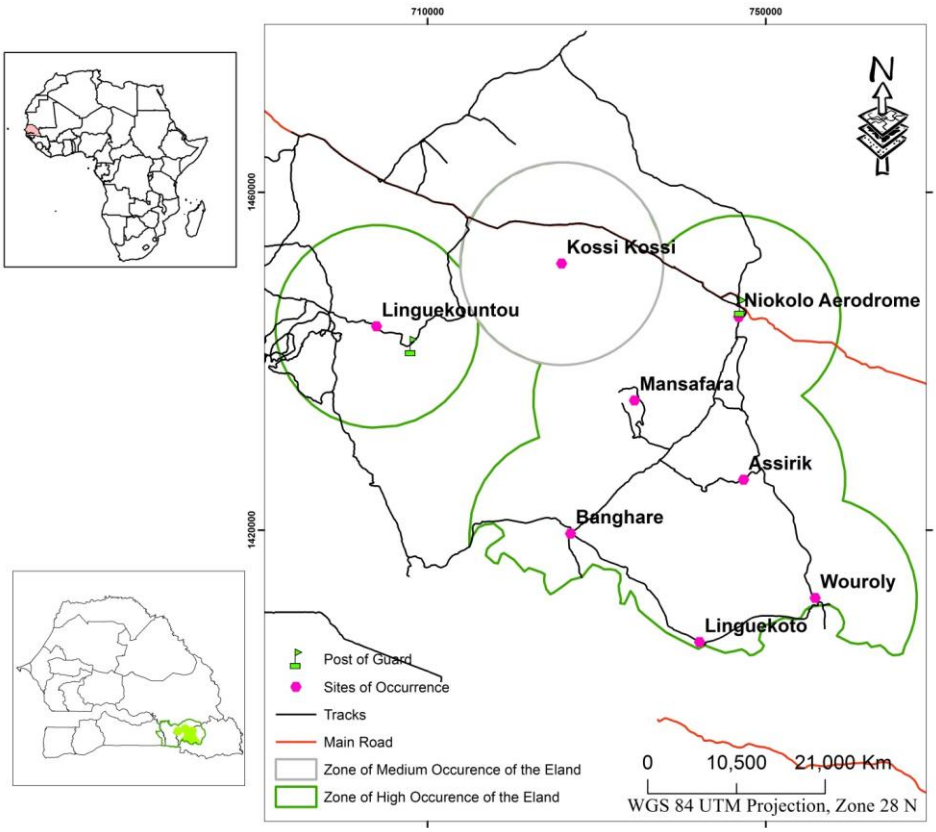

Figure 1. Location of the study sites.

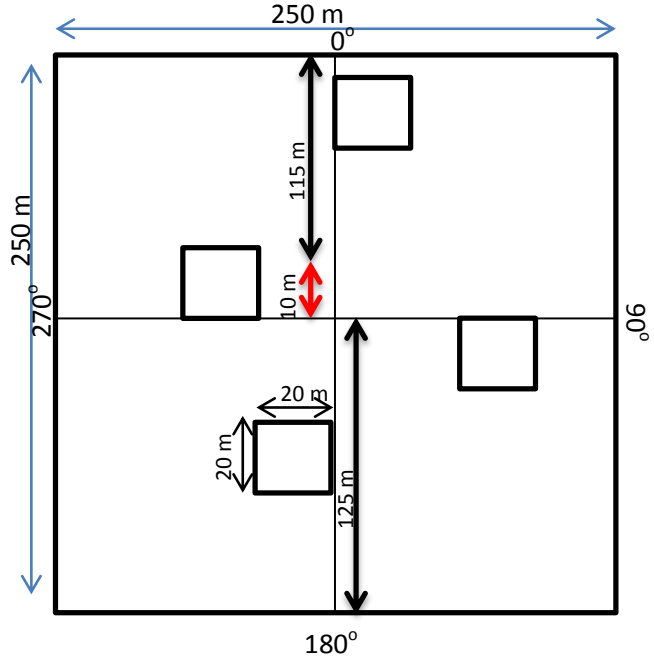

Figure 2. Sampling design.

(N=156 plots) was computed with a margin error of 9% using the following formula of (Dagnelie, 1998):

$$N = t^2_{1-\alpha/2} \frac{cv^2}{d^2} \quad (1)$$

Where N: sample size, $t^2_{1-\frac{\alpha}{2}}$ = 2.04 as value of the Student t distribution test at probability of 0.975 and Cv= 57 % as coefficient of variation of basal area from 30 trees' individuals randomly chosen during a pre-inventory.

Woody plants with dbh ≥5 cm were assessed for their species names and number following (Berhaut, 1967; Lebrun and Stork, 1991, 1997). The altitude and the soil hardness were recorded respectively with an altimeter and a penetrometer. The tree and herbaceous cover were estimated in percentage and the occurrence or not of fire was noted according to traces left.

Data analysis

To test discrimination of the zones of occurrence Derby Eland according to their plants species composition, the matrices of trees species abundance per plot were submitted to a non-metric multidimensional scaling (NMDS) which produces an ordination based on Bray-Curtis dissimilarity (Kruskal, 1964a; Kruskal and Wish, 1978). Confidence ellipses were built for each group of plots at 95%. Before analyses, data quality control led to removal empty and duplicated plots. Then species indicator value analysis, based zones of Derby Eland occurrence in rows and species abundance in columns were used to identify indicator species of each group of plots (De Cáceres et al., 2012). Indicator species are determined using an analysis of the relationship between the species abundance values from a set of sites and the classification of the same sites into site groups (zones of Eland occurrence in our case). The indicator value index (IndVal) is the product of two components, referred to as 'A' and 'B'. Component 'A' called the specificity or the positive predictive value of the species is the probability that the surveyed site belongs to the target site group given the fact that the species has been found. The Component 'B' called the fidelity or sensitivity of the species is the probability of finding the species in plot belonging to the site group. Only the first five most significant species or species combinations were also reported. Alpha diversity indices were computed for each the global stand and for zone of Derby Eland's occurrence as follows:

1. Species richness (S) is the number of species recorded in each zone of occurrence and in the global stand.
2. Shannon-Wiener diversity index (H') was calculated using this formula**:**

$$H' = -\sum_{i=1}^{i=s} pi \log_2 pi \quad (2)$$

Where p (i) = ri /R (ri is the mean number of individuals of the species i and R is the total number of individuals of all species).

3. Evenness coefficient or Pielou's evenness (E_H) measures the diversity degree of a stand compared with the possible maximum. Its value varies between 0 when one or few species have higher abundance than others to 1 when all species have equal abundance (Magurran, 2004). It is computed as following formula:

$$E_H = \frac{H'}{H_{max}} \text{ with } H_{max} = \log_2 S \quad (3)$$

Where *H'* represents the Shannon-Wiener's diversity index, H_{max} is the maximum value of the diversity index and S the number of species recorded in plots.

A canonical correspondence analysis (CCA) was implemented (ter Braak, 1986; terBraak, 1987) to assess the relationship between the environmental factors and the floristic composition. The CCA model and the significance of the fitted environmental variables were evaluated by the Monte Carlo permutation test with 499 permutations (Hejcmanovã-Nežerková and Hejcman, 2006). These analyses were run in R 3.1.2 using packages vegan (Oksanen et al., 2002) for NMDS and CCA, while indicator species analysis was implemented in Indic species packages (De Caceres and Legendre, 2013). Tests of comparison were executed in Minitab 14.

RESULTS

Floristic composition and diversity

Fifty trees species belonging to 40 genera and 29 families were recorded (Appendix 1). The most represented families were Combretaceae *(*13.92%), Leguminosae-mimosoideae (12.66%), Leguminosae-caesalpinioideae (11.39%), *Leguminosae-papilionoideae (*7.59%), Rubiaceae (7.59%) and Tiliaceae (6.33%). The most abundant species were *Combretum glutinosum* Perr. ex DC., (28.79%), *Pterocarpus erinaceus* Poir. (12.42%), *Crossopteryx febrifuga* (Afzel. ex G. Don) (7.30%), *Strychnos spinosa* Lam. (7.18%) and *Hexalobus monopetalus* (A. Rich.) Engl. & Diels (7.06 %).

The non-metric multidimensional scaling (NMDS) indicated a very good ordination of the plots with r^2 = 0.943 and a stress value of 0.122 (Figure 3). Figure 3 indicates no clear discrimination of the plots, suggesting that floristic composition is quite similar among zones

The species richness and Shannon-Wiener diversity index are higher (S=50 and H'= 3.99) in ZHPEO than in ZMPEO (S=18 and H'=3.20) whereas Pielou's index is higher in ZMPEO (Eq= 0.77) than in ZHPEO (Eq= 0.71) (Table 1). Species indicator analysis (Table 2) reveals no indicator species in ZHPEO while the most indicator species or species combinations for ZMPE O included *Combretum glutinosum* + *Crossopteryx febrifuga, Crossopteryx febrifuga, Combretum glutinosum* + *Pterocarpus erinaceus, Crossopteryx febrifuga* + *Pterocarpus erinaceus* and *Combretum collimum* + *Crossopteryx febrifuga.*

Relationship species-environmental variables

The results of the CCA indicated that the first three axes accounted for 69.46% (29.39% for the first axis, 21.45%

Table 1. Floristic parameters of the zones of occurrence of the Derby Eland.

Parameters	Zone of occurrence of the Eland		Global (n = 140)
	Medium (n = 13)	High (n = 127)	
Specific Richness (S)	18	50	50
Shannon I*ndex* (H')	3.20	3.99	3.92
Pielou's evenness (Eq)	0.77	0.71	0.69

n is the total number of plots in each zone of Derby Eland occurrence.

Table 2. Indicator species of the zones occurrence of the Derby Eland.

Probability of Derby Eland occurrence	Species combinations	A	B	IndVal	p-value
	Combretum glutinosum + Crossopteryx febrifuga	0.817	0.692	0.752	0.002
	Crossopteryx febrifuga	0.787	0.692	0.738	0.002
Medium	*Combretum glutinosum + Pterocarpus erinaceus*	0.734	0.615	0.672	0.034
	Crossopteryx febrifuga + Pterocarpus erinaceus	0.811	0.461	0.612	0.005
	Combretum collimum + Crossopteryx febrifuga	0.932	0.385	0.599	0.001
High	-	-	-	-	-

A= specificity, it is the probability that the surveyed site belongs to the target site group given the fact that the species has been found; B= fidelity, it is the probability of finding the species in sites belonging to the site group; IndVal = Indicator Value Index.

Table 3. Correlation between axes and environmental variables.

Environmental variable	CCA1	CCA2	CCA3
Soil type	-0.031	-0.169	0.512
Fire	-0.287	0.508	-0.705
Altitude	-0.882	0.145	-0.041
Hardness	0.269	-0.089	-0.507
Herbaceous cover	-0.204	-0.073	0.743
Tree cover	0.087	0.828	-0.083

Values ≥ 0.5 presenting significant correlations with axes are in bold.

for the second one and 18.61% for the third one) of the total variation captured by the CCA. Most of the environmental variables showed high correlations (0.51 to 0.88) with the three axes (Table 3).Axis 1 is negatively correlated to altitude, while fire and tree cover are positively correlated to axis 2 (Table 3). Axis 3 is positively correlated to soil type and herbaceous cover and negatively correlated to fire and hardness (Table 3). Projections of these environmental variables on these three CCA axes with the plots (Figure 4a, b) showed that plots of ZMPEO are located in area with low altitude and low tree cover, less occurrence of fire and on short (sandy) to compact clay soils (less hard) whereas plots of the ZHPEO scattered showed a correlation with high altitude and high tree cover, more occurrence of fire and hard substrate (outcrop granite).

DISCUSSION

Floristic composition and diversity

Predominant families such as combretaceae, leguminosae-mimosoideae, leguminosae-caesalpinioideae, leguminosae-papilinoideae, rubiaceae and tilliaceae found are in accordance with findings run on the diets of Derby Eland in NKNP (Hejcmanová, et al., 2010). The richness of 50 woody species with dbh ≥ 5 cm assessed on 6.24 ha is different compare to the 59 species of trees and shrubs identified on an area of 5 km^2 (Hejcmanovā-Nežerková and Hejcman, 2006) but lower than the106 woody species found on an area of 228 km^2both in NKNP (Traore, 1997). This diversity is an important asset for herbivorous browsers such as Eland

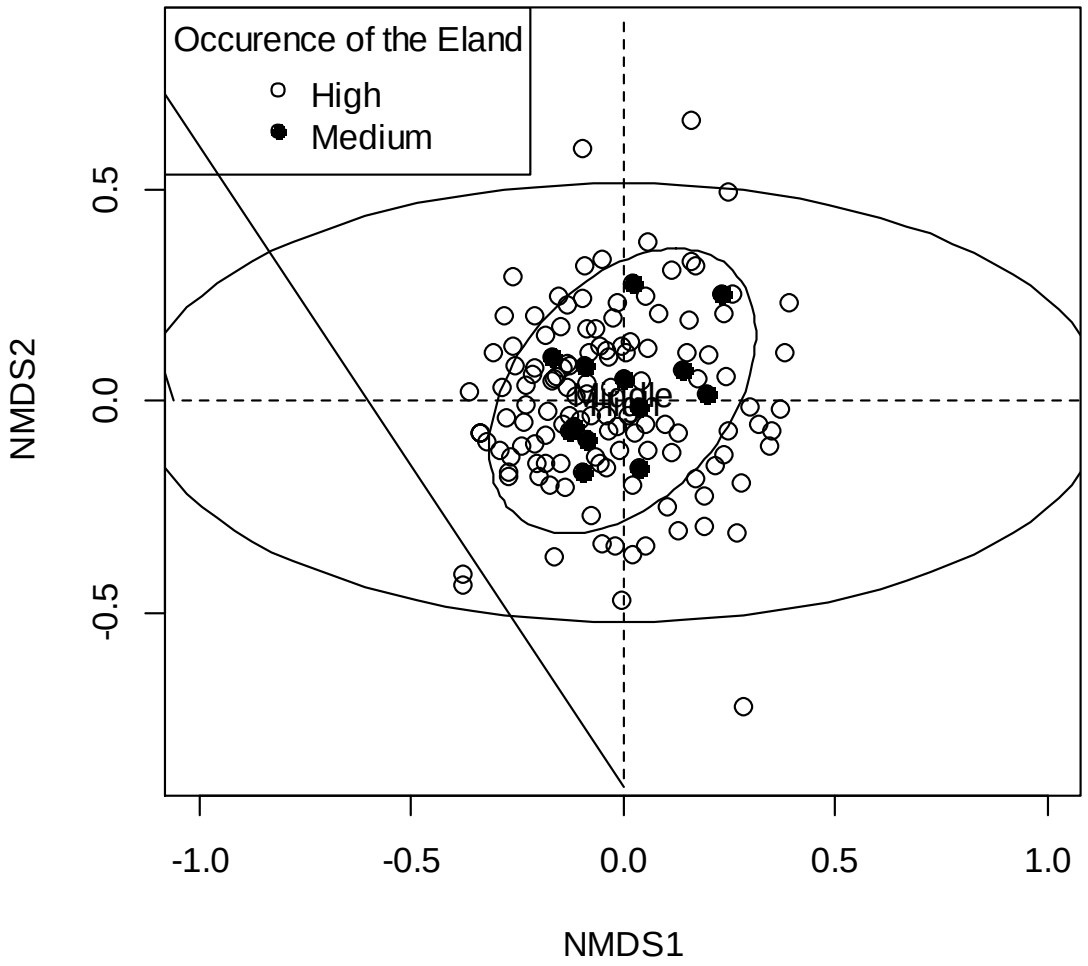

Figure 3. Non-metric multidimensional scaling of plots from zone of medium and high occurrence of Derby-Eland.

which find variate fodder within their habitat. However, this woody plant richness is very low compared to those found in of the Eastern Eland's (*T. d. gigas*) habitat. Indeed Grazian and d'AlessiSilvio (2004) recorded 212 species and Bro-Jorgensen (1997) noted less than 10 common species in the habitat of the Eastern Eland in Central African Republic. This difference may be attributed to data collection method, geographical location and local climatic conditions. Habitats of the Western and the Eastern Eland are also different in terms of species composition (Spinage, 1986; Bro-Jorgensen, 1997; Kingdon, 1997). The Eastern Eland is found in *Isoberlinia doka* (Craib & Stapf) savannah (Bro-Jorgensen, 1997; East, 1998) while this species is not recorded in Senegalese flora (Berhaut, 1967; Ba et al., 1997).

The NMDS analysis reveals that the vegetation of the confined area of the Derby Eland in NKNP harbours almost the same woody species (Figure 3). This finding supports hypothesis that the Eland frequents habitat with a quite similar floristic composition (Kruskal, 1964b). This floristic similarity is witnessed by the results of species indicator analysis. Indeed even though some species or combinations of species present specificity none fidelity of species recorded in the Derby Eland habitat (Dufrene and Legendre, 1997; De Cáceres and Legendre, 2009; De Cáceres et al., 2012) (Table 2).

Relationship species-environmental variables

The CCA analysis reveals that fire, soil type, altitude and trees cover are the most important environmental factors influencing the vegetation distribution. Overall, shrubs and small trees are found in ZMPEO whereas big trees are found in ZHPEO. Traore (1997) and Hejcmanovā-

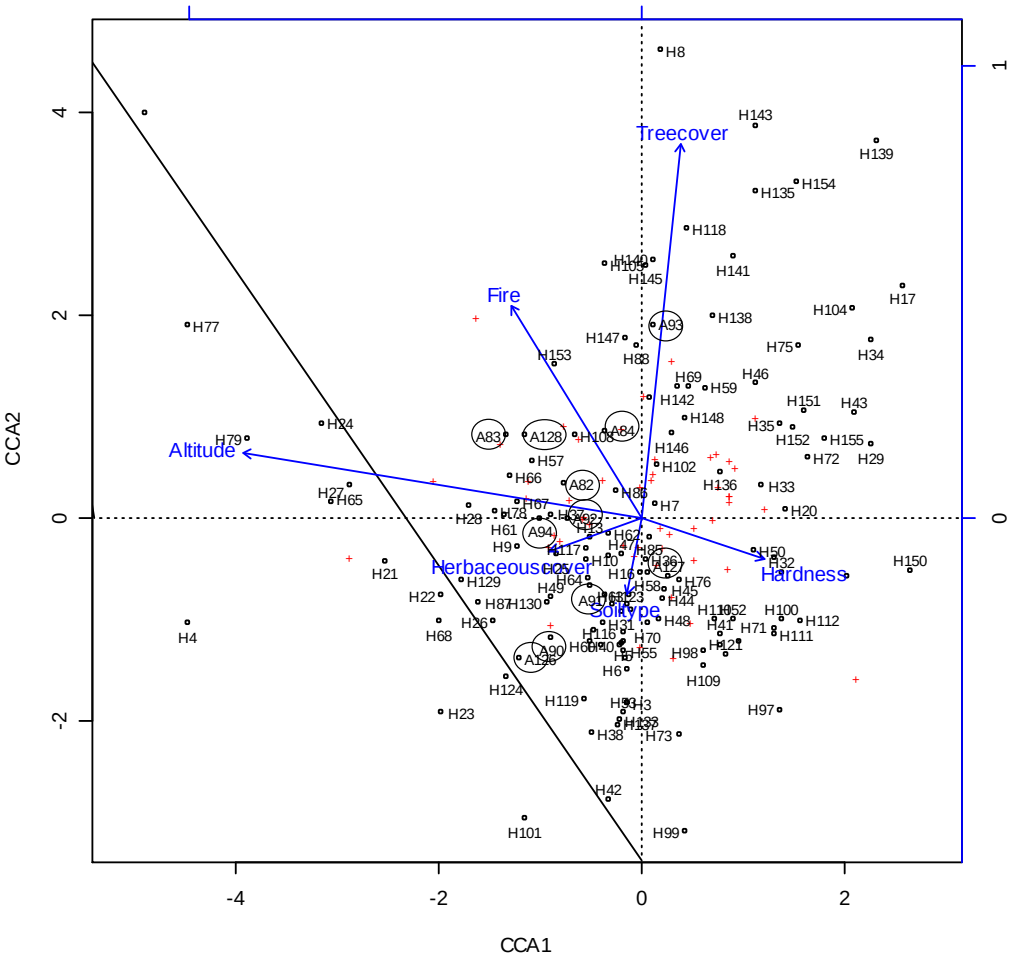

Figure 4a. Influence of environmental variables on the floristic composition in the (a) axes 1 and 2, (b) axes 1 and 3; Loading of sample units from zones of medium (A, black circle) and high (H) occurrence of Derby-Eland.

Nežerková and Hejcman (2006) identified soil type and topography as factors impacting the species composition of the NKNP. Topography was also described as key factors determining Eland habitat (East, 1998), and this is witnessed by park rangers' observations. Indeed migratory movements are noticed from low altitude and marshy areas to high altitude and hilly rocky areas from the dry season to the raining season (park rangers' observations).

Mbow (2000) identified fire as patter controlling the species composition in NKNP. Indeed early fires are used every year by park rangers as tool management to prevent damages of late fires occurring in the late dry with catastrophic consequences. These fires improve regrowth of some herbaceous species participating to herbivores feeding, increase sight possibilities for tourism and remove predation for herbivores. In NKNP apart from removal predation and preventing consequences of late fire, these early fires do not impact really on Derby Eland survival because Hejcmanová et al., (2010) found that the Western Derby Eland feeds on grasses less than 5%. In contrast Bro-Jorgensen (1997) admitted that Eastern Eland never feeds on grass while Hillman and Fryxell (1998) showed that Eastern Eland takes a few amount of fresh sprouting grass in the early wet season. Trochain (1940) and Lawesson (1995) argued that climatic conditions are the most important factors that determine the vegetation NKNP and habitat of Derby Eland.

CONCLUSION AND RECOMMENDATIONS

The zones of occurrence of the Derby Eland has a high floristic diversity of which Combretacea is the dominated

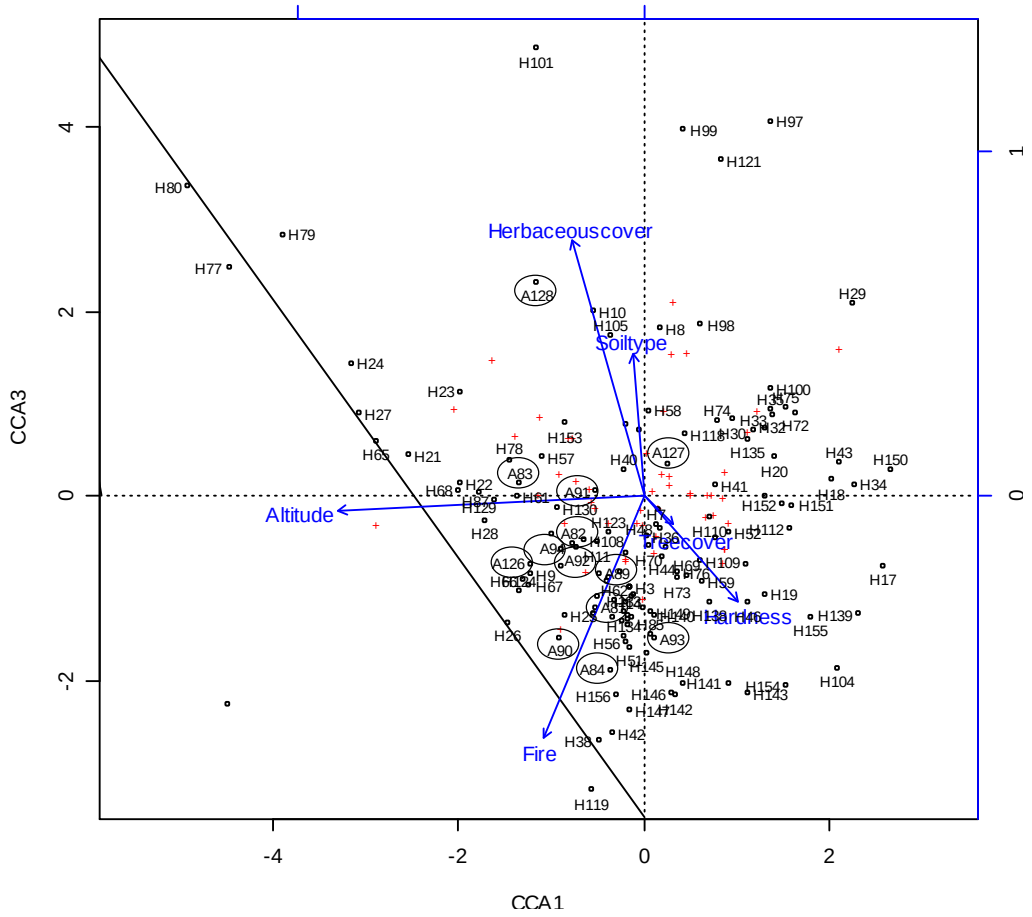

Figure 4b. Influence of environmental variables on the floristic composition in the (a) axes 1 and 2, (b) axes 1 and 3; Loading of sample units from zones of medium (A, black circle) and high (H) occurrence of Derby-Eland.

family even though the estimated number of plant species in NKNP is exceeding 1000 (Madsen et al., 1996). Altitude, fire occurrence and vegetation cover were the most important environmental factors influencing the distribution of these species. These factors were identified as influencing factors on the vegetation of NKNP but they seem not to have negative impact on the floristic composition because Hejcmanovā-Nežerková and Hejcman (2006) identified similar species richness. However, compare to the habitat of its relative relative the Eastern Derby Eland; the Habitat of the Western Derby Eland has less rich and diverse flora.

Nevertheless information on the floristic composition of Derby Eland's confined area is bedrock for its conservation, and will assist management decisions on the choice of new sites for future *in-situ* conservation fencing for the remaining wild population in NKNP and eventually for the *ex-situ* population at Badian and Fathala reserves. To enhance a sustainable management and conservation of the Derby Eland in NKNP, further to the settlement of the *in-situ* enclosure, it is highly recommend the use of telemetric tools like GPS collars and camera traps in order to enhance information in its last wild habitat.

Conflict of Interests

The authors have not declared any conflict of interests.

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Evolution of policies and legal frameworks governing the management of forest and National Parks resources in Gabon

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In the Congo Basin region, sustainable management of forests and protected areas is mostly biodiversity oriented while little is known about governance effectiveness of such forest resources, especially in Gabon. This paper assesses available policy, legislations and institutions to enhance the management of Gabonese forests and National Parks resources. Data was gathered through systematic review of literature and policies and face to face interviews of experts in three key institutions. National Parks represent a restrictive conservation strategy adopted by the Gabonese government. Resource harvesting and gathering is prohibited in National Parks boundaries. Identified issues include; little participation of the local communities in forest resource management and poor benefits redistribution among stakeholders. The current policy framework promotes strongly the economic development of the timber sector and biodiversity protection than the rights and livelihoods security of local communities. Several institutions are involved in resources management but their mandates over biodiversity protection tend to overlap, providing possible obstacles to their efficient performance. The establishment of a new type of institutional arrangement for protected areas which would integrate biodiversity protection and secure local people's livelihoods is therefore needful. Institutional collaboration and communication among these institutions should also be encouraged to avoid the overlap of their mandates.

Key words: National Parks, forests, governance effectiveness, policy, legislations, resources management, Gabon.

INTRODUCTION

Worldwide, several countries have embarked on establishing and managing protected areas since they are considered as cornerstones for biodiversity conservation and sources of socio-cultural and economic values for the society (Muhumuza and Balkwill, 2013; Watson et al., 2014). Six categories (Ia, II, III, IV, V and VI) of protected areas have therefore been established by the IUCN according to their management objectives

(Phillips, 2003; Dudley,2008). Protected areas of categories Ia, II, III, IV and V aim at strictly protecting biodiversity and encouraging scientific research, environmental education and ecotourism development while protected area's category VI tends to reconcile biodiversity conservation and sustainable use of natural resources in its boundaries (Gardner, 2011; Burgin and Zama, 2014). However, the latter category tends to be poorly implemented worldwide, and this despite increasing pressure from the World Congress on Protected Areas (WCPA) to promote new forms of conservation governance such as: (i) governance by government; (ii) shared governance; (iii) private governance; and (iv) governance by indigenous peoples and local communities themselves (Dudley, 2008).

Currently, just few countries have embarked on establishing all the six categories of protected areas along with such new forms of conservation governance (Dudley, 2008), especially in Brazil. However, little is known about the effectiveness of such conservation governance in most developing countries including those located in the Congo basin region including Gabon. Evaluating conservation governance's effectiveness therefore requires a critical assessment of key principles guiding forests and National Parks' resources management (Lockwood, 2010). These key principles are: i) legitimacy (decentralization in decision-making); ii) transparency (transparent decision-making); iii) accountability (regulation of power abuse); iv) inclusiveness (participatory decision making); v) fairness (avoiding discriminatory practices); vi) connectivity (effective coordination and coherent policy); vii) and resilience (adaptive management). They are commonly used as a benchmark to judge governance effectiveness over protected forests and represent valuable tools to guide policy makers' decisions about how well institutions (government levels) and processes (policy, laws, institutions) should work (Lockwood et al., 2010).

Despite the increasing implementation of protected areas of type Ia, II, III, IV and V, biodiversity continues to decline through illegal use and often generate conflicts between local people and parks' managers over use of protected resources (Larson and Ribot, 2007). Overcoming the issue of biodiversity decline has driven scholars such as Traynor and Hill (2008) and Shackleton (2009) to suggest the enactment of clear policies and legislations to clarify how natural resources should be managed and how benefits generated should be redistributed to all stakeholders. Local people's participation in conservation governance and involvement in decision making process affecting their lives have also been suggested as possible solutions to enhance conservation governance (Chopra et al., 2005). Lessons learnt from few successful cases studies carried out in the Tropics tend to emphasize that reconciling biodiversity conservation and development goals may lie on: i) establishing an enabling environment that promote greater compliance of local communities with protected areas conservation strategies; ii) delivering effective conservation benefits to local communities; iii) implementing environmental education programs that contribute to change of local communities' behavior with regards to resource use and raise their conservation awareness, and iv) developing and strengthening of local institutions (Bruner et al., 2001; Bajracharya et al., 2005).

Understanding governance effectiveness over forests through the analysis of governance key principles may therefore help policy-makers in various ways: i) to assess how power and responsibilities are exercised and how decisions are taken; ii) to understand procedures through which stakeholders can follow to have their say with regards to issues affecting their lives; iii) to improve the efficiency of forests and protected forests resource management; and iv) to grasp how well institutions function towards achieving assigned goals by the state (Graham et al., 2003). Such understanding is particularly important for most developing countries of the Congo basin such as Gabon which are still lagging behind towards embracing the new forms of conservation governance that integrate biodiversity conservation and socioeconomic development of local communities.

Gabon, belonging to the Congo basin region, has a total forest area of 26.8 million ha. Productive forest represents more than seventy one percent of the national territory and area under strict nature protection accounts for almost (11.0%) 3.0 million ha of the national territory designated as National Parks (FAO-ITTO, 2011). The establishment of protected areas in Gabon falls mostly within one single category (category II) known as National Parks (RFUK, 2014). Over the past two decades, the Gabonese government has made efforts towards sustainable management of its forests and its rich biodiversity, with the enactment of two relevant policies including: i) The Forest Code N^{o} 16/01 of the 31st December 2001; and ii) The National Park Law N°03/2007 of 27th August 2007. These two policies aim not only at regulating access, use, trade, marketing and management of forest resources but also contribute to promoting the industrialization of the timber sector and its sustainable management as well as to the protection of biodiversity (Gabonese Republic, 2001, 2007). However, they both fail to address the dependence of local people's livelihoods on forest resources located within protected areas and to design a practical framework to successfully guide forest and National Park resources management (Christian and Kasumi, 2014).

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Locally, forest and land use are regulated through: (i) strict control over access and use of forest and related products; and (ii) zonation of the national forest into three distinct areas including outside, buffer zone and inside of the park. Access and use of resources are freely allowed only outside of the park, regulated in the buffer zone and strictly prohibited inside the park, despite local people dependence on resources therein. In this regard, the role of protected areas in sustaining local people's livelihoods has been poorly taken into account from inside of National Parks, thus, threatening their livelihoods in meeting households needs from forest resources (Sassen and Wan, 2006). Reconciling prohibition of access and use of forest resources inside of protected areas and socioeconomic development of local people is therefore needed (Naughton-Treves et al., 2005) as a viable alternative to strict state's control over protected forests. Integrating local people's livelihoods needs into conservation and forest management initiatives requires that enacted policies and legislations comply with the following: i) securing local people's rights over forest resources; ii) promoting stakeholders consultation and accountability of their opinions over protected areas issues; iii) promoting incentives to local communities to participation in forest resources management; iv) defining clear roles and responsibilities of stakeholders in conservation and forest management initiatives; and v) promoting fair benefits sharing among stakeholders (Lockwood, 2010).

This study represents a supportive research which complements three previous studies conducted around communities living and depending on forest resources of the Ivindo National Park in Gabon. The results of these studies have shown that: i) rural people around the park use various indigenous fruit trees and their livelihoods depend on them (Christian and Kasumi, 2014); ii) rural people face restriction by the state over access and use of forest resources, especially inside of National Parks; and iii) rural people complain about decline in resource availability due to the impacts of past logging operations in the area, climate change (unpredictability of rainfall), and unsustainable harvesting practices (Yobo and Kasumi, 2014; Yobo and Ito, 2015). The implementation of future rules and regulatory approaches to regulate access and use of resources, and on-farm tree planting to reverse the declining fruit trees populations and reduce pressure on protected forests around the Ivindo National Park have been suggested as measures towards sustainability (Christian and Kasumi, 2014, Yobo and Kasumi, 2014, Yobo and Ito, 2015).

According to Naughton-Treves et al. (2005), the Convention on Biological Diversity (CBD) and the World Commission on Protected Areas (WCPA) have shifted initiatives on protected areas management from strict biodiversity conservation to sustainable use-management of forest resources by local and indigenous people themselves. Therefore, this study aims at critically assessing available policies, legislations and institutions in Gabon that are geared towards enhancing governance effectiveness of forests and National Parks resources in the country.

This is captured by answering five research questions: i) What type of protected areas are available in Gabon according to the IUCN protected areas management categories?; (ii) What are the available policies and legislations governing forest and protected areas in the country?; (iii) How are resources regulated within the forest and National Parks boundaries?; (iv) Who holds legal responsibility over forest and National Parks resources management in the country?; and (v) To what extent is conservation governance over forest and National Parks effective gauged against well-known standard principles of protected forests governance such as: legitimacy, transparency, accountability, inclusiveness, fairness, connectivity and resilience that were described previously.

MATERIALS AND METHODS

Study area

Located in Central Africa, Gabon is covered by about 22 million ha of rainforest (85% of the national territory) (Megevand, 2013). Thirteen National Parks have already been created throughout of the nine provinces of the country (in 2002) representing about 11.2% of the national territory (de Wasseige et al., 2009). The assessment of key experts viewpoints about their responsibilities and governance effectiveness on forest and National Parks resources has been conducted only in the Ogooué Ivindo and Estuaire provinces. Also included are the General Directorate of Waters and Forestry (GDEF), the World Conservation Society (WCS), and the National Park National Agency (ANPN) are among the three key institutions accessed (Figure 1). The DGEF is part of the Ministry of Water and Forests that is engaged in sustainable management of the national forests. National forest is divided into state permanent forest domain (logging concessions, protected areas) and rural forest domain (non permanent forests) (Art. 5 and 6, Gabonese Republic, 2001). The former cannot be converted into other land uses while the latter can and it is set aside for local community use only (Art. 12, Gabonese Republic, 2001). The WCS, a well-known international NGO, has its headquarters in Libreville (Estuaire province) and its technical pool is located in Makokou around the Ivindo National Park (Ogooué Ivindo province). It provides to the ANPN, technical support and scientific knowledge on various aspects including: protection and resources management, and research and management of National Parks. The ANPN, under the supervision of the presidency of the Republic, is responsible for the management of National Parks. Each park is under the responsibility of a conservator (Art. 43, Gabonese Republic, 2001). Its main objective is to develop the legal and institutional framework with regards to the management of National Parks and the ecotourism sector (Art. 30, Gabonese Republic, 2007).

Data collection and analysis

Data collection did not focus on assessing the local people's perceptions and dependence on forest resources (even though they

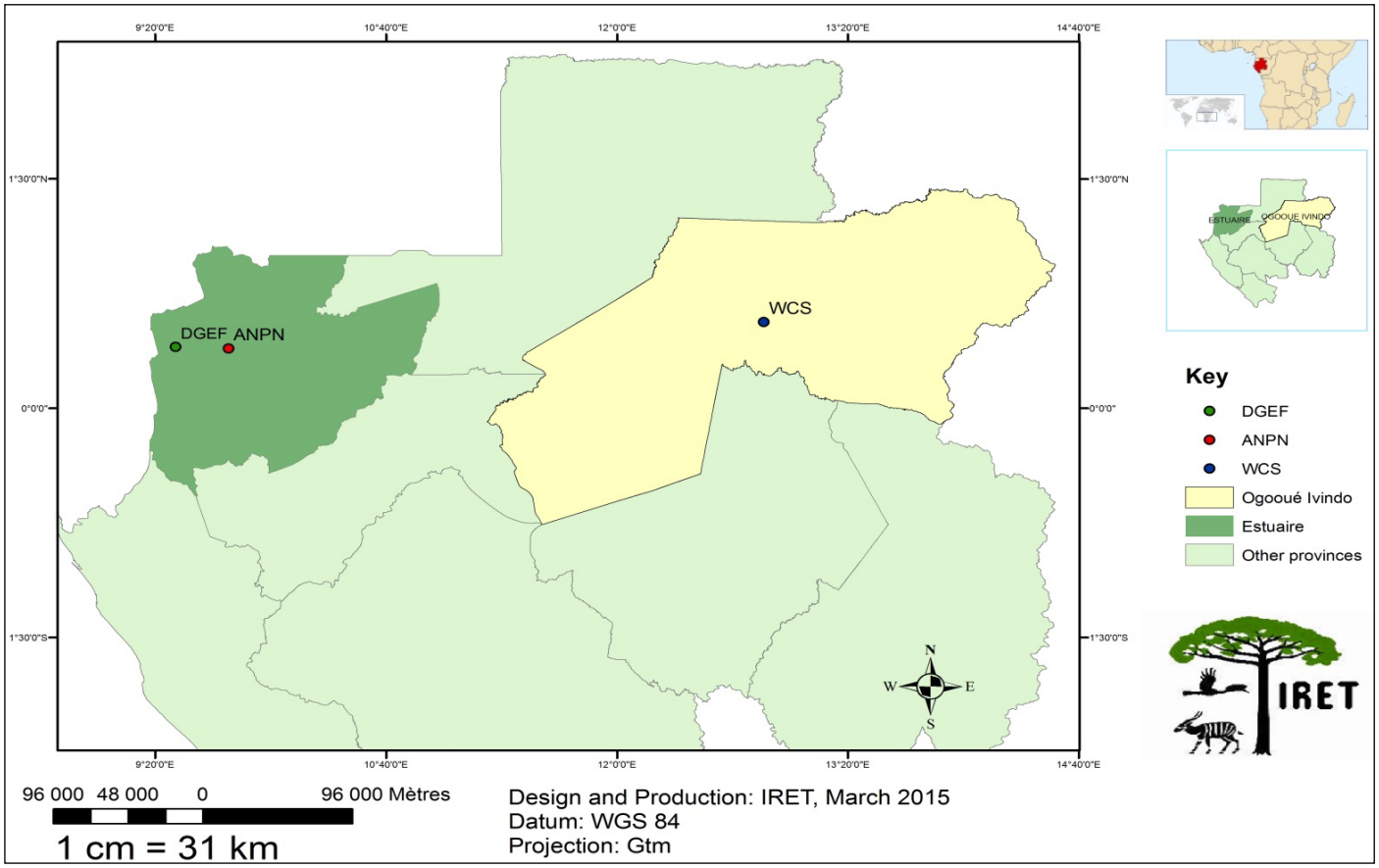

Figure 1. Localization of the study sites.

are at the center of the problem) because the previous three studies earlier mentioned had tackled the issues. The selection of these provinces have been driven by: i) The presence of institutions interested in forest and National Parks resources management; ii) the presence of the target populations, especially around the Ivindo National Park; and iii) the possibility of comparing and generalizing conclusions obtained from data collected on key institutions responsibilities and views about effectiveness of governance over forest and National Parks resources. The latter point is particularly important to scale up outcomes of this study to other National Parks wherein similar institutions are also situated.

Three key experts were selected (one in each institution) based on hierarchical positions in their respective institutions and technical know-how on protected forests management and governance effectiveness. Data was collected through a qualitative approach that consists of: i) a systematic review of literature of forest and protected areas' governance worldwide; ii) selection of national policies and legislations on the topic; iii) a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of national policies and legislations; and iv) a face to face interviews with the three key experts. The systematic review of literature (including national policies and legislations) aims at identifying, assessing and synthesizing aspects related to forest and protected areas' governance in relation to the seven key governance principles (Lockwood et al., 2010). National literature accessed was read to determine if it met the criteria for inclusion of at least one of these seven key governance principles that are shown below in brackets: i) legitimacy (decentralization in decision-making); ii) transparency (transparency process in decision-making); iii) accountability (regulation mechanism of power abuse); iv) inclusiveness (stakeholders participatory process in decision making); v) fairness (avoiding discriminatory practices); vi) connectivity (effective coordination and coherent policy); and vii) resilience (adaptive resources management approach). If the literature accessed does not contain one of these criteria, therefore it was not selected for gauging the effectiveness of protected forest governance.

The selection and analysis of available policies and legislations consists of four steps: i) preliminary selection of policies and legislations through an exhaustive inventory; ii) first assessment of all selected policies and legislations based on key governance principles; iii) second assessment of all selected policies and legislations; and iv) the final assessment of short-listed policies and legislations (Dlamini, 2007). SWOT Analysis aims at identifying some challenges affecting the implementation of governance effectiveness over forest and National Parks and suggesting appropriate measures to overcome them (Ahenkan and Boon, 2010). The face to face interviews conducted with key experts aims at: i) assessing institutional responsibilities with regards to forest and protected areas management and possible overlap of mandates among them; and ii) checking out whether or not the seven key governance principles (mentioned earlier) are acknowledged in policies and regulations; if not for what reasons?.

RESULTS

Forests areas are allocated for conservation versus

Table 1. Comparison values between areas of forest allocated to protection, timber production, under certification process and community forests in Gabon.

Forest areas	Names	Areas (ha)	UICN categories	International legal status
	Minkébé	756 000	II	UNESCO (2005)[2]
	Lopé	491 291	II	UNESCO (2007)[1]
	Moukalaba Doudou	449 548	II	UNESCO (2005)[2]
	Ivindo	300 274	II	UNESCO (2005)[2]
	Batéké Plateau	204 854	II	UNESCO (2005)[2]
	Loango	155 224	II	RAMSAR (2006)[3]
National Parks	Cristal Mounts	119 636	II	Unknown
	Mwagna	116 475	II	Unknown
	Waka	106 938	II	Unknown
	Mayumba	97 163	II	Unknown
	Pongara	92 969	II	RAMSAR (2006)[3]
	Akanda	53 780	II	RAMSAR (2006)[3]
	Birougou	69 000	II	UNESCO (2005)[2]
	Total area	3 013 152	II	
	Land in national territory	26 800 000		
	Dense forest area	21 190 000		
	For Production	19 000 000		
	Gazetted for exploitation in 2006	12 000 000		
	Under management process (1+2+3+4)	6 368 424		
Forest	(1) Area under preparatory phase	1 906 888		
	(2) Area under management plan	1 538 688		
	(3) Management plan submitted	117 606		
	(4) Management plan agreed	2 805 242		
	For community purpose	23 750		
	Area under certification in process	4 968 186		

Source: Schmidt-Soltau, 2005, Nasi et al., 2006, ANPN, 2011, UNESCO, 2005a,b&c, UNESCO, 2007, RAMSAR 2007a,b,c&d. Areas under certification in process (ISO 14001, Pan African Forest Certification, Forest Stewardship Council & Keurhout, etc and that up to date only five communities forest have been established throughout of the country. Subscripts 1 & 2 indicate sites that have already been listed as UNESCO World heritage and RAMSAR sites while subscripts 3 & 4 indicate sites that have only been suggested as UNESCO World heritage and RAMSAR sites by the Gabonese government.

productive, certified and community forests in Gabon. Table 1 shows the proportion of forests that were allocated for conservation purpose (National Parks), production (sustainable timber extraction), certification and community forests along with management categories of National Parks and their international status. Since the area of productive forest covers almost 71.0% of the entire territory, 23.7% are under forest management process, and 18.5% are dedicated to certification process and that only 11.2% of forest area under protection (National Parks) and less than 1.0% of forest areas has been allocated to community forests therefore it can be emphasized that the state's primary goal in forest management is for economic development, biodiversity conservation rather than sustainable use of protected forests. Gabon has ratified several international conventions including the Ramsar (sensitive ecosystems) and the World Heritage of UNESCO and that some of these thirteen National Parks have already been listed or are on the verge of being listed as the world heritage of UNESCO or Ramsar sites.

Table 2 presents the existing policies and associated regulations that govern forests and National Parks resources management along with objectives assigned by the Gabonese government. The Forest Code (2001), the National Park Law (2007) and related decrees aim at promoting the economic development of the timber sector, sustainable management of its resources as well as biodiversity protection and ecotourism development but focus less on supporting rural livelihoods and regulating their dependence on Non Timber Forest Products locally known as Forest Products Other than Timber (PFABO).

State regulation approaches by land use types in the country

Table 3 summaries the state approaches over regulation of access and use of forest and National Parks resources for both biodiversity conservation and sustaining local

Table 2. Existing laws and legislations guiding forest and National Parks resources management in the country.

Place and Law		List of policies and regulations	Major objectives
Forest	Law	-Law N° 16/01 of 31st December 2001 (Forestry Code)	-Promotes sustainable management of forest to enhance the economic, social and cultural development of the country (Art. 2)
	Regulations	-Decree N° 000692/PR/MEFEPEPN of the 24th August 2004	-Promotes customary use fruits of local communities on forest, fauna, wildlife and fishing (Art. 1)
		-Decree N° 001029/PR/MEFEPEPN of 2004	-Intends to regulate harvesting, transformation and trade of Forest Products Other than Timber (PFABO) (Art. 1)
		-Decree N° 001028/PR/MEFEPEPN on community forests of 2007	-Sets the conditions of establishing community forest (Art. 1)
		-Ordinance N° 011/PR/2008 of 25th July 2008 amending some provisions of Law N° 16/01 of 31st December 2001 (Forestry Code)	-Amends some provisions of the forest code (Art. 1) -Defines PFABO, local community, customary use rights and economic rights of sale (Art. 2)
National Parks	Law	-Law N°03/2007 of the 27th August 2007 (National Parks)	-Promotes sustainable protection of biodiversity and ecotourism development (Art. 2)
	Regulations	-Decree N°000019 of the 9th January 2008	-Sets the status of the ANPN (Art. 1)

Source: Gabonese Republic, 2001, 2004a,b, 2007a,b, 2008a.

Table 3. Available regulation approaches by land use types in Gabon.

Land use types	Locations	Local people livelihoods' activities					
		NTFP gathering / trade	Hunting	Fishing	Fuelwood	Timber exploitation	Agriculture
Logging concession	Inside	Requires permission from the forest administration	Requires permission unless traditional practices are used	Required permission unless traditional practices are used	No permission required	Requires permission and a management plan	Prohibited by the Forest Code
	Outside (Community forest)	No permission required for meeting customary and economic rights	Subsistence hunting is allowed unless drugs, explosives, power rifles are used	Subsistence fishing is allowed unless drugs, poisons and are used (Art.261)	No permission required	Allows for community uses under a simple management plan	Subsistence is allowed but industrial agriculture requires a management plan
National Parks	Inside	Strictly prohibited	Strictly prohibited	Strictly prohibited	Not prohibited	Strictly prohibited	Strictly prohibited
	Buffer zone	Requires a permission (Art. 14)	Requires a permission (Art. 14)	Requires a permission (Art. 14)	No permission required	Requires a permission and management plan	Permission and management plan needed (industrial agriculture)
	Outside	Permission is required unless it falls under the customary and economic rights	Permission is required unless it falls under the customary and economic rights of local communities	Permission is required unless it falls under the customary and economic rights of local communities	No permission required	Requires a permission and simple or comprehensive management plan	Requires a permission and simple or comprehensive management plan

Source: Gabonese Republic, 2001, 2007.

people's livelihoods over Non Timber Forest Products gathering and trade, hunting and fishing, deadwood collection, agriculture and logging activities. Deadwood and branches' collection are the only forest products that are allowed to be freely collected in the permanent forest domain of the state (productive forest and National Parks) and rural forest domain. Other livelihood activities are regulated through: i) permits requirement that are delivered by the Water and Forest administration or by the National Park National Agency (ANPN); and ii) an agreed land or forest management plan. The use of drugs, poisoned baits, explosives, power rifles are prohibited while hunting as well as the use of drugs, poisons or toxic products and explosive devices while fishing. This means that only traditional techniques are legally allowed to be used by local communities while hunting and fishing (Gabonese Republic, 2001, 2007).

A comparative method to analyze the existing forest and National Parks laws through SWOT Analysis

Table 4a and b represent a SWOT (Strengths, Weaknesses, Opportunities and Threats) Analysis of the existing laws and legislations that govern the management of forests and National Parks resources in Gabon. The lack of "practical" mechanism that should not only regulate land uses from the state forest (productive forest and National Parks areas including outside, buffer zone and inside of the park) and customary and economic rights of local communities on use of forest, wildlife, NTFPs gathering and fishing resources by amounts, quotas, etc are among the key weaknesses of such regulations. Opportunities to overcome such weaknesses might be played by the newly established National Consultative Committee for the management of the NTFPs sector (CCN-NTFPs). The CCN-NTFPs representing a participative platform should contribute to initiate debate about the importance of usage regulation mechanisms in the country.

Responses of key experts regarding their major responsibility in meeting assigned goals by the state

Table 5 shows key experts responses to questions asked about their major responsibility in the implementation of forest and National Parks policies and legislations in the field. Several responsibilities have been highlighted by these three institutions. However, they tend to have similar areas of expertise, especially with regards to control, repression of law breakers and biodiversity protection. This overlap of mandates of these institutions might represent a possible obstacle towards achieving their goals over forest and National Parks resources management in the country.

Key experts' responses on governance effectiveness of forest and National Parks resources in Gabon

Table 6 highlights key experts' responses on questions asked about the effectiveness of governance of forests and National Parks resources in the country. Key experts have highlighted that existing policies and regulations have all integrated the seven key governance principles in their regulatory framework for the successful management of forest and protected areas resources. However, the implementation of such key governance principles tends to be weak, especially on ground.

DISCUSSION

Towards improved governance over forest and protected resources in Gabon

Gabon has demonstrated a strong political will to conserve its rich biodiversity by establishing a network of thirteen National Parks (2002) that covers about 11.0% of the national territory. However, this network belonging to a single category II of the IUCN management categories known as National Parks is strongly biodiversity conservation oriented than sustainable use. In addition, areas of forest that have been allocated for timber production, sustainable forest management and certification processes represent 71.0, 23.0 and 18.5% of the national territory, respectively, while community forest area accounts for less than 1.0% of the national territory (Table 1). This category of protected areas characterized by a "no take" policy within its boundaries implies that local people who depended on forest resources that are actually located inside of the park are no longer allowed to enter and use them to sustain their livelihoods. Thus, the prime goals of National Parks establishment were not directed to secure local people's dependence over resources located inside of the parks boundaries but they were rather oriented towards strict biodiversity protection, eco-tourism development and conservation of its natural and national cultural heritage (Art.2, Gabonese Republic, 2007). The latter assertion is in line with the study of Sassen and Wan (2006) who pointed out that local people living and depending on forest resources of the Ivindo National Parks (Gabon) complain about restriction over access and use of forest resources actually located inside the park. Such restrictions have not only driven the issue of illegal access and use of forest resources but also caused the decline of forest resources in rural areas of Zimbabwe (Mudekwe, 2007). Overcoming restrictions over access and use of protected forests has driven scholars such as Hayes and Ostrom (2005), Locke and Dearden (2005), Naughton-Treves et al. (2005) to suggest a new form of conservation governance that should consist on allying biodiversity conservation and

Table 4a. SWOT Analysis of the existing laws on forest and National Parks resources management in Gabon.

Content	Laws	
	Law N° 16/01 of the 31st December 2001	**Law N°03/2007 of the 27th August 2007**
Strenghts	-Promotes the economic and sustainable management of timber sector -Promotes participatory forest management -Advocates for customary rights of local communities	-Promotes strict biodiversity protection and ecotourism development - Promotes participatory forest management - Advocates for customary rights of local communities
Weaknesses	-Poor community forest's development -No regulations' tools for resources uses -More emphasis on economic development than livelihood security of local communities	-Poor community forest's development (outside of parks) -No regulations' tools for resources uses -More emphasis on biodiversity protection than livelihood security of local communities
Opportunities	-National Consultative Committee in NTFPs as key platform for discussing issues related to the promotion and development of the forest and NTFPs sector	-ANPN and related partners are valuable actors for discussing issues affecting the development of the sector and local people livelihoods
Threats	Policy failure to reconcile both sustainable management of protected forests and livelihood security of local communities	Policy failure to reconcile both biodiversity conservation and livelihood security of local communities

Sources: Gabonese Republic, 2001, 2007; FAO, 2012.

Table 4b. SWOT Analysis of the existing legislations on forest and National Parks resources management in Gabon.

Content	Legislations			
	Decree N° 000692/PR/ MEFEPEPN regulating customary use rights	**Ordinance N° 011 /PR/ 2008 of 25th July 2008 amending some provisions of the forestry Code**	**Decree N° 001029/PR/ MEFEPEPN regulating usages**	**Decree N° 001028/ PR/ MEFEPEPN creating community forestry**
Strenghts	-Free customary rights is allowed in rural forest domain (Art. 14) -Attempts to regulate customary rights in use of forest, hunting, gathering and fishing (Art 2)	-Economic rights to trade NTFPs is allowed -Poverty alleviation through trade of NTFPs in rural areas (Art 4)	-Attempts to initiate regulation of customary rights local communities	-Recognizes customary rights of local communities
Weaknesses	-Practical regulation mechanisms of use of forest, wildlife, gathering and fishing resources by amounts, quotas..are lacking	-Practical regulation mechanisms of NTFPs gathered and sold by amounts, quotas..are lacking	-Practical regulation mechanisms of uses are lacking by amounts, quotas…	-Practical regulation mechanisms of community forests are lacking
Opportunities	-CCC-NTFPs must play a role in usage regulation	-Idem	-Idem	-Idem
Threats	-Most of community forest lack of management plans	–Economic dependence but there is no regulation mechanism	-Lack of practical regulation mechanisms for resources uses	-Community forests fails to act as poverty reduction tool

Source: Gabonese Republic, 2004a,b and c, 2008.

Table 5. Key experts responses regarding their responsibility in meeting assigned goals by the state.

Institutions	Major responsibilities
General Direction of Water and Forestry (DGEF)	- Raises awareness on issues affecting the forest sector -Controls, represses law breakers through imprisonment and fines provision -Monitors, endorses management plans and their implementation on the grounds -Carries out forest resources inventories -Protects forest resources via forest agents
National Park National Agency (ANPN)	-Implements national policies on protected areas, -Promotes the value of natural resources and its cultural heritage -Develops means and procedures for natural habitats, wildlife and species protection -Promotes and regulates ecotourism activities -Controls, represses law breakers through imprisonment and fines provision -Protects biodiversity protection via “eco-guards” patrol
World Council Society (WCS)	-Protect_biodiversity -Promotes conservation and environmental education programs -Raises awareness on wildlife protection in National Parks -Provides technical and scientific advice to the ANPN on following matters: *protected areas resources management and touristic infrastructures building up *eco-guards’ capacity building and biodiversity protection.

Survey results, 2010.

security of livelihoods of local people who depend on the resources located inside protected areas.

Considering that governance over forests refers to the interactions between processes (laws, policies and institutions), structures (government levels), and customs (traditional regulatory means), therefore, it has an influence on the direction through which forest and National Parks resources should be managed. Successfully arguing about governance over forests requires that emphasis is directed towards the following aspects: i) how the current forest code, National Parks laws and associated legislations influence the management of forest resources; ii) how the roles of institutions and their responsibilities are exercised over forest resources management; and iii) how the needs and interests of local people are taken into account in decision-making affecting their lives (Dearden et al., 2005).

The current forest code (2001) of 14 years old has as objectives to contribute to: i) the industrialization of the timber sector and its sustainable management to enhance the contribution of the sector to the state’s revenue (Art. 2, Gabonese Republic, 2001). On the contrary, the state has little focus on regulating access and use of forest resources including Non Timber Forest Products (NTFPs) gathering and trade, hunting and fishing, agriculture and logging activities by local people. Dead woods and related branches are the only forest products that are allowed to be freely collected throughout national forests including permanent forest estate (productive forests) and non permanent forest estate (rural forest domain). The other livelihood activities are either prohibited or poorly regulated through: i) requirement for permission from the central forest administration; ii) agreed management plan; iii) allowing the use of traditional practices, except poisoned baits, power rifles for hunting and toxic products and explosive devices for fishing; and iv) the use of activities that have “no” negative impact on forest.

The poor regulation of local people’s livelihoods has driven the phenomenon of decreasing resources and their mismanagement in rural areas of Makokou in Gabon (Christian and Kasumi, 2014, Yobo and Ito, 2015). According to the same scholars, setting up careful land use regulation for the benefit of all stakeholders while building up the capacity of the local communities to successfully manage their forests can contribute to overcome such issues and ensure sustainability. However, achieving such a lofty objective necessitates an effective devolvement of rights and responsibilities from the central government to local communities (Mudekwe, 2007), along with proper regulatory norms (Christian and Kasumi, 2014). It is worth mentioning that zonation of the national forest into permanent forest domain (productive forests and protected areas [National Parks, forest and faunal reserves, etc) (Art. 6)] and non-permanent forest estate (rural forest domain) is an indication of the Gabonese government’s effort towards biodiversity protection and regulation of uses of forest resources in the country. User regulations in permanent forest domain

Table 6. Key experts responses on governance effectiveness of forest and National Parks resources in Gabon.

Governance principles	General direction of water and forestry	National Park National Agency & World Council Society
Legitimacy	-Decentralized decision-making is acknowledged by the law but poorly implemented on the ground	-Decentralized decision-making is acknowledged by the law but poorly implemented on the ground
Transparency	-Transparency process in decision-making is acknowledged by the law but stakeholders' consultation over decisions affecting their lives is lacking in practice	-Transparency process in decision-making is acknowledged by the law but stakeholders' consultation over decisions affecting their lives is lacking in practice
Accountability	-Institutions holding authority and liability for forest management are known by the law but communities institutions are barely functional	-Institutions holding authority and liability for conservation are known by the law but communities institutions are barely functional
Inclusiveness	-Stakeholders' participation in decision-making processes is acknowledged by the law but the process is not effective on the ground	-Stakeholders' participation in decision-making processes is acknowledged by the law but the process is not effective on the ground
Fairness	-Benefits' redistribution is acknowledged by the law but it is poorly implemented	-Benefits' redistribution is acknowledged by the law but it is is poorly implemented
Connectivity	-Forest policy focuses more on sustainable development of protected forests and economic development but emphasize less on livelihood security local communities	-National Parks' policy focuses more on biodiversity conservation and ecotourism development but emphasizes less on livelihood security local communities
Resilience	-Forest policy seems to fail balancing sustainable development of protected forests and local people livelihood security	-National Parks' policy seems to fail balancing biodiversity conservation and local people livelihood security

Survey results, 2010.

such as productive forests consist on granting logging permits to stakeholders on demand and on a basis of an approved management plan by the forest administration (Art. 20).

The forest administration represents the institution in charge of the management of the national forest sector. On the contrary, the non permanent forests domain designed mainly for community forestry activities tend to be poorly managed. Customary use rights granted by the state to local people tend to be poorly regulated on the ground due to personnel shortage (Massoukou, 2007). In order to exercise their customary use rights, local communities must have an agreed and simplified management plans approved by the forest administration (Art. 156). Currently, few community forests have been established throughout the country and that rural communities are still striving to develop their own logging operations (Meunier et al., 2011). The slow process of legalization of community forests and the struggle under which the pilot project led by DACEFI (Development of Community Alternatives to Illegal Logging) to establish "well" working institutions are among the reasons explaining why only five community forests have been established since 2001 (Meunier et al., 2011). As a result, it is still quite early to evaluate the effectiveness of community forests initiatives in safeguarding forest and enhancing local communities livelihoods in Gabon (Meunier et al., 2011; Boldrini et al., 2014).

Regarding the National Parks policies and legislations, the National Park Law of 2007 has been established with aims of strict protection of forest resources, sustainable development of

National Parks, eco-tourism development, and conservation of its natural and national cultural heritage (Art.2). In National Parks, land uses are regulated in different manners including by: i) dividing forest estate into periphery zone, buffer zone and inner zone; ii) strict prohibition of access and use of resources inside of the park; iii) regulation of access and use of forest resources in buffer zone, except those that have “no” impacts on resources base; and iv) allowing free access and use of resources outside of the park (Table 3). Despite the availability of such law, a legal frameworks is needed to regulate practically: i) the management of protected forest resources in different locations of the park on the basis of customary use rights that have been granted by the state to local people; ii) how local people could participate in protected areas resources’ management and in decision-making that affect their lives; iii) how benefits generated from the park should be redistributed among stakeholders; iv) how rights and responsibilities of local people should be devolved with regards to the management of protected areas resources; and v) how conflicts based resources use should be managed among stakeholders (Dudley, 2008; Christian and Kasumi, 2014; Yobo and Ito, 2015).

Elsewhere, the lack of such regulatory framework has driven serious negative impact on both forest and local people’s livelihoods. According to Baffoe (2007), Lockwood (2010) and Lockwood et al. (2010), the successful integration of local people needs and interests in conservation initiatives passes through policy and legislation’s enhancement and their compliance with the following key governance principles: i) securing local people’s ownerships over forest resources; ii) promoting the consultation of stakeholders regarding decisions that affect their access to natural resources; iii) promoting incentives to the participation of local people into forest management; iv) precisely define roles and responsibilities of stakeholders that are engaged in conservation initiatives; v) promoting fair benefits sharing or redistribution among stakeholders. Although, most of the countries of the Congo basin have successfully integrated these key governance principles in their policy and legislations, however, their implementation is of poor efficiency on the ground (RFUK, 2014), notably in Gabon (Sassen and Wan, 2006). Locally, practical approaches to regulate resources usages and dependency (natural resources gathering, hunting and fishing, logging operations and agriculture and fuel wood collection) of local people on protected forest resources are lacking (Yobo and Kasumi, 2014a; Yobo and Ito, 2015).

There is therefore a need to establish new models of conservation governance that integrate biodiversity and sustainable regulation of local people’s livelihoods needs. The latter approach has emerged under the drive of the World Commission on Protected Areas (WCPA) (Dudley, 2008) and tends to discard the “Yellowstone” a type of protected areas. In that management approach, the needs and interests of local communities/ indigenous people are not taken into account since they are excluded from owning, managing and benefiting from the management of National Parks resources (Colchester, 2004). Studies carried out with local people living and depending forest resources of the Ivindo National Park (Gabon) tend to emphasize such a trend (Christian and Kasumi, 2014; Yobo and Ito, 2015). Despite the livelihood dependency of local people living around that park on forest products such as indigenous fruits species, they complain about resource decline driven by various anthropogenic factors and that they face restriction in access and use of forest resources inside of the park. They concluded that there is a need for designing future rules and regulations mechanisms for a successful utilization of forest resources of the park for both subsistence and income generation. Addressing the needs and interests of local people passes also through stakeholders consultation (Mudekwe, 2007). In the case of this study, the Consultative Committee in NTFPs (CCN-NTFPs) might play a key role in providing a platform of discussion about issues affecting local people’s livelihoods dependence over forest and protected areas (Table 4a and b). Issues of concerns that might be discussed may include how roles and responsibilities of institutions involved in forest and protected areas management should be effectively devolved to local communities for enhancing protected areas governance in the country.

Responsibilities of institutions interested in forest and National Parks resources management

The Gabonese government has devoted responsibilities over the management of its forests and protected areas (National Parks) to several institutions such as the General Direction of Water and Forestry (DGEF), the National Park National Agency (ANPN), the World Council Society (WCS) (Table 5). Although, these three institutions have different areas of intervention but some of them tend to overlap, especially with regards to biodiversity protection, wildlife conservation, and controlling and repressing law breakers. The DGEF and the direction of fauna and hunting of the ministry of waters and forests have not only the primary roles of regulating forest resources and wildlife conservation respectively but are also responsible of fining laws breakers when accessing and using illegally permanent forest estate. The WCS provides technical advice to the ANPN. The latter institution under the presidency of the republic is responsible for the management of the thirteen National Parks of Gabon but it is also responsible for protecting the rich biodiversity contains inside of buffer zone of 5 km long. Prior to the Forest Code of 2001, such buffer zones established around all National Parks were under the management authority of the ministry of waters

and forests but today, their management has been transferred to the ANPN (Gabonese Republic, 2007). However, it is not uncommon to encounter that the DGEF of the waters and forests ministry and the ANPN can be both involved in the management of biodiversity located inside of such buffer zones. The current forest code (2001) and National Park law (2007) have both acknowledged that carrying out livelihoods activities in buffer zones should not be detrimental to the environment of the zone and require an agreed management plan delivered by the relevant institution (Gabonese Republic, 2001, 2007).

The overlap of responsibilities among these institutions is not the result of assigned mandates by the state but it is rather due to the lack of knowledge about the physical boundaries of buffer zones (including National Parks) since there are no visible marks on the fields. In addition, discussions with key experts revealed each institution tends to operate independently with no veritable interaction and communication with each other. Overcoming such issue calls for communication and coordination between institutions, especially on the ground (Burdett, 2003). Interaction and cooperation among institutions could contribute to improve institutions performance (Johnson and Urpelainen, 2012) while the lack of interaction and cooperation among institutions may affect their performance with regards to forest resources management. Consequently, a careful interaction and communication among institutions may contribute to lessen the issue of overlap of responsibilities of institutions over protected forest resources management as it is evidenced in this study.

Evaluation of the effectiveness of governance over forest and National Parks resources in the country

The Gabonese government has made efforts towards setting up its vision for the “efficient” management of its forests and National Parks resources by integrating the seven well known key governance principles in its forest and National Parks laws and regulations. However, the effective implementation of such key governance principles tends to be weak on the grounds as highlighted by key experts responses (Table 6). The latter point is in line with the study of Massoukou (2007) which has shown that there were not transparency process nor fairness and equity in distribution of revenues gained from the exploitation of timber of the Equatorial Company of Wood (CEB) that is located in the Haut Ogooué province and consisting of 15 villages of 4919 inhabitants. In other regions of Gabon, the study of Sassen and Wan (2006), carried out around the closest communities of the Ivindo National Park (North-East of Gabon), has emphasized that local people needs and interests were not taken into account when planning and designing the management plan of that park. Recent studies of Christian and Kasumi (2014) and Yobo and Ito (2015) carried out around the same local communities has also shown that access and use of forest resources tend to be prohibited by park managers despite local people’s dependence on resources located inside of the park. Thus, the primer aim of National Parks establishment was not designed to sustain local people’s livelihoods but rather to protect its rich biodiversity. These results are in line with the meta-analysis study of Porter-Bolland et al. (2012) which emphasizes that across the tropics, local people livelihoods dependence on forest resources was not taken into account in resources conservation initiatives and that local people’s rights were neither acknowledged nor secured. Acknowledging and securing local people’s rights passed through an effective decentralization mechanism over the management of forest resources (Agrawal and Gupta, 2005). In case of Gabon, a decentralization policy exists. However, it tends to be poorly implemented on the ground (Meunier et al., 2011), as it is the case in most countries of the Congo region.

Some of the consequences of the increasing expansion of protected area’s network in the Congo basin (second in size after the Amazon with over 180 million hectares) are: i) further protection measures to safeguard its rich biodiversity; and ii) less concerns directed towards addressing the needs and interests of forest-dependent peoples in resources management (RFUK, 2014). As a result, available national policies and legislations tend therefore to: i) be highly restrictive over protected areas resources access and use; ii) promote less protected areas governance led by indigenous peoples and local communities themselves; and iii) exclude more local people from management of forest and protected areas (Sassen and Wan, 2006; RFUK, 2014). This contributes to the threats on the livelihood of local communities who depend on the resources (Stevens, 2010), especially in the absence of alternatives to compensate local communities from losing access and use over their forests. The reconciliation of biodiversity conservation in protected areas and socioeconomic development of local and/or indigenous people is therefore needed (Naughton-Treves et al., 2005). However, caution in their future implementation is needed since such approach depends strongly on social, economical and political contexts of the country.

CONCLUSION AND RECOMMENDATIONS

Gabon has an established network of thirteen National Parks throughout of the country as an opportunity to increase biodiversity conservation and sustainable management of its rich ecosystem, and that large areas of forest have been allocated for timber production (sustainable timber extraction) and certification for economic development. However, the state has focused less on securing the livelihood of local communities since National Parks belong to one single category II that are characterized by “no take” policy, especially inside of

their boundaries. In those areas, access and use of resources are prohibited by available laws contributing therefore to threaten the livelihoods of local people living close by and depending on protected resources to some extent. In order to guide the management of its forest and National Parks resources, two key policies including the forest code (2001) and the National Parks law (2007) along with several regulations (decrees and ordinances) have been enacted. These policies and regulatory framework aim at achieving dual goals including: i) the industrialization of the forest sector and its sustainable management; and ii) forest protection and biodiversity conservation, eco-tourism development and conservation. On the contrary, such policies and regulatory framework have focused less on: i) addressing the livelihoods needs and interests of local people on resources base and secure their rights and participation into resources management and decision-making affecting their lives; ii) regulating resources uses in various locations of the park; and ii) reconciling both the livelihood's dependence of local community and biodiversity conservation at the same time.

Responsibilities over forests and National Parks resources management have been devolved by the state to several institutions including the General Direction of Water and Forestry, the National Park National Agency and the World Council Society, especially with regards to biodiversity conservation (forest and wildlife), patrolling and enforcing laws. However, there is an overlap of institutional mandates of these three institutions that might hamper the effectiveness of conservation governance, especially if left unchecked. Although, the seven well known key governance principles have been successfully integrated in the relevant policies and associated regulations to enhance forest and National Parks resources management and its biodiversity conservation, however, these key governance principles tend to be poorly implemented on the ground. This may contribute to undermining the already achieved goals by the state with regards to forests and National Parks resources management on one hand and threaten the livelihoods security of local people who depend on such resources on the other hand.

The following recommendations are drawn from this study,

i) Clearly redefine the responsibilities of the institutions involved in the management of forest and National Parks resources
ii) Care has to be taken by policy makers to successfully implement the seven key governance principles to meet both biodiversity conservation and livelihood security of local people, especially on the ground
iii) Integrate the needs and interests of local people in policies and legal frameworks that govern the management of forest and National Parks through pilot studies. Once found successful, such study can be scaled up to other National Parks and that policies and legal frameworks should be improved accordingly.

Conflict of Interests

The authors have not declared any conflict of interests.

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Field evaluation of naturally occurring mosquito repellents in Mt. Kenya Region, Kenya

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Malaria continues to claim about 2 million lives annually worldwide. In Kenya, malaria equally depicts a morbid picture. It poses a major threat to the lives and health of 20 million people in Kenya and is a major killer mainly of children under five years and expectant mothers. This research was aimed at identifying plants used by communities in repelling mosquitoes. Community meetings were held at the District Culture Office, Embu with participants from Nyeri, Kirinyaga and Embu counties. The plants that were used by the community in repelling mosquitoes were identified.

Key words: Mosquito, repellence, malaria, Mt Kenya region.

INTRODUCTION

For the last 60 years, the world community has been putting a lot of effort in getting rid of malaria globally. However, these attempts have not been very successful, especially in the developing countries, where malaria is still a major killer (Tognotti, 2009; Biscoe et al., 2004). Apart from management of the malaria by chemotherapy and clearing of mosquito breeding sites, prevention of bites is a strategy that is also applied. Avoiding bites is achieved by shunning infested habitats, wearing protective clothing, and using insect repellent whereby, applying repellent to the skin may be the only feasible way to protect against insect bites (Fradin and Day, 2002). Tawatsin et al. (2001) also reported mosquito control and personal protection from mosquito bites as the most important measures in controlling mosquito borne diseases. The World Health Organisation has been involved in popularizing the usage of insecticide treated mosquito nets (World Health Organization (WHO), 2013), which though a good approach, may not be entirely sustainable since supply of free nets is not guaranteed. Further, mosquitoes are also likely to develop resistance to chemicals in treated nets and it is not possible to be under nets the whole day. It has been reported that resistance has been widely identified to pyrethroids by the mosquito vector, and these are the chemicals that are highly relied upon in long lasting insecticide treated nets (WHO, 2011).

When African Heads of State and Government met in

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Table 1. County of origin of participant herbalists.

County	Frequency	Percent
Embu	10	59
Kirinyaga	3	18
Nyeri	4	24
Total	17	100.0

Nigeria in the year 2000, they declared a total war against malaria, which is an initiative of the World Health Organization (WHO and UNICEF, 2003). This initiative was started due to the recognition of the great health, social and economic importance of malaria. The disease is estimated to cost Africa up to US$ 12 billion annually. This has slowed economic growth by up to 1.3% and the entire Africa's population is at risk (World Bank, 2007). Pregnant women and young children are known to be at the highest risk. Many drugs are used in treating malaria, with artemisinin combination ranked best, but still the parasite is capable of developing resistance to many of these drugs. One of the best approaches to controlling malaria is the development of cheap natural repellents.

N,N-diethyl-3-methylbenzamide (deet) is the most commonly used chemical in most repellent formulations in the market which has remained the case since 1954 when it was discovered (Tawatsin et al., 2001; Chen-Hussey et al., 2014). There are many concerns about the safety of use of deet, with toxicity concerns ranging from mild to severe, more so in children (Tawatsin et al., 2001; Isman, 2006; Park et al., 2005). Psychosis, immediate contact dermatitis following dermal application, generalized pruritus and angioedema and conjunctival damage from application to the eye have been noted from the use of deet (Ellenhorn, 1997 as cited in Koren et al., 2003). Accordingly, many chemists consider an effective alternative to deet for personal protection against mosquitoes and biting flies to be the holy grail (Isman, 2006).

Many plants have been used as mosquito repellents. Among the common plants used as repellents include citronella, cedar, verbena, pennyroyal, geranium, lavender, pine, cajeput, cinnamon, rosemary, basil, thyme, allspice, garlic, peppermint, eucalyptus, lemongrass and soybean, usually due to the presence of essential oils (Trongtokit et al., 2005; Fradin and Day, 2002). In many studies that have been done, these plant based repellents have been found to provide less protection times than deet (Fradin and Day, 2002; Isman, 2005). A good repellent should be effective against a wide array of biting arthropods for at least 8 hours, be non-toxic, non-irritating, odorless, and non-greasy and such a repellent is yet to be developed (Fradin, 1998; Bissinger and Roe, 2010 as cited in Karunamoorthi, 2012).

In this regard, continued research on new repellents is important. Therefore, the purpose of the study was to identify the plants used by communities around Mt. Kenya in repelling mosquitoes, with an aim of establishing whether there is potential for new but effective repellents.

METHODOLOGY

Herbalists were invited to a stakeholder meeting where information about the use of herbs in producing mosquito repellents was collected with assistance from Department of Culture, Embu county. A structured questionnaire was also administered to individual herbalists. The information constituted the local name of the herb, the habitat, form, part of the plant harvested, preparation and administration. This was followed by a field visit to the localities mentioned by the herbalists to verify the plants mentioned. Plant specimens were further taken to herbarium at Egerton University for authentication.

RESULTS AND DISCUSSION

From the participants in the discussion it was found that the majority were from Embu county, where the meeting was held (Table 1).

Most commonly used plant species

A list of plant repellents was given by the practitioners. The species were ranked by their frequencies. *Tagetes minuta* was the most commonly used (52.9%) repellent. The other commonly used repellents were *Azandracta indica* oil (35.3%), *Azandracta indica* plant material (23.5%) and *Caesalpinia volkensii* (23.5%). Cowdung though not a plant was also reported to be used as a repellent by 23.5% of the practitioners. From this list, *Azandracta indica* was used more frequently than the others since it was used in two forms; as an oil and the plant material itself. The use of the plant in both forms was reported by 58.8% of the participants. This was higher than the per cent reported for *Tagetes minuta* (52.9%). These results are summarised in Table 2.

Families of repellents

From the list of repellents that were reported, the frequency of the plant families was determined (Figure 1). The Lamiaceae family had the largest proportion of the repellents (21.7%). The families: Asteraceae, Caesalpinaceae, Meliaceae, Solanaceae and Verbenaceae were each represented by two plant species, while all the other families were each represented by just one species. According to Isman (2005) the mint family (Lamiaceae) provide most of the essential oils produced commercially from plants. Similarly in this study, the largest proportion of repellent plants belonged to this family.

Table 2. List of all the repellents ranked by frequency

Local name	Scientific Name	Family	Frequency	Per cent	Ranking
Mubangi	*Tagetes minuta*	Asteraceae	9	52.9	1
Neem oil	*Azandracta indica oil*	Meliaceae	6	35.3	2
Neem plant	*Azandracta indica*	Meliaceae	4	23.5	3
Mubuthi/Mucuthi	*Caesalpinia volkensii*	Caesalpinaceae	4	23.5	3
Cowdung	-	-	4	23.5	3
Mutaa	*Ocimum basilicum*	Lamiaceae	3	17.6	4
Gacuki	*Ocimum americanum*	Lamiaceae	2	11.8	5
Wanjiru wa Ruriii/weru	*Ajuga remota*	Lamiaceae	2	11.8	5
Mwenu/Mwinu	*Senna didymobotrya*	Caesalpinaceae	2	11.8	5
Muthiriti	*Lippia kituensis*	Verbenaceae	2	11.8	5
Kavovo/Muvovo	*Leonotis mollisima*	Lamiaceae	2	11.8	5
Queen of the night	*Lippia caviodora*	Verbenaceae	1	5.9	6
Muchuki	*Epilobium hirsutum*	Onagraceae	1	5.9	6
Sodom apple	*Solanum incanum*	Solanaceae	1	5.9	6
Muthuthi	*Mytenus senegalensis*	Celasteraceae	1	5.9	6
Muthiga	*Warburgia ugandensis*	Canellaceae	1	5.9	6
Muringa	*Cordia abyssinca*	Boraginaceae	1	5.9	6
Muretha	*Gnidia glauca*	Thymelaeaceae	1	5.9	6
Mukau	*Melia volkensii*	Meliaceae	1	5.9	6
Mukanga	*Antidesma venosum*	Euphorbiaceae	1	5.9	6
Muhua	*Tithonia diversifolia*	Asteraceae	1	5.9	6
Mbaki	*Nicotiana tabacum*	Solanaceae	1	5.9	6
Kareria	*Mormodica foetida*	Cucurbitaceae	1	5.9	6
Gatambogo	*Caparis sepiaria*	Capparaceae	1	5.9	6
Aloe	*Aloe* species	Aloaceae	1	5.9	6

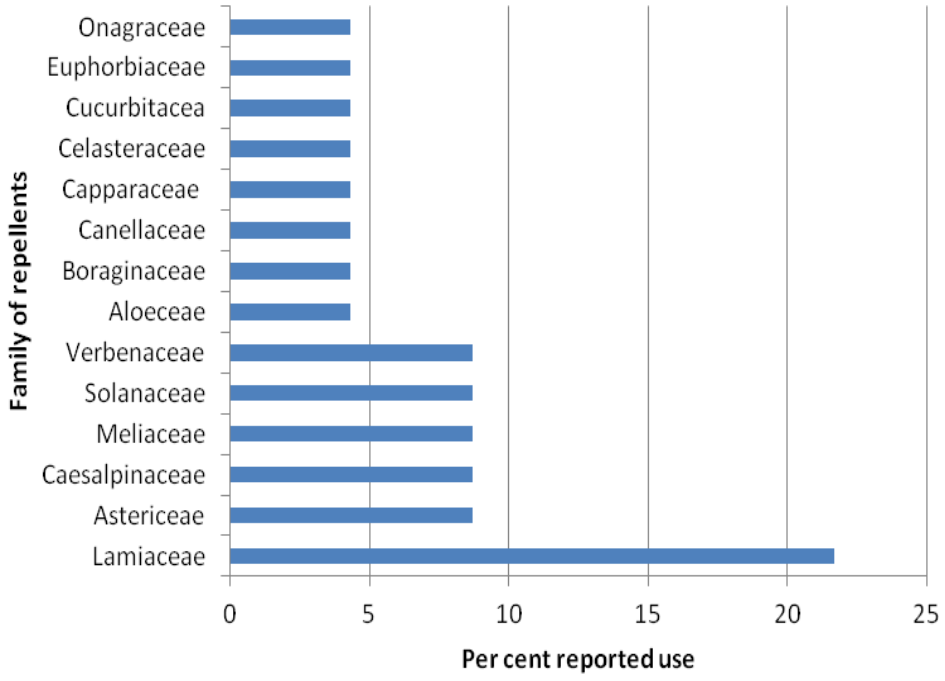

Figure 1. Family of the repellents used.

Table 3. Perceived 'most effective' repellent.

Repellent	Scientific Name	Frequency	Percent	Rank
Neem oil	*Azandracta indica* oil	3	17.6	1
Muchuki	*Epilobium hirsutum*	3	17.6	1
Mubuthi	*Caesalpinia volkensii*	2	11.8	2
Mubangi	*Tagetes minuta*	2	11.8	2
Neem plant	*Azandracta indica*	1	5.9	3
Gatambogo	*Capparis sepiaria*	1	5.9	3
Queen of the night	*Lippia caviodora*	1	5.9	3
Muthiriti	*Lippia kituensis*	1	5.9	3
Mabaki	*Nicotiana tabacum*	1	5.9	3
Mutaa	*Ocimum basilicum*	1	5.9	3
Muretha	*Gnidia glauca*	1	5.9	3
Total		17	100	

Most effective repellent

The participants were requested to each give the repellent that was most effective. This is because what is commonly used may not necessary be most effective, as use may be influenced by availability. The repellents perceived as most effective were *A. indica* oil (17.6%), *E. hirsutum* (17.6%), *C. volkensii* (11.8%) and *T. minuta* (11.8%) (Table 3). When both forms of use of *A. indica* (plant material and oil) were considered its reported per cent as most effective was highest (23.5%). Some of the plants identified in the study are also reported in other studies as repellents and some as pesticides. Neem plant (*A. indica*) and its products and *Ocimum basilicum* have been cited as natural repellents demonstrating good efficacy against some malaria species (Tawatsin, 2001). Isman (2006) stated that *Nicotiana tabacum* has a long history of use as an insecticide against soft-bodied pests but because of extreme toxicity of pure nicotine to mammals has seen its use declining gradually. Other plants reported as repellents include *Lippia* spp., *Ocimum* spp., *Tagetes minuta* (Maia and Moore, 2011; Shooshtari, 2013). *Lippia kituensis* was reported to have acaricidal activity (Kosgei et al., 2014 as cited in Nyabayo, 2015) while it was reported as having mosquito repellent properties (Amer and Mehlhorn, 2006 as cited by Manimaran and Cruz, 2014). No mention of use of *Capparis sepiaria* as a repellent was found in literature though a plant in the same family, *Capparis tomentosa,* has been reported as a repellent (Kishore et al., 2011). Similarly *C. volkensii* was reported as an antimalarial in literature (Ochieng' et al., 2012 as cited in Haque et al., 2012).

Method of use of the repellents

For the repellents that were commonly used, the respondents were requested to elaborate on how they were utilised. The plant materials were used by placing in the room while fresh, smoking, as an infusion, powder and by boiling. Smoking method was applied to more repellents than the other methods with a total of six plant species being smoked. Smoking was done in different ways for instance, using repellent oil in lamps as was the case with neem oil and placing on wood stoves to produce smoke as was the case with *C. sepiaria*. Some fresh plants were placed in the room or near the bed and their strong smell would keep away the mosquitoes for example, *O. basilicum*, *T. minuta* and *O. americanum* (Table 4).

The neem plant, *C. volkensii* and *T. minuta* were used as powder which was applied on the body to repel the mosquitoes. Some of the repellents were used as an infusion whereby the plant was placed in boiled water and allowed to cool and the water was then used in a bath, which was the case for *Lippia kituensis* and *Lippia caviodora*. Boiling was also done where the plant was placed in boiling water and the steam was used to repel the mosquitoes. While most of the repellents could only be used in one way, others were used in more than one way. These include *O. americanum* that could be smoked, *T. minuta* used as a powder and both could be placed in room while fresh. Neem plant was smoked and was as well used as a powder. Maharaj (2010) recognized that communities in Africa had historically employed traditional methods to keep away mosquitoes by ways such as burning of cow dung or certain plants, or the placement of specific plant parts in and around the sleeping area. Innocent et al. (2014) reported that repellent plants were used by communities in Tanzania by: burning charcoal in containers placed at different locations inside the homesteads to generate smoke and volatile emissions, application of ground fresh materials or small pieces at selected places within the homesteads and soaking plant parts or powder in water and then spraying.

CONCLUSION AND RECOMMENDATIONS

From this study, it was noted that there are many indigenous plants in use by communities within Mt. Kenya region with potency for repelling mosquitoes, with some not reported previously as potential repellents. Further research is recommended on these plants to verify the chemistry of the compounds in the different species which can be extracted, formulated and dispensed in the control of malaria. It is also important for empirical studies to be done on efficacy of the repellents and potential toxicological properties of the plants.

Conflict of Interests

The authors have not declared any conflict of interests.

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