Ecological challenges for the buffer zone management of a West African national park

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Abstract In sub-Saharan Africa, the management of buffer zones around protected areas do not often take into serious account the needs of resource exploitation by the local populations or the conservation needs of these areas. We described the ecological characteristics and management issues affecting the buffer zone around the Fazao-Malfakassa National Park (FMNP); a 192,000-ha protected area in central-western Togo of utmost conservation importance within the Dahomey Gap region. We focussed on the 10-km radius buffer zone around the park. Using 2015 sentinel-2 images we analysed land cover patterns and described existing ecological zones. We complemented these with field surveys and interviews with 300 persons living in 22 villages within the buffer zone to describe the conditions affecting the resident human population. Although over 80% of the total buffer zone area is altered, we identified four areas of high conservation value (total area = 65,594 ha). Interviewees recognized that slash-and-burn was the most common form of land use, followed by agroforestry practices. Agriculture, charcoal and firewood production were the main drivers affecting habitats, and land conflicts were recurrent due to the rise in human population. The decline in agriculture, reported by interviewees in some sectors, was attributable to ravages of crops by elephants. Three independent diversity indices showed that in well-preserved zones, a greater diversity of animals (with similar utilization frequencies) were hunted than in altered sites (where grasscutters were the dominant hunted species). There were also significant differences between altered and well-preserved zones in terms of plants used for charcoal production and for non-timber forest products. We advocate the development of community-controlled hunting areas to enhance the conservation value of the four well-preserved zones. Instead, promoting sustainable agricultural production systems in the degraded areas can help to further stabilize the agricultural front and reduce land pressure on the park.

Keywords Buffer zones management; Human Pressure; Biodiversity; Standardized questionnaires; Fazao-Malfakassa National Park; Togo

INTRODUCTION

Protected areas are an essential component of conservation strategies (Aubertin 2013; Gross et al. 2015). To play their roles fully and sustainably, protected areas should be managed in a way that considers the needs and concerns of local populations, not only within the core zones, but also in the buffer (=peripheral) zones (e.g. Dudley 2008; Aubertin 2013). Buffer zones (sensu Sayer, 1991; Binot et al. 2007; Mathevet et al. 2010) are used for activities that are compatible with ecologically sustainable practices that support directly or indirectly conservation and research, and importantly serve ecological buffering functions (Shafer 1999; Martino 2001; Andersson *et al*. 2017). Thus, inside buffer zones, some restrictions are placed on resource exploitation and land use in support of the protection of the protected area itself (Newmann 1997). For instance, whereas hunting and/or fishing may be seasonally forbidden and anyway monitored, several benefits go directly to local communities including those related to wildlife (wages, income, meat), social services and infrastructure (clinics, schools, roads), and political empowerment through institutional development and legal strengthening of local land tenure (Newmann 1997). Additionally, in the buffer zones of African protected areas there has often been an applied effort at assuring the cultural survival and to incorporate indigenous knowledge and practices in conservation management (e.g., Newmann 1997)

Although some management activities are undertaken to enhance the conservation values of the area (Sayer, 1991; Wells and Brandon 1993) and to provide benefits to neighboring rural communities (Wells and Brandon 1992, 1993), the main goal of buffer zones is still to protect biodiversity, but this protection has to be harmonized with the derivation of benefits to local people (Martino 2001).

Although few studies have investigated the effectiveness of buffer zones in terms of their ecological buffering functions, a number have focused on the socioeconomic aspects (see Heinen and Mehta 2000; Whitelaw *et al*. 2014; Gross-Camp *et al*. 2015). Ecological functions of buffer zones include: (i) the enhanced conservation of species with high mobility

(Barzetti 1993) or of ecological relevance (i.e. ecosystem engineers or "landscape species" sensu Alexandre *et al*. 2010), (ii) their functioning as physical barriers to human encroachment (Martino 2001; Andersson *et al*. 2017), (iii) reduction of the edge effects (Shafer 1999), and (iv) enhancement of the environmental services provided by the reserve (e.g. Martino 2001; Andersson *et al*. 2017). However, several studies noticed that local people do not receive economic benefits from the establishment of buffer zones; for instance, establishment of ecological corridors for wildlife may involve relocation of communities with economic compensations, but these were normally irrelevant compared to the social, cultural and economic damages due to the translocation (Mwalyosi 1991; Heinen and Mehta 2000; Martino 2001; UICN/PACO 2011, 2012). Thus, the establishment and management of buffer zones is often a very complicated task for the governmental and non-governmental agencies devoted to it.

In sub-Saharan Africa, the management of the buffer zones does not usually consider the needs of resource exploitation by the resident populations (e.g., traditional hunting or fishing, collecting fallen timber, harvesting fruit (Mwalyosi 1991; Brandon 1997; Gami 2000; Ministere de l'Environnement et des Ressources Forestieres 2008)), or the conservation needs and values of their natural resources (Hanon *et al.* 2008). The operative definition of buffer zones also varies across countries in terms of their extension and zone of influence. For instance, concerning the trans-country W Regional Park, the buffer zone was 3 km radius in Benin and 1 km in Burkina Faso (Lungren and Bouché 2008). However, it was 10 km in Central African Republic (Gami 2000), with no specification in Togo (UICN/PACO 2012). These different buffer widths are also driven by the size and shape of the protected area in question and obviously by the various socio-ecological roles that are also very relevant in defining a buffer (Hanon *et al.* 2008). Thus, defining a buffer zone is much more than just deciding a consistent width around a given protected area by the respective governmental agencies (e.g., Andersson *et al.* 2017). The operative definition of buffer zones also varied in terms of the rights of the resident human populations (village dynamics, rights or prohibitions of use) (UICN/PACO 2012). Therefore, many buffer zones are seen by local populations as a mere geographical expansion of state authority beyond the boundaries of protected areas (Martino 2001). Buffer zones should be perceived as areas in which sustainable use of natural resources is promoted to benefit both local communities and wildlife (Wild and Mutebi 1997).

Although much scientific literature is currently available on the functions and problems affecting buffer zones in African protected areas since the 1990s (e.g., Vujakovic 1987; Mwalyosi 1991; Newmann 1997; Wild and Mutebi 1997), almost nothing has been published to date on buffer zones of parks and natural reserves in Togo (UICN/PACO 2008). Despite being one of the smallest African countries with a population of about 7.6 million (DGSCN 2014), this country has an increasingly successful economy (annual GDP growth has averages 5.5% in the last 10 years, higher than most Sub-Saharan economies (World Bank 2017). Being heavily based on agricultural development (accounting for about 40% of GDP; World Bank 2017), the Togolese economy also generates serious problems for the conservation of natural areas and wildlife (UICN/PACO 2008). This means that understanding the functionality and problems affecting buffer zones in the country can be crucial in heightening the management of protected areas (UICN/PACO 2008).

In this paper, we explore the ecological challenges affecting the management of the buffer zones in one of the country's most important protected areas, the Fazao Malfakassa National Park (hereby FMNP). By employing satellite image analysis and an interview-based approach with local communities we investigate ongoing landscape patterns and uncover the most pressing issues. More specifically, we aim to answer the following key question: what are the locally-perceived drivers affecting the buffer zone? In order to answer to this major question, we specifically investigated the following questions too: (i) Are there any areas of remarkable conservation value for both landscape characteristics and wildlifethat should be considered in the management of the FMNP buffer zone? (ii) What drivers affect these areas? (iii) What are the best options for enhancing the ecological filter value of the buffer zones for the management objectives of FMNP? To answer these questions, we (i) identify areas with high conservation value, (ii) undertake an inventory and analysis resource exploitation practices and (iii) identify the determinants of the agriculture and landscape dynamics in the area.

MATERIALS AND METHODS

Study area

Located in the central part of the Atakora mountains, and extending between the longitudes East 0 ° 36 'and 1 ° 2' and the latitudes North 8 ° 21 'and 9 ° 10' at the boundary between Sudanese and Guinean savannah vegetastion zones (Figure 1), The Fazao-Malfakassa National Park (PNFM) has an area of 192,000 hectares, or 3.4% of the Togolese territory. This protected area was created in 1975 as a result of the merger of the protected areas of Fazao (162 000 hectares) and Malfakassa (30 000 hectares) in a Wildlife Reserve by Decree No. 372 / EF of 15 May 1954 (IUCN / PACO, 2008). FMNP was managed by the Ministry for the Environment and Forestry Resources (MERF in French) up to 1990, by Franz Weber Foundation between 1990 and 2015, and by MERF afterwards (Atsri et al. 2018). Surveillance patrols of the park are mainly conducted by ecoguards recruited from the riparian villages. Populations are informed about management decisions but they do not participate in decision-making mechanisms and are rarely consulted formally. However, since 2013 they have been organized informally by village associations of participative management of protected areas (AVGAP) in each village legally recognized by the national territorial administration. These associations aroused by the park manager do not have operating budgets. There are no formal agreements on the sharing of responsibilities and powers between the manager and these organizations of local populations on management actions. The park is drained by the rivers Mô, Anié, Koui and Kpawa, and is characterized by an annual rainfall varying between 1200 and 1500 mm.

In 2010, human population inhabiting the buffer zone of FMNP was estimated at 60,216 (DGSCN 2014), with a density that has increased from 21 inhabitants / km² in 1981 to 47 inhabitants / km² in 2010 (growth rate = 2.81%, DGSCN 2014). There are many villages around the park. These villages are populated by various ethnic groups including Kotokoli, Agnanga, Bassar and Kabyè. Most of the landscape consists of agricultural fields, with a patchy mosaic of closed-canopy forests (semi-deciduous, dry deciduous and riparian forests) and open forests, as well as wooded savannahs.

Protocol

Three "altered" and three well preserved zones were surveyed during the present study (see below for details). These areas were selected after being identified using the land use map of the buffer zone (within a 10 km radius around the FMNP), with a visual interpretation of colored images and supervised classification of the 2015 Sentinel-2A MSI of December 21st image (10m resolution) for discriminating different types of land cover using the maximum likelihood algorithm. This method is based on Bayes' theorem, which makes it possible to describe the classes contained in the image based on the probability density concept (Robin 2007). These are two MSI images not covered by dry season clouds that have been mosaicked to cover the entire study area. This method of land cover analysis has yielded excellent results in the study of FMNP habitat dynamics (Atsri et al. 2018). The classified image of the peripheries was thus validated according to the approaches used by Atsri et al. (2018).

In order to keep a “standard” size of the buffer around the whole protected area, for this paper we used an area of 10 km beyond the park’s boundary as ‘buffer zone’ (Figure 1). Thus, we interviewed (by questionnaire) only people living permanently in villages situated within the buffer zone area. The questionnaire was administered to 300 persons (150 from well-preserved and 150 from altered areas) from 22 out of 75 villages situated around the park (Appendix 1). These 22 villages were randomly selected among those available within the buffer zone area. Twelve of the villages were in three degraded areas and 10 villages in three well preserved areas on the outskirts of the FMNP. This sample represented 0.5% of the total population of the riparian villages. Interviewees were selected on a voluntary basis; they were not paid for participating in the study and they were firstly informed of the aim of the study. In the villages, we firstly explained the aim of the study to the village chief, and the number and type of participants we needed. He/she then asked some residents to participate. The interviews were facilitated and translated by a person of the same ethnicity of the village we were working on. In order to ensure the independence of the answers, all the interviewees were approached individually, taking into account the state of conservation of the buffer zone. We focused our interviews on farmers (other than chiefs and hunters) because, in the area, almost all farmers are both carbonizers and firewood collectors. These farmers are involved in the production of wood during periods of low agricultural activity (after harvests between November and February). Wood carvers, local mat and and basket weavers, and nut peakers do not occur in the study area.

An area was considered to be "degraded" if it was characterized by a predominance ($\geq$ 65%) of agricultural fields, agroforests, human settlements and important tree cutting areas (exploitation for charcoal or firewood). On the other side, it was considered "preserved" if it was characterized by a predominance of natural ecosystems (forests and savannahs), and by the absence of agricultural fields, agroforests and woodcutting. This questionnaire focused on land use practices, forestry and wildlife resources in the buffer zones, as well as on the different types of land-use conflicts and different agricultural practices. More specifically, each questionnaire consisted of the following questions for each interviewee:

(i) what is the most common form of land use in the surroundings of your village (three pre-selected options available for choice: slash-and-burn, fallow, agroforestry);

(ii) what are the most important resource exploitation practices in the surroundings of your village (for instance, agriculture, hunting, etc.)? Interviewees were allowed to freely describe the various practices without any pre-selected option made by the interviewers.

(iii) what are the different types of conflicts related to the use of resources? (three pre-selected options available for choice: human / wildlife conflicts, land conflicts, ranger / farmer conflicts);

(iv) what is the evolution of the agricultural front in the last five years? (three options : growing, stable, decrising);

(v) what are the reasons for the observed agricultural front dynamics? Interviewees were allowed to freely describe the various reasons without any pre-selected option made by the interviewers.

(vi) what are the most hunted animals?;

(vii) what are the most exploited forest species for charcoal, firewood and non-timber forest products?

The study areas were selected after being identified using the land use map of the buffer zone (within a 10 km radius around the FMNP), with a visual interpretation of colored images and supervised classification of the 2015 Sentinel-2A MSI of December 21st image (10m resolution) for discriminating different types of land cover using the maximum likelihood algorithm. The main landuse characteristics are presented in Appendix 2. This method is based on Bayes' theorem, which makes it possible to describe the classes contained in the image based on the probability density concept (Robin 2007). Each area was considered 'altered' if it was characterized by a predominant presence of agricultural fields, agroforestry zones, houses, and areas of clear-cutting of trees (exploitation for charcoal or firewood), whereas it was considered as 'well preserved' if it was characterized by a predominant presence of natural ecosystems (forests and savannahs), and by the absence of agricultural fields, agroforestry zones, and areas exploited for wood.

Field surveys were conducted also through line transects to observe faunal species of conservation value (primates, elephants, ungulates, reptiles), and possibly to determine their apparent status in the different surveyed areas.. Details of the field methodology utilized during these surveys are presented elsewhere (e.g., Ségniagbeto *et al*. 2017, 2018), but included random visual encounter surveys in suitable sites, heard calls, and examination of hunted specimens in local bushmeat markets (Ségniagbeto 2009; Ségniagbeto *et al*., 2017). These species were selected on the basis of their easy detectability in the field, thus allowing the experimenters to make sound comparisons of their kilometric abundances between altered and well preserved areas.

Data analysis

Kilometer abundance indices (KIA) of several target vertebrates were calculated according to the status of the area (degraded and preserved). KIA was the ratio of the number of individuals observed to the distance traveled in kilometers. This index makes it possible to appreciate the apparent abundance of species in an area:

$$\text{KIA} = \frac{\text{Number of observed individuals}}{\text{total distance walked in km}}$$

Frequencies of different types of answers by interviewees were analyzed by χ^2 test. In order to analyze the differences between altered and well-preserved zones in terms of variety of frequently hunted animals, three distinct measures of community diversity were calculated for each village (Magurran 1988; Hammer 2012):

(a) Dominance index = 1-Simpson index, and ranges from 0 (all taxa are equally present) to 1 (one taxon dominates completely the community of hunted animals);

(b) Simpson's diversity index. This index measures the 'species diversity' of the community of hunted animals, and ranges from 0 to 1.

(c) Evenness, calculated by Pielou's formula:

$$e = H/\log S$$

with H representing Shannon's index, and S the total number of taxa recorded in in each study area (Magurran 1988).

Overall differences of KIA mean estimates of target animal species between altered and preserved areas were assessed by Mann-Whitney U-test. Species-specific differences in KIA estimates between altered and preserved areas were assessed by Mann-Whitney U-test on the independent sampling surveys for each species. In order to differentiate the two zone types (altered versus well-preserved) in terms of their quantitative hunted animals community composition (as emerged from interviewees' responses), we used a One-Way Analysis of Similarities (ANOSIM). ANOSIM is roughly analogous to an ANOVA in which the univariate response variable is replaced by a dissimilarity matrix, i.e. with distances that were converted to ranks (Clarke 1993). Significance was computed by permutation of group membership, with 9,999 replicates, and Bray-Curtis was used as distance measure. ANOSIM was performed in R-software, using Vegan package (Oksanen et al. 2010), whereas, for all the other statistical tests, the software PAST 3.0 version (Hammer 2012) was used, with alpha set at 5%.

RESULTS

Biodiversity characteristics of the well-preserved and altered buffer zones

Despite strong anthropogenic pressures on the buffer zone of the FMNP (identified through Sentinel as mentioned above), four clearly defined well-preserved areas were identified (zones 1 to 4, see Figure 1), with a total area being estimated at 65,594 hectares. In three of these well preserved areas, we also conducted our interviews. The main ecological characteristics of these areas are summarized in Table 1, whereas the abundance estimates for the target animal species (KIA estimates) are presented in Table 2. Overall, the mean KIA abundances of the target species (lumped together) did not vary significantly among protected area and buffer zones (Mann-Whitney U-test: $z = -0.161$, $U = 94$, $P = 0.872$). However, when analyzing the various species separately, it resulted that *Kobus kob*, *Tragelaphus scriptus* and *Philantomba walteri* were significantly more abundant in the protected area, and *Thryonomys swinderianus* in the buffer zone (in all cases, $P < 0.05$ at Mann-Whitney U test).

Zone 1 is dominated by woodland savannah with scattered islands of dense semi-deciduous forests. We directly observed several species of conservation concern, including elephants (*Loxodonta africana*), that use these areas as a refuge during periods of heavy rains. Other frequently observed species were baboons (*Papio anubis*), Spot-nosed Monkey (*Cercopithecus petaurista petaurista*), mona monkeys (*Cercopithecus mona*), Buffon's kobs (*Kobus kob*), West African crocodiles (*Crocodylus suchus*), pythons (*Python sebae* and *Python regius*) and tortoises (*Kinixys nogueyi*).

Zone 2 is characterized by tree and woodland savannah on hydromorphic soils scattered by small open forest fragments dominated by *Isoberlinia* trees (Fabaceae). We observed large herds of Buffon's kob, waterbuck (*Kobus ellipsyprimnus*), pata monkeys (*Erythrocebus patas*) and baboons in the open forest patches and in the wooded savannahs. Elephants were regularly observed in this zone, and indeed they make incursions into the cultivated fields (particularly of yam) especially in this zone.

Zone 3 is characterized by a mosaic of hills and plains dominated by woodland savannah, with scattered patches of open forests and dry dense forests. In this zone, non-timber forest products cited by the respondents are widely sold in the local markets surveyed. There was an abundance of *Detarium senegalense*, *Pentadesma butyracea, Parkia biglobosa* and *Vitellaria paradoxa* fruits and their derivatives in local markets. These observations confirm the strong exploitation of these non-timber forest products cited by respondents both inside and outside the park (peripheral areas). Our study did not take into account fungi. Nevertheless, studies already conducted in and around the park have identified, through ethnomycological surveys, 23 taxa commonly used by people for food, two taxa for medicinal and food purposes, while a taxon is used exclusively for medicinal purposes (Kamou et al. 2015). On the other hand, insects are not exploited in the area for trade or for food (our unpublished data). Some primates (*Colobus vellerosus* and *Cercopithecus mona*) were observed during our surveys, while also consuming these fruits.

Zone 4 is also a mosaic of woodland savannah and open forests with large patches of dense forest. There are permanent ponds in this area, where elephants were regularly observed. These areas were also frequented by forest buffalo (*Syncerus caffer nanus*) and hartebeest (*Alcelaphus buselaphus*), but also baboons, pata monkeys, tortoises (*Kinixys nogueyi*) and turtles (*Pelomedusa subrufa* and *Pelusios castaneus*) were regularly observed.

In the altered areas, where the agricultural lanscape is dominant (>80% of the total landscape area), the fauna appeared highly depleted, with virtually no species of conservation value. Mammal fauna is dominated by such habitat generalists as *Thryonomys swinderianus*, *Cricetomys gambianus*, and *Hystrix cristata*. Large ungulates were not observed, whereas small duikers (*Philantomba walteri*) were extremely rare. The reptilian fauna of altered areas was dominated by lizards and snakes. Spitting cobras (*Naja nigricollis*) and African puff adder (*Bitis arieens*) were relatively common, and represented a main threat to local farmers.

Exploitation of buffer zone resources: interview-based approach

What is the most common form of land use?

Since there were no statistical differences between answers by interviewees in the altered versus well-preserved zones (χ^2= 5.28, df = 3, P = 0.152), we pooled the data from the two zone types. Overall, slash-and-burn was considered the most common form of land use by 38.5% of the interviewees, agroforestry by 35.2%, fallow by 21.1%, whereas 5.2% did not have any opinion.

What are the most important resource exploitation practices?

Interviewees' answers on the resource exploitation practices, in relation to the state of conservation of the buffer zones, are given in Figure 2. Although the exploited resource types were identical in altered and well-preserved areas, there were significant differences between the two categories of area (χ^2= 38.15, df = 7, P < 0.0001). Hunting, honey harvest and non-timber forestry products extraction were significantly more frequent in well-preserved areas, whereas bush fires in altered areas are identical regardless of the state of conservation of the buffer zones (Figure 2). More specifically, in degraded areas agriculture (85%) was the dominant activity followed by choarcal production (60%). Nevertheless, in intact areas, hunting is the second most important activity behind agriculture, according to 55% of respondents.

What are the different types of conflicts related to the use of resources?

Human / wildlife conflicts were identified by 50% of the respondents, land conflicts by 25%, and ranger / farmer conflicts by 10%. 8% of the respondents did not have any opinion, and 1% answered that there is no land-use conflict in the area. Human / wildlife conflicts are linked to ravages or destruction of crops by elephants (yams) and primates (maize). Elephant incursions into yam fields have increased in recent years with remarkable economic losses for farmers.

What is the evolution of the agricultural front in the last five years?

About 78% of 150 respondents interviewed in the altered areas suggested that, during the last five years, the agricultural front has decreased in the altered buffer zones. Conversely, according to 37% of the 150 respondents interviewed in the well-preserved areas, the dynamics of the agricultural front are stable, whereas another 35% of the 150 interviewees considered it to be progressing in the well-preserved areas.

What are the reasons for the observed agricultural front dynamics?

Based on interviewees' opinion, the drivers of the evolution of the agricultural front differed significantly ($\chi^2 = 43.23$, df = 3, $P < 0.0001$) according to the state of conservation of the buffer zones (Figure 3). Low agricultural yields were behind the origin of the advancement of the agricultural front according to most interviewees in altered areas (58% of respondents). On the other hand, soil fertility (33%) and demographic increase (33%) explained the progress of the agricultural front in well-preserved areas according to our interviewees (Figure 3). About 20% of people did not have any opinion on this issue (Figure

3). According to the interviewees, the main crops grown are maize (26%), cowpea (20%) and soybean (15%). The cultivation of yam (10%) and cotton (0.4%), which are well known to be devastating for forests and savannahs, was reported to be declining in recent years by the majority of respondents.

According to the interviewees, the explanatory factors of the regressive dynamics of the agricultural front are manifold (Table 3), and differed significantly between altered and well-preserved areas (χ^2= 26.41, df = 5, P < 0.0001). The presence of the mountains has stabilized the agricultural front in well-preserved areas. Thus, in the western part of the park, which is nevertheless highly anthropized, any progress on the agricultural front is naturally limited by the cliffs. On the other hand, the ravages of crops by elephants and primates have pushed the front back into altered areas (Table 3). In addition, the lack of adequate land development facilities (8%) and the availability of cultivable land (possibility of fallowing) (3%) are other factors contributing to the stability of the agricultural front in well-preserved areas. Interestingly, the activity of rangers was not viewed as a main reason for the decline and/or stability of the agricultural front in the buffer zones of the park (Table 3). The percentage of respondents without opinion was much higher in altered areas than in well-preserved areas (Table 3).

What are the most hunted animals?

Overall, 15 groups of animals (mostly mammals, and especially ungulates) were mentioned by the interviewees (Table 4). The most hunted species differed significantly between altered and well-preserved zones (χ^2= 58.71, df = 14, P < 0.0001). This difference is not surprising, as the very different environmental conditions between altered and well-preserved zones certainly support considerably different animal communities. In particular, grasscutters (*Thryonomys swinderianus*) and hares (*Lepus* spp.) were the dominant prey for hunters in altered zones whereas several animal groups were similarly hunted in well-preserved areas (Table 4). Interestingly, the Simpson's diversity index (0.864 in altered zones versus 0.907 in well-preserved zones), the dominance index (0.136 versus 0.093), and the evenness index (0.728 versus 0.818) were significantly different between the two zone types (one-way ANOSIM: mean rank within zone types = 101.4; mean rank between zone types = 136.6; R = 0.252, P = 0.0066), thus supporting the notion that, in well-preserved zones, hunters utilize a higher variety of animal preys with similar utilization frequencies. This pattern is consistent with the expected higher diversity and evenness, and lower dominance, of the communities of animals in pristine versus degraded areas (e.g., Magurran 1988).

What are the most exploited forest species for charcoal, firewood and non- timber forest products?

The list of the most used plant species for charcoal, firewood and non-timber forest product exploitation, according to the interviewees' responses in both altered and well-preserved zones, is given in Table 5. The differences were statistically significant between zone types both in terms of plants used for charcoal production (χ^2= 40.24, df = 8, P < 0.0001), and for non-timber forest products (χ^2= 44.22, df = 3, P < 0.0001) but not for firewood (χ^2= 8.1, df = 6, P = 0.231).

DISCUSSION

General patterns of the FMNP buffer zone dynamics

Our study identified a remarkable heterogeneity in the quality of the FMNP buffer zones for conservation value, with more than 80% of the territory being largely altered (made almost exclusively of agricultura fields) and of very low conservation value (Figure 2). This is not surprising, given that most of the savannah habitat within the Dahomey Gap is now cultivations, plantations and human settlements (e.g., UICN/PACO 2008, 2012). Nonetheless, because of the presence of four zones of high conservation value inside the FMNP buffer zone, adopting a clear management strategy for the whole buffer zone area, without taking into consideration whether the area is altered or well-preserved, is certainly wrong. Instead, it is important to adopt different management strategies in the different areas of the buffer zones, on the basis of the habitat types, the available resources and the local development dynamics. Therefore, understanding the local environmental development dynamics still stands as the necessary prerequisite for producing a well-working management plan for the FMNP buffer zones. In this regard, our interview data can be valuable for a better understanding of the local environmental development dynamics.

Agriculture and charcoal production are identified by local residents as being the main drivers of the anthropization of the altered buffer zones. These results confirm the predominant role of agriculture and woodfuel production in the transformation of natural areas in Africa (Hosonuma et al., 2012). Nevertheless, transhumance is becoming a major constraint for the effective management of many protected areas in West Africa, such as the W transboundary park between Benin, Burkina Faso and Niger (Manceron 2011). Indeed, the availability of fodder resources and livestock watering points in protected areas attracts transhumant pastoralists who settle there during their stay. This installation of livestock in protected areas causes severe habitat degradation through the pruning of fodder trees such as *Afzelia africana* and *Pterocarpus erinaceus*. This habitat degradation is accompanied by the rapid depletion of water points already reduced by drought. This coexistence leads to recurrent conflicts between protected area ecoguards and transhumant pastoralists. Unregulated traditional hunting is instead the main driver of habitat alteration in the well-preserved areas of the FMNP buffer zones. This unregulated hunting may induce the gradual depletion of wildlife in protected areas, especially antelopes (Ly 2001; Grande-Vega et al. 2016 ; Hema et al. 2017). Thus, it is necessary that the authorities governing the FMNP should carefully monitor and control the hunting pressure, at least in the four well-preserved areas where remarkable faunal species can still be regularly encountered. In the well-preserved areas, also the extraction of timber and non-timber products were considered to be rampant by our interviewees, and thus may represent considerable threats that should be carefully considered in implementing management plans at the local scale. Previous studies also observed similar issues in other West African protected areas (e.g., UICN/PACO 2008).

Land conflicts have become very recurrent in the region, given the scarcity of land availability and the rampant growth of the human population density. Prior to the 1990s, land acquisition was inherited or donated according to customary rules. Between 1992 and 1994, the massive settlement of landless populations in certain areas of the FMNP as a result of the socio-political unrest increased pressure on land, and caused the introduction of other ways of accessing land, including land purchase and tenant farming. As a result, there are many open and latent conflicts between the legal holders of land rights and the current land users that are heavily affecting the management strategies in the FMNP buffer zones.

Our interviewees also pointed out that, in the altered areas of the buffer zone, the agricultural front decreased substantially in recent years, particularly in the lowland, and less so in the hills. This decline in the agricultural front is largely attributable, according to them, to the ravages of crops caused by the incessant incursions of elephants and primates into the cultivated fields. Although it cannot be excluded that this perception is exaggerated, nonetheless it indicates that the presence of human/wildlife conflict is considered a very serious theme for the people inhabiting the FMNP buffer zones. Thus, the FMNP governing authorities should put strong effort in trying to minimize the negative interactions occurring between local communities and elephants. The human/elephant conflict is locally enhanced by the growing "insularization" process (sensu Hausser 2013) of the FMNP, with the increasingly degraded buffer zones that offer scarce habitat quality but abundant food (yams and cassava) to the elephants. In fact, elephants whose population increases in the FMNP, tear tuber plants (yams and cassava), graze and trample on cereals (maize and sorghum). Interestingly, yam plantations were shown to be the main target of elephant raids also in Nazinga Game Reserve, Burkina Faso (Hema et al. 2018). This situation has resulted in a remarkable reduction of the areas of yam cultivation in both the studied areas in FMNP buffer zones and in Burkina Faso. This damage peaks at the phenological stages of heading and fruiting of crops (Danquah and Oppong, 2014). In response to the numerous looting of crops by these animals, populations are intensifying poaching (Binot et al., 2007). In addition, these human-elephant conflicts forced some peasants to desert the area and abandon the yam crop, resulting in a progressive de-population of the southeastern plains of the park. A similar situation was observed on the outskirts of the Forest Management Unit of Kabo in Congo (Nsonsi, 2017). Managing the elephant-wildlife conflict is not easy, as elephants are really clever and can be easily habituated (Hema et al. 2018): changing the crops currently preferred by both locals and elephants implies an opportunity cost to local communities. In addition, elephants may learn to also raid the new crops. New modern methods to control elephants should be devised and used, using examples from other countries (Hema et al. 2018).

Concerning the factors of the regression or stabilization of the agricultural front in the buffer zones, our study revealed that a much higher percentage of respondents (about 60%) did not have any opinion in the altered areas, whereas almost all the interviewees (about 80%) had a clear opinion of the ongoing processes in the well-preserved areas. We suggest that this difference is due to the highly dynamic and fluid environmental condition in the altered areas, where a rapid succession of bushlands, agricultural lands and human settlements may occur in almost the whole territory within a very short timespan.

Management options

The current state of the FMNP buffer zones offers several management alternatives that are compatible with the conservation of protected area resources. We think that these management alternatives should be very different between altered and well-preserved zones.

Management options in well-preserved buffer zones

Management options in the four well-preserved zones include the development of hunting areas that should be self-managed by the distinct villages, following the model that has already been applied for the Pendjari National Park (Benin) or Arly National Park (Burkina Faso). In fact, the Pendjari National Park is surrounded by three hunting areas (Porga, Batia and Konkombri) with a total area of 176,000 hectares (Brugière et al., 2015) and by self-managed village hunting areas. This model of development and management of the buffer zones has strengthened the protection of the core area and promoted the conservation of resources for the benefit of local populations (Bouché et al., 2011). Promoting the creation of carefully managed hunting zones is a real mechanism for involving local populations in management because they generate substantial benefits (Grazia, 1997). However, the Government still remains the main beneficiary of revenues from the exploitation of these hunting areas through concession fees, management and slaughter fees, guide licenses, management licenses and permits, in addition to taxes and value-added taxes (Bouché et al., 2011). For example, Bouché et al. (2011) showed that the Government of Benin received 37% (i.e. 433,000 Euro) of the financial flow in 12 years against approximately 220,000 Euro for the populations (zone rental fee and guide fees) within the framework of the management of the Konkombri hunting area adjacent to Pendjari Park. Nevertheless, 30% of hunting revenues from hunting areas in the Pendjari have been allocated to local development apart from the direct benefits derived from tourism activities related to guiding, hospitality and catering (UICN/PACO 2011).

In addition, the four zones of high conservation value, being core sites for wide groups of large mammals including elephants and buffalos, could be used profitably for enhancing ecotourism (Tchamie, 1994; Hausser, 2013) and eventually also 'scientific tourism', for instance by creating a field research station that can attract scientists from outside Togo. Effective and participatory implementation of these management options would significantly reduce pressures on park resources (Binot and Joiris 2007, Manceron 2011).

Management options in altered buffer zones

Promoting sustainable agricultural production systems in the degraded areas can help to further stabilize the agricultural front and reduce land pressure on the FMNP. In fact, the promotion of agroforestry associated with composting techniques can improve soil fertility and increase the agricultural yields of local residents (Hubert et al., 2008). Some local species with high economic value for local populations such as Shea (*Vitellaria paradoxa*), Tallow tree (*Detarium senegalense*), Butter tree (*Pentadesma butyracea*), African locuste bean tree (*Parkia biglobosa*) and Negro pepper tree (*Xylopia aethiopica*) are to be promoted primarily in reforestation and agroforestry activities.

The reduction of human-elephant conflict is also mandatory in these altered zones. This reduction can be achieved by the exclusion of certain crops such as yams and maize in the buffer zones regularly frequented by elephants (Hema et al., 2018) and the promotion of alternative crops such as chili and ginger. This strategy to combat crop damage has already been successfully tested in the fields near Kakum National Park in Ghana (Danquah and Oppong, 2014). On the other hand, the decommissioning of these areas could increase the human-wildlife conflict and the resentment of the owners of land rights who were dispossessed of their lands when the protected area was classified. The appropriate solution would be to assign the status of areas of sustainable agriculture to these areas as part of a zoning plan to allow the Government to maintain control over the use of these lands (for the case of Pendjari National Park, see Sabi, 2015).

In order to apply a well-working management plan for the FMNP buffer zones, it should be considered that in the buffer zones the land tenure system is complex, as are the outlying areas of Pendjari in Benin and Arly in Burkina Faso (Zomahoun, 2002). Indeed, the lands belong to the local populations and their property is inherited mainly through inheritance within the descent of each family in the cultivated areas despite the introduction of other modes of access to land such as the purchase land and rent. Nevertheless, traditional chieftaincies and local administrative institutions play an important role in the allocation and allocation of unexploited land. This traditional chieftaincy can affect uses of general interest in consultation with the population on undeveloped lands such as well-preserved peripheral areas of the FMNP. The erection of the four preserved areas of the FMNP in hunting zones can be facilitated by these provisions by relying on the national legislation on the creation and management of community forests in force in Togo. The problem of land availability is thus real for the populations, but remains relative because of an inappropriate management of the exploitations, the waste of the land capital and the non-exploitation of the agricultural resources for lack of investment capital (Lompo, 2010). Land issues related to buffer zone management can be solved through consultation and negotiation processes that lead to shared responsibility and benefit contracts. The implementation of these management arrangements can be achieved within the framework of the UNESCO MAB zoning of FMNP as it was the case in the national parks of Pendjari and Arly as part of a management plan participatory park and its buffer zones. The local populations of the FMNP are organized in different groups around activities related to cotton, corn and soybean cultivation, similar to those of the national parks of Pendjari and Arly. There are also similarities between these three parks in terms of socio-economic activities dominated by agriculture, hunting and woodfuel exploitation (Green and Szaniawski 1981, Zomahoun 2002).

Given the dynamics of the buffer zones of the FMNP and related socio-economic and ecological issues, the implementation of the management and planning provisions of the park could be done effectively through participatory processes, involving land rights holders, land resource users, and local hunters in the decision-making process for development and the definition of resource use rules (Poisson, 2009). This type of participated management should be implemented in four phases: (1) the preparation of the partnership marked by awareness campaigns and the identification of the relevant actors; (2) consultation and capacity building; (3) negotiation of the management plan and specific agreements; and (4) implementation and monitoring of management arrangements (Poisson, 2009).

CONCLUSIONS

This study identified four areas of ecological interest, covering an area of 65,594 hectares around the park. These were areas of preferential movement, refuge and grazing mammals. The availability of natural resource potential determined the predominance of socio-economic activities. Thus, agriculture and woodfuel production dominated the degraded areas; hunting and honey harvesting were instead more important in the preserved areas. The main conflicts related to the use of resources were: human / wildlife conflicts, land conflicts and ecoguard conflicts / farmers.

The populations have estimated that the decline of the agricultural front, in recent years in degraded areas including the plains, is mainly related to the ravages of crops caused by incessant incursions of elephants and primates into the fields. The promotion of the four areas with high conservation value could catalyze the emergence of an alternative valuation of the fauna of the protected area. Promoting sustainable agricultural production systems in degraded areas can also help stabilize the agricultural front and reduce land pressure on the MFNP. It is advised that the data of this study should be supplemented by the in-depth and mapped analysis of the environmental and conflict risks of the buffer zones.

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Table 1 Zones of ecological interest that were identified in the buffer area of Fazao Malfakassa National Park. In this table, dense forest would mean a forest patch with the trees crowd together forming a predominantly 70-90% canopy, whereas an open forest patch would have a predominantly 40-60% canopy.

Zone	Area (ha)	Vegetation type	Potentiality of development
Zone 1	5 860	Woody savannah with dense forest islets	Elephants and primates (ecotourism)
Zone 2	20 034	Woody savannah with open forests	Elephants, Buffon's Kob, salt pans, permanent ponds and marshlands
Zone 3	19 400	Woody savannah with both open and dry dense forests	Forest patches with high potential for the production of non-timber forestry products, and ecotourism for primate observations
Zone 4	20 300	Wooded savannah with open forest and with islands of dense forest	Elephants, Buffon's Kob, salt pans, permanent ponds and marshlands

Table 2 Abundance of selected animal species across transects in the well-preserved versus (16.5 km) altered (19.5 km) buffer zones of Fazao Malfakassa National Park. For the statistical details, see text

Species	KIA in altered area	KIA in well-preserved area
	Mammals	
Kobus kob	0.41	1.09
Tragelaphus scriptus	0.05	0.30
Syncerus caffer nanus	0.00	0.06
Philantomba walteri	0.20	0.73
Lepus sp.	1.85	0.67
Thryonomys swinderianus	3.18	1.94
Squirrels	1.49	0.48
Phacochoerus africanus	0.00	0.18
Mongooses	0.36	0.55
Genetta spp.	0.31	1.03
Primates	1.33	1.21
	Birds	
Francolins	1.28	0.85
Guinea fowls	1.13	0.97
	Reptiles	
Varanus niloticus	1.28	0.73

Table 3 Factors of the regression or stabilization of the agricultural front in the buffer zones of Fazao Malfakassa National Park, according to the local population answers. Numbers would indicate the percentage of respondents

	altered area	well-preserved area
Presence of mountains	35	49
culture destruction	33	30
repression by rangers	20	6
without opinion	12	3
lack of equipment	0	8
land availability	0	3

Table 4 List of the most hunted animals according to the interviewees' responses in both altered and well-preserved zones of the Fazao Malfakassa National Park buffer zones. Numbers would indicate the number of times that each species was mentioned by independent interviewees.

Species	Altered zone	Well-preserved zone
Kobus kob	8	18
Tragelaphus scriptus	1	5
Syncerus caffer nanus	0	2
Philantomba walteri	4	12
Phacochoerus africanus	0	3
Mongooses	7	9
Genetta spp.	6	17
Phacochoerus africanus	0	3
Primates	26	20
Thryonomys swinderianus	62	32
Squirrels	29	8
Lepus spp	36	11
Francolins	25	14
Guinea fowls	22	16
Varanus niloticus	25	12

Table 5 List of the most used plant species for charcoal, firewood and non-timber forest product exploitation, according to the interviewees' responses in both altered and well-preserved zones of the Fazao Malfakassa National Park buffer zones. Numbers would indicate the number of times each species was mentioned by independent interviewees.

Species	Altered zone	Well-preserved zone
Charcoal		
Burkea africana	96	102
Lophira lanceolata	83	65
Detarium microcarpum	66	34
Erythrophleum suaveolens	26	53
Prosopis africana	25	38
Pterocarpus erinaceus	26	53
Vitellaria paradoxa	28	46
Terminalia spp	55	42
Without opinion	25	36
firewood		
Lophira lanceolata	67	59
Detarium microcarpum	52	37
Pterocarpus erinaceus	27	38
Terminalia spp	39	42
Combretum spp	29	27
Crossopteryx febrifuga	29	36
Without opinion	13	22
Non-timber forest products		
Parkia biglobossa	77	29
Vitellaria paradoxa	88	34
Pentadesma butyracea	4	28
Detarium senegalense	36	24

Figure 1 Map of the study area, the buffer zone of the Fazao-Malfakassa National Park (Togo, West Africa)

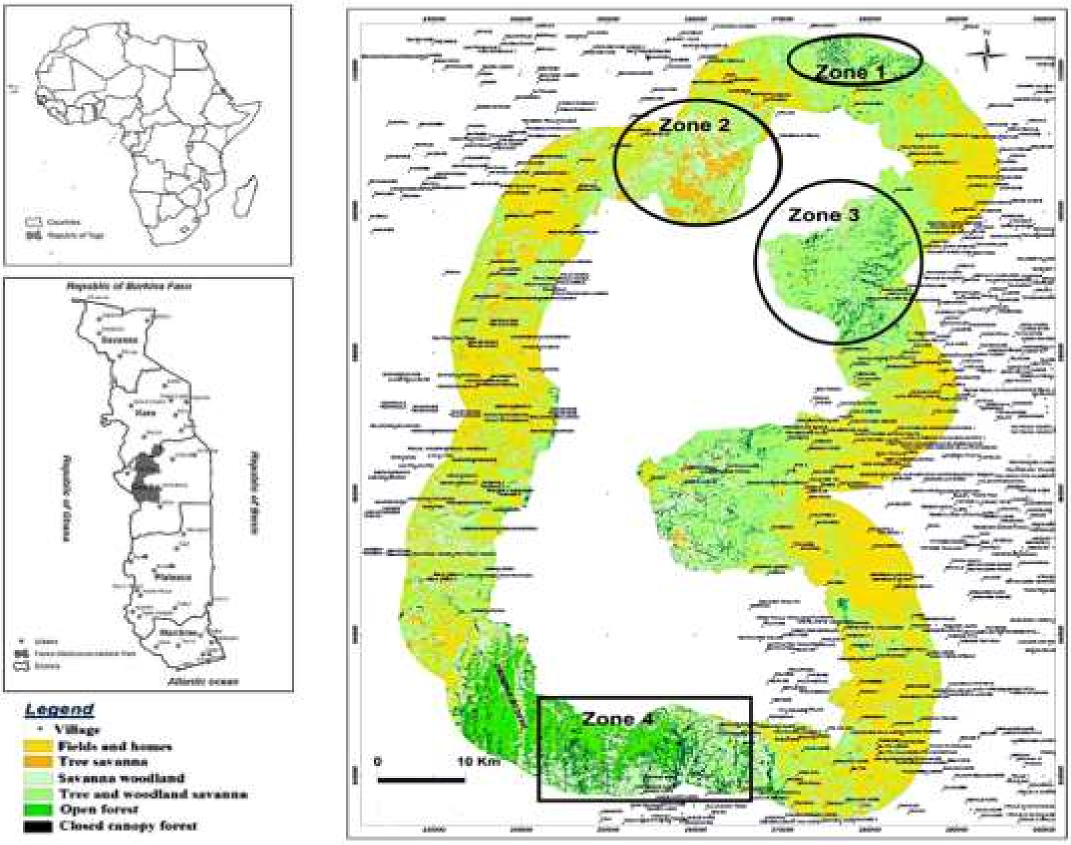


Figure 2 Resource exploitation practices, in relation to the state of conservation of the buffer zones of Fazao Malfakassa National Park, according to the local population answers (%). Symbols : NTFP = non-timber forestry products

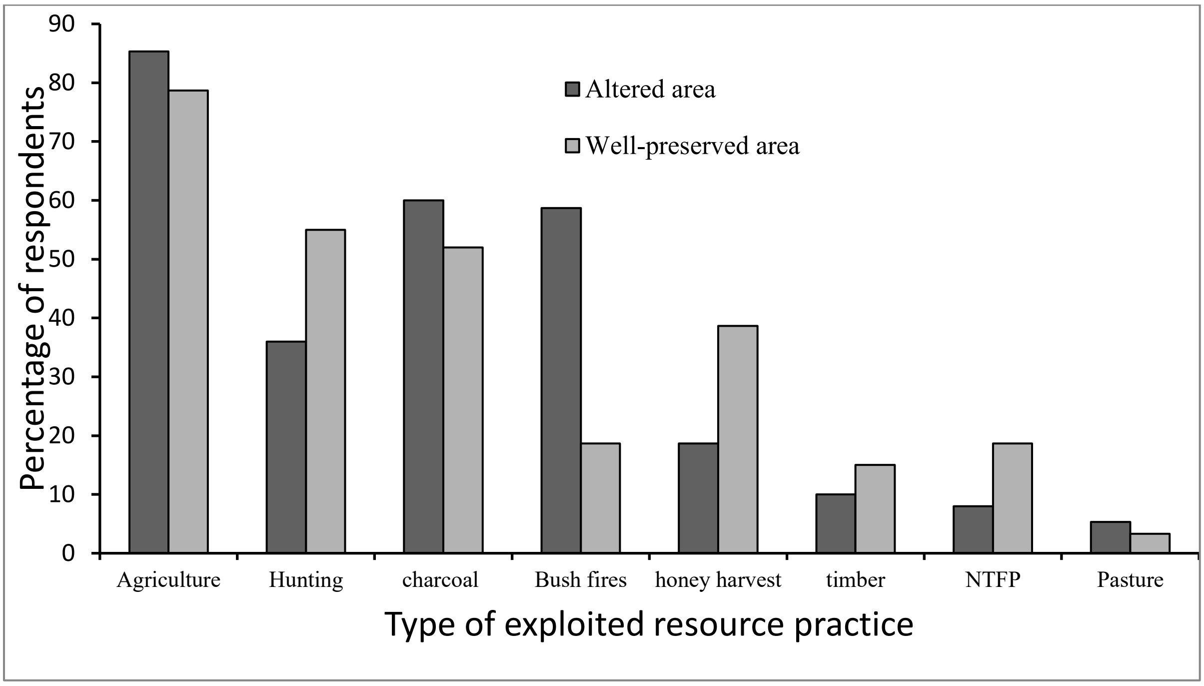
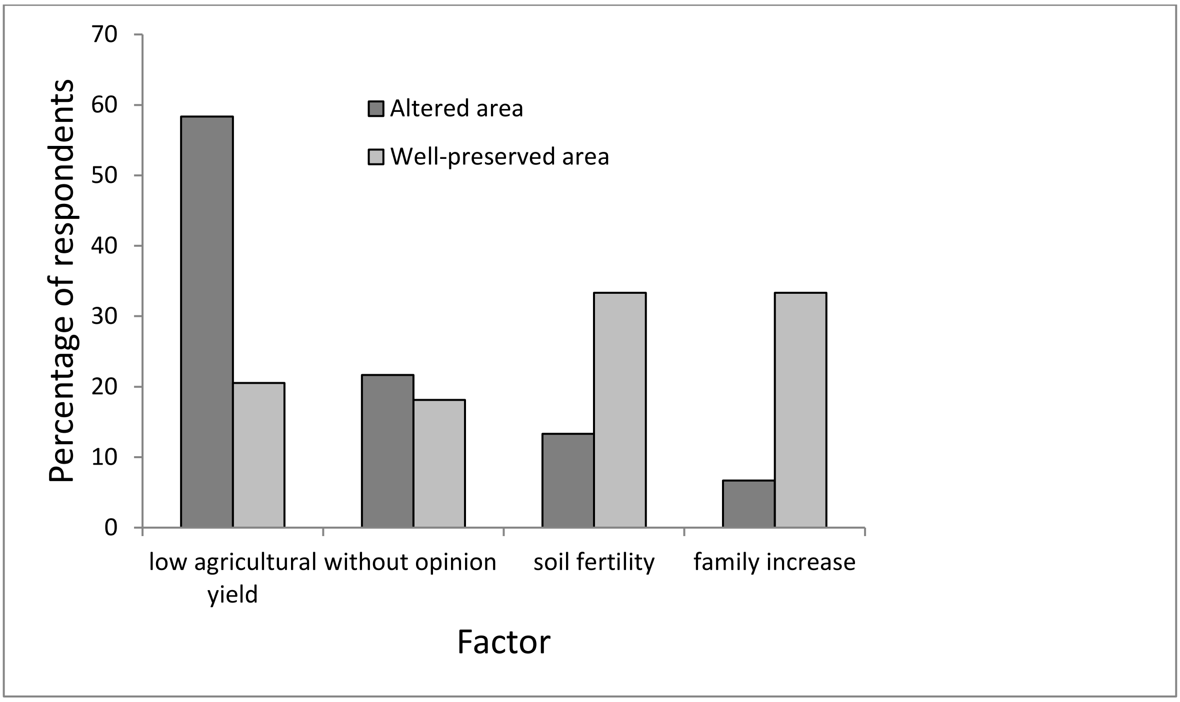


Figure 3 Factors of the evolution of the agricultural dynamics of the peripheral areas of Fazao Malfakassa National Park, according to the local population answers (%).



Appendix 1 List of the villages where the questionnaire surveys were carried out, including details of their geographic coordinates, their zone type (altered or well-preserved), and number of interviewed persons in each village

Village name	Longitude	Latitude	Zone type	No. of interviewees
Agbamassomou	0°36'34,3''E	8°37'53,86''N	Altered	12
Tassi	0°38'24,5''E	8°41'0,34''N	Altered	12
Gnabana	0°54'53,97''E	8°44'50,38''N	Altered	14
Melamboua	0°54'19,34''E	8°41'20,93''N	Altered	12
Fazao	0°46'14,05''E	8°41'37,88''N	Altered	22
Kagningbara	0°38'47,5''E	8°52'21,21''N	Altered	8
Kpawa	0°49'29,47''E	8°16'55,05''N	Altered	10
Tchatchakou	0°36'8,26''E	8°34'11,34''N	Altered	10
Mewedè	0°54'3,00''E	8°24'33,71''N	Altered	15
Hèzoudè	0°53'36,51''E	8°26'12,1''N	Altered	10
Kpeyi Solingo	0°52'12,95''E	8°32'10,55''N	Altered	10
Boulohou	0°40'13,03''E	8°46'30,94''N	Altered	15
Tchawari	0°59'7,07''E	8°49'15,58''N	Well-preserved	20
Folo	0°39'59,71''E	8°56'17,65''N	Well-preserved	12
Baghan	0°41'42,64''E	9°4'13,56''N	Well-preserved	22
Koui	0°43'24,36''E	8°15'38,16''N	Well-preserved	28
Elavagnon_todji	0°45'58,62''E	8°16'26,36''N	Well-preserved	10
Kpalou	0°44'40,65''E	9°10'2,32''N	Well-preserved	14
M'poti	0°46'39,33''E	8°14'17,02''N	Well-preserved	12
kalaré	1°2'43,26''E	8°52'1,53''N	Well-preserved	12
Lama Tessi	1°4'12,87''E	8°50'5,89''N	Well-preserved	12
Sakalaoudè	1°0'30,05''E	8°50'50,09''N	Well-preserved	8

Appendix 2 Main landuse characteristics of the study area on the basis of the of the 2015 Sentinel-2A MSI of December 21st image (10m resolution)

Vegetation type	Superficie (ha)	Percent area occupied
Fields and homes	191.609	57
Tree savannah	55.820	17
Savannah woodland	20.822	6
Tree and woodland savannah	43.778	13
Open forest	13.824	4
Closed canopy forest	8.947	3