

Influences of Human Activities on the Vegetation Cover of the Protected Area Complex in the North Cameroon Region

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Abstract

The diversification and intensification of human activities in and around protected areas is leading to the destruction of natural ecosystems, the disruption of natural modes of dispersion and migration of wildlife species, and the disappearance of biodiversity. The aim of this study is to identify, describe and analyze the various influences of human activities on the plant cover of the protected area complex in North Cameroon. The methodological approach adopted is based on an integrated approach combining field data (floristic surveys and surveys of degraded areas), socio-economic surveys and spatial analyses. The inventory of 264 plots showed that the plant cover of the study area is organized into three plant groupings: closed formations, intermediate formations and open formations. The floristic richness of each varies according to ecological factors and exposure to human disturbance. Agriculture and livestock farming are still the major disturbances. In the space of 23 years, the agricultural area has increased more than fivefold, from 98,826.43 hectares in 2000 to 507,038.61 hectares in 2023, an increase from 2.77% to 14.22%. Apart from natural fodder (herbaceous plants), certain ligneous plants such as *Azelia africana*, *Stereospermum kunthianum*, *Khaya senegalensis*, *Pterocarpus erinaceus*, *Danielia oliveri*, *Acacia sieberiana* and *Ficus sycomorus* are much in demand as livestock feed, which is accelerating the decline in plant cover. Finally, analysis of the biodiversity index shows the loss of biodiversity integrity over time.

Keywords

Anthropization, Plant Landscape, Fragmentation, Plant Formation, Protected Area, North Cameroon

1. Introduction

Cameroon has set up a network of protected areas covering around 20% of its territory, with the aim of increasing the biogeographical representativeness of natural habitats, preserving essential links, maintaining genetic diversity and acting as a buffer against environmental change [1] [2]. The complex of protected areas in the North Cameroon Region, with its significant potential and biological diversity, represents one of the ecological zones of international importance for the conservation of Africa's large mammalian fauna, and is also recognised as one of the major reservoirs of biodiversity and essential climate regulators [3] [4].

This complex is under increasing pressure from human activities such as agriculture, sedentary and transhumant livestock farming, mining and the carbonisation of wood for charcoal production [5]-[7]. These activities structurally alter natural landscapes [8], while at the same time compromising the ecological refuge function of protected areas [9]. Geldmann *et al.* (2019) [10] argue that simply creating protected areas is not enough to guarantee the preservation of ecosystems if local pressures are not regulated. In this context, analyzing the influence of human activities on the vegetation cover of the study area becomes a crucial issue for a good understanding of ecosystems and the ecological processes that take place there, as well as maintaining the natural modes of dispersion and migration of wildlife species between the national parks of the North Cameroon region. There are more than 40 different species of large and medium-sized mammals, the most emblematic of which are the elephant, lion, Derby eland, buffalo, giraffe, hippotrague and hippopotamus [11]. The objective of this work is to characterise the various threats posed by anthropogenic activities to the plant cover of the protected area complex in the region studied, using an interlocking methodological approach. The combination of multisource data and several data processing and analysis tools provides a specific and innovative approach to identifying and analyzing the impacts of anthropogenesis on natural landscapes.

1.1. Geographical Context

The complex of protected areas in the North Cameroon region (**Figure 1**) is located between latitudes 7°42' and 9°00' north and between longitudes 12°15' and 15°064' east. It comprises three national parks (Bénoué, Bouba-Ndjidda and Faro) and 32 zones of hunting interest (ZICs). Its geographical particularity, with its topographical and edaphic diversity, a climate characterised by two strongly contrasting annual seasons, and the influence of numerous watercourses, means that the region has Sudanian-type vegetation with an interlocking mosaic of plant units [12]. The presence of species highly characteristic of the Sudanian zone and of species associated with the north of the Guinean zone results from its location between the Sudano-Sahelian sector and the northern escarpment of the Adamaoua plateau.

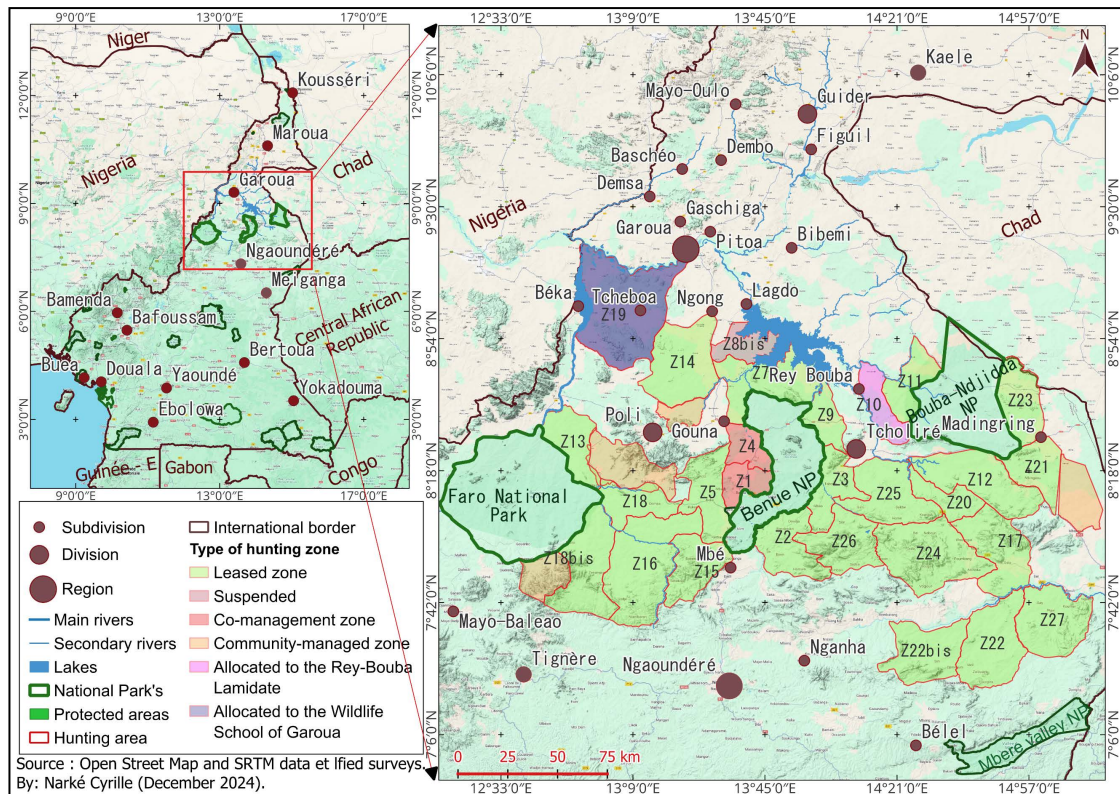


Figure 1. Location of the complex of protected areas in the North Cameroon region.

1.2. Methodological Approach

The methodological approach adopted for this study is generally based on an integrated approach combining field data, socio-economic surveys and spatial analyses. To characterise the vegetation cover, 264 floristic point surveys of 400 m² were carried out throughout the study area using the Braun-Blanquet sigmatist method [13]. These surveys were supplemented by specific surveys in areas degraded by human activities. In order to contextualise the dynamics observed, socio-economic surveys were carried out among farmers, gold miners and livestock breeders to understand their practices and their impact on the environment. A total of 369 stakeholders throughout the study area were surveyed using a digital survey form designed in the KobotoolBox platform and deployed without the interviewers' smart phones.

Spatial analysis was carried out using Sentinel-1 and Sentinel-2 satellite images, acquired via the Google Earth Engine platform, and processed with the Orfeo ToolBox (OTB) plugin in QGIS using a non-parametric automatic learning model called Random Forest. The procedure was carried out in three key stages, namely the learning phase, where points of interest (ROIs) are created and the associated spectral values are extracted, based on knowledge of the terrain and image analysis; the modelling phase, using the module to train a model to recognise classes via their mean radiometric signatures, which are then applied with, and finally the evaluation phase, where the model is validated by comparing predictions and ac-

tual data using evaluation metrics such as overall accuracy, precision, recall and F-score, thus ensuring the reliability of the classification.

These tools were used to map changes in vegetation cover over several years, identify degraded areas and quantify their extent. The satellite data was supplemented by statistical and spatial analyses using RStudio and QGIS, in order to model the relationships between anthropic activities and changes in vegetation.

2. Results

2.1. Characteristics of the Vegetation Cover in the Northern Protected Area Complex

The inventory of 264 plots yielded 10,937 individuals, including 123 woody species belonging to 41 families. The best represented families in terms of species richness are: Combretaceae and Mimosaceae with 11 species each; Fabaceae with 10 species; Anacardiaceae with 08 species; Cesalpiniaceae with 07 species; Rubiaceae and Moraceae with 05 species each; and Myrtaceae with 03 species. The most dominant species belong to the Combretaceae family with 3164 individuals for 11 species; Cesalpiniaceae with 2605 individuals for 07 species; Anonaceae with 861 individuals for 03 species; Fabaceae with 766 individuals for 10 species, Rubiaceae with 480 individuals for 05 species, Meliaceae with 423 individuals for 02 species, Euphorbiaceae with 357 individuals for 06 species, Mimosaceae with 314 individuals for 11 species, and Hymenocardiaceae with 200 individuals for 01 species.

Generally speaking, the plant cover of the study area is organised into three plant groups: closed formations (gallery forests and open forests), intermediate formations (wooded savannahs and tree savannahs) and open formations (shrub savannahs and grassy savannahs). Their floristic richness varies according to ecological factors and natural or human disturbances [14]. Analysis of the demographic structure of woody plants in the study area (Figure 2) revealed signs of strong antitropical pressures on the plant cover, as well as natural recovery mechanisms through the good natural regeneration observed in the high abundance of trees in the less than 2-metre (1,713 individuals) and 2 to 5-metre (2,079 individuals) classes.

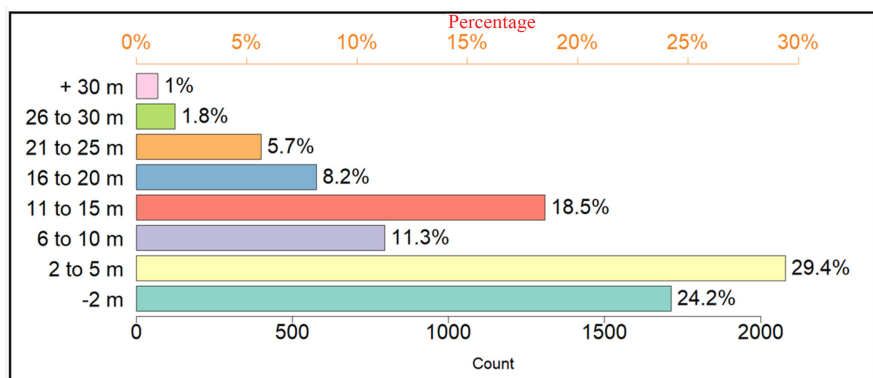


Figure 2. Number of woody plants by size class.

Woody plants between 6 and 10 metres in height accounted for only 796 individuals; those between 11 and 15 metres in height totalled 1,308 individuals; those between 16 and 20 metres in height totalled 577 individuals; 400 individuals for woody plants between 21 and 25 metres in height; 125 individuals for woody plants between 26 and 30 metres in height and only 70 individuals for those over 30 metres in height. **Figure 4** shows the spatial distribution of the different plant formations present in the area.

Analysis of **Figure 3** shows that wooded savannas cover the largest area (1,000,380 ha, 28.06%). They are followed in turn by shrub savannas (804,437.2 ha, 22.56%), fields and fallows (507,038.6 ha, 14.22%), open forests (490,156 ha, 13.75%), wooded savannas (388,861.1 ha, 10.91%), gallery forests (154,104.5 ha, 4.32%), grassy savannas and flood meadows (118,895.4 ha, 3.34%), bare and built-up land (70,090.68 ha, 1.97%) and, finally, water and burnt land (31,103.54 ha, 0.87%).

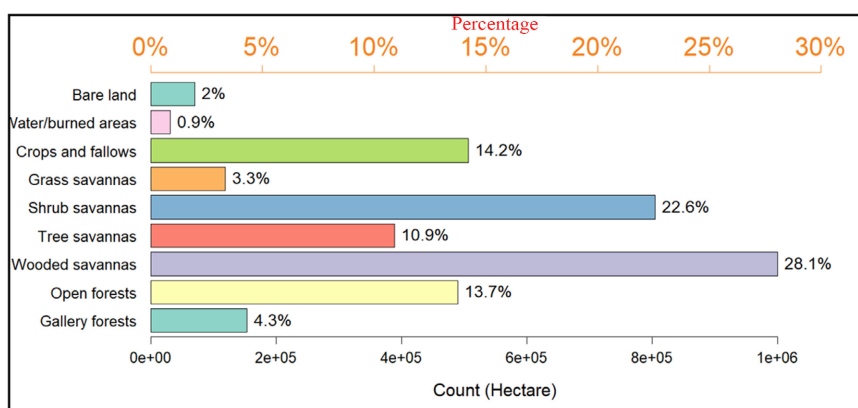


Figure 3. Spatial distribution of different plant formations.

2.2. The Influence of Agro-Pastoral Activities on Plant Cover

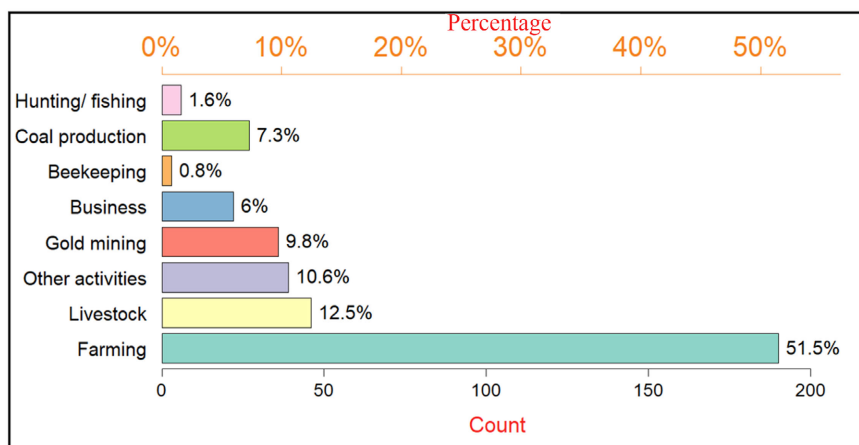


Figure 4. Main activities of the population.

The evolution of the agricultural front towards conservation areas, often characterised by the conversion of natural areas into agricultural plots and pastures, leads to

excessive clearing of woody vegetation and fragmentation of natural habitats [15]. Socio-economic data processing has shown that agriculture is the main activity in the area, accounting for more than 50% of the population (Figure 4).

Moreover, 21 floristic surveys of 400 m² carried out in agricultural areas provided further support for this assertion (Figure 5).

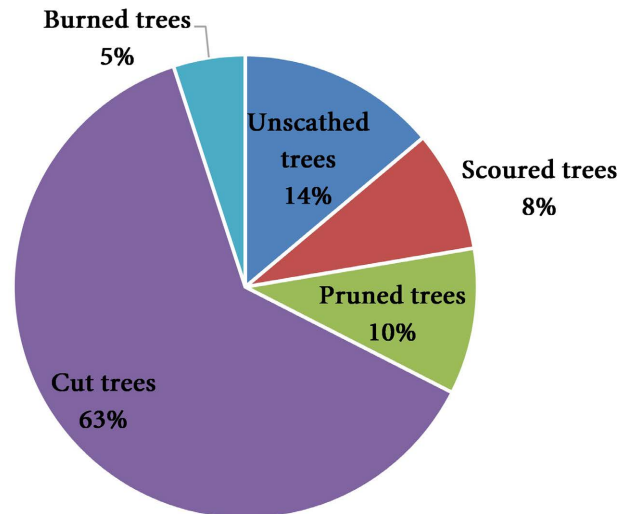


Figure 5. Condition of woody plants observed in plots set up on agricultural land.

Figure 5 shows that of the 1138 woody plants inventoried in the agricultural areas, a significant majority have been cut down (711 trees, *i.e.* around 62.5% of the total), illustrating the strong pressure exerted by agriculture and the carbonisation of wood for charcoal production. Only 13.9% of the trees (158 trees) are intact, indicating that the integrity of the plant cover has not been preserved. Pruned and debarked trees, 116 and 96 respectively (around 10.2% and 8.4%), show signs of stress or human intervention. Finally, 57 burnt trees (5%) suggest the impact of fires, potentially caused by human activities or natural incidents. Plots P8 and P21 show the highest levels of cut trees, with 117 and 57 respectively, which could indicate areas of high pressure. Overall, these data reflect a worrying trend towards degradation of the vegetation cover, and hence fragmentation, requiring more rigorous management and conservation measures to preserve these ecosystems.

In addition, PCA was applied to the results obtained from the flora surveys carried out in the fields in order to assess the relationships between these woody states (Figure 6).

The results show that the control plots variable contributes the most to the first principal component (PC1), explaining 43.1% of the variance, while the debarked woodlands dominate the second principal component (PC2), explaining 19.5% of the variance. The biplot reveals a significant dispersion of observations, indicating distinct effects of the treatments on the protected areas. The arrows in the biplot show that woody species in the control plots and debarked woody species have

major influences on the respective dimensions of variation. This analysis helps to visualise the relative impacts of different treatments and to inform sustainable management strategies for protected areas.

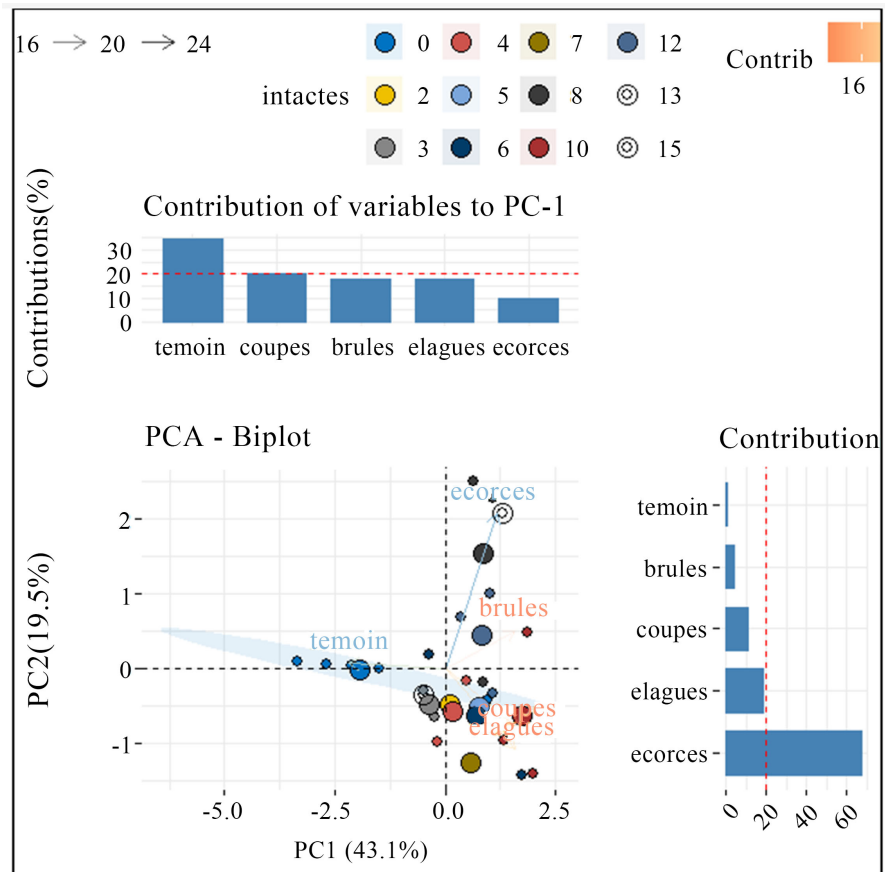


Figure 6. Principal component analysis of the state of woody vegetation in agricultural plots.

Furthermore, using data extracted from land-use maps for 2000, 2013 and 2023, we were able to characterise the spatial evolution of agricultural land in the area (**Figure 7**).

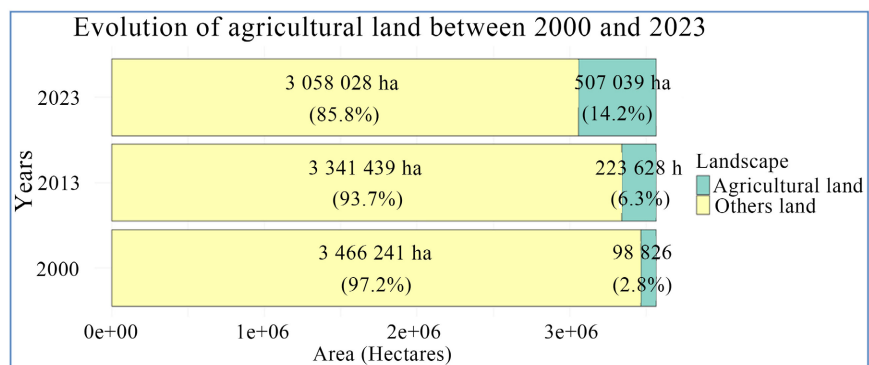


Figure 7. Change in agricultural land between 2000 and 2023.

In 2000, agricultural land was relatively small, representing just 2.77% of the total surface area. In 2013, the agricultural area more than doubled compared to 2000, reaching 223,628.41 hectares, with a significantly increased percentage (6.27%). This increase indicates a significant expansion of agriculture in thirteen years, probably in response to increased demand for farmland. For the year 2023, the agricultural area has more than doubled since 2013, reaching 507,038.61 hectares or a percentage of 14.22%. In general terms, the increase in figures indicates a growing and alarming trend in the expansion of agricultural land in this area. In the space of 23 years, the agricultural area has increased more than fivefold, from 98,826.43 hectares in 2000 to 507,038.61 hectares in 2023. The percentage of the total area has also followed an upward curve, rising from 2.77% to 14.22%. This rapid growth could be due to a combination of factors, such as population growth, increased demand for agricultural products and perhaps policies favouring agricultural expansion. **Figure 8** shows the spatial evolution of agricultural fields over time.

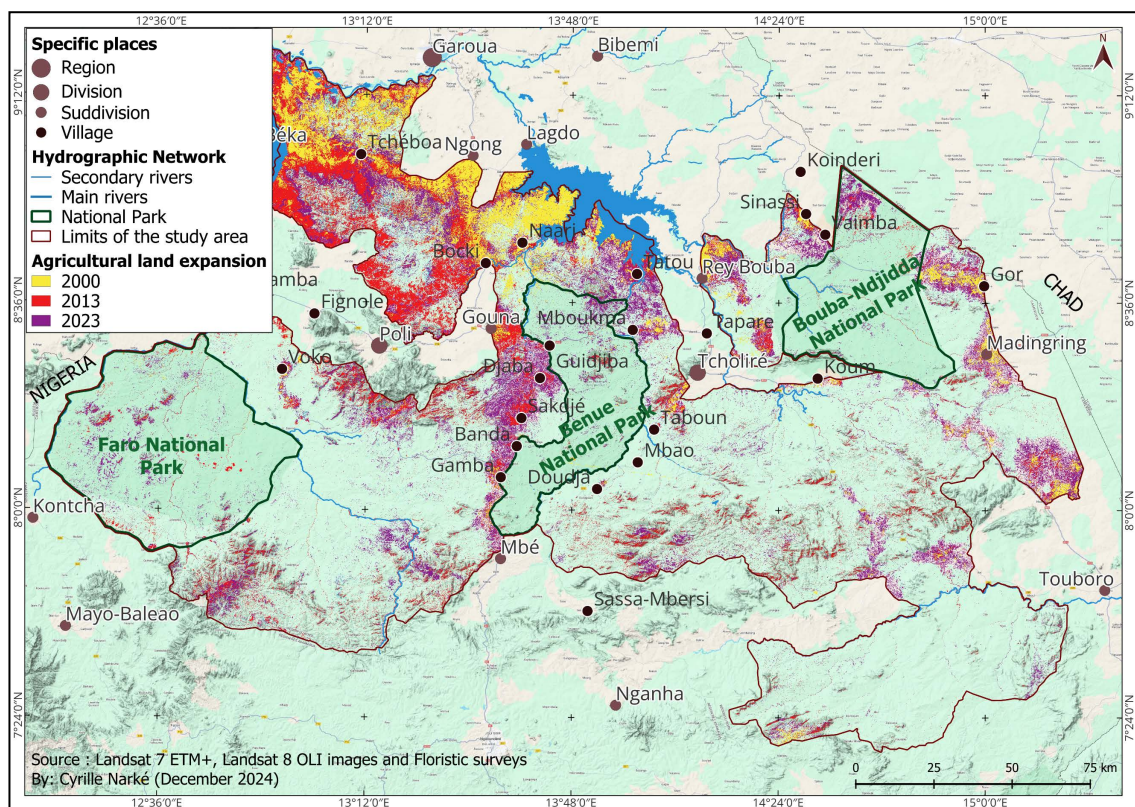


Figure 8. Spatial expansion of agricultural plots between 2000 and 2023.

Apart from agriculture, the results of the floristic surveys show that the wealth of woody flora in the complex of protected areas studied is valued more highly by livestock farmers for the nutrition of their livestock. In addition to natural fodder (herbaceous plants), certain woody species such as *Azelia africana*, *Stereospermum kunthianum*, *Khaya senegalensis*, *Pterocarpus erinaceus*, *Danielia oliveri*, *Acacia sieberiana* and *Ficus sycomorus* are much in demand as livestock feed,

thereby accelerating the degradation of the plant landscape. **Table 1** shows the woody species most commonly used to feed livestock.

Table 1 shows that *Azelia africana* is the species most used for this purpose, with a total of 246 individuals pruned and 72 discarded; it is followed by *Pericopsis laxiflora* and *Burkea africana* with 96 and 83 individuals pruned respectively. This indicates their importance as livestock feed. On the other hand, species such as *Terminalia schimperiana*, *Acacia sieberiana* and *Khaya senegalensis* are used much less, showing little pruning or cutting. Some species, such as *Daniellia oliveri* and *Prosopis africana*, are moderately used, while others such as *Detarium microcarpum* and *Lannea* sp show very limited use. In particular, *Azelia africana* and *Anogeissus leiocarpus* show signs of regeneration, with 7 and 6 young trees respectively, which is positive for the sustainability of these resources. The low number of offshoots and saplings in other species raises questions about either their capacity for regeneration or the fact that they are subject to more pressure that prevents them from regenerating.

Table 1. Woody species most commonly used to feed livestock.

Species	Intacts	Scourced	Pruned	Rejects	Cut	Dried	Young stock
<i>Azelia africana</i>	23	0	246	72	1	0	7
<i>Pericopsis laxiflora</i>	213	0	96	34	0	0	0
<i>Burkea africana</i>	413	1	83	4	1	0	0
<i>Daniellia oliveri</i>	267	0	77	0	0	1	0
<i>Terminalia schimperiana</i>	37	0	2	0	0	0	0
<i>Prosopis africana</i>	166	0	53	0	0	2	0
<i>Acacia sieberiana</i>	108	0	44	0	0	0	0
<i>Ficus glumosa</i>	68	0	37	0	0	0	0
<i>Vitellaria paradoxa</i>	81	0	15	0	0	0	0
<i>Anogeissus leiocarpus</i>	0	1	2	0	7	6	0
<i>Detarium microcarpum</i>	0	0	3	1	0	0	0
<i>Isobertinia doka</i>	53	0	1	1	2	0	0
<i>Acacia hockii</i>	9	0	4	0	0	0	0
<i>Khaya senegalensis</i>	21	0	2	0	0	0	0
<i>Entada africana</i>	190	0	5	1	0	0	0
<i>Monotes kerstingii</i>	33	0	3	0	0	1	0
<i>Sterculia setigera</i>	27	0	1	1	0	0	0
<i>Lannea</i> sp	0	1	3	0	0	0	0

2.3. Influences of Frequent Bush Fires on Vegetation Cover and Its Development

Bush fires have a significant influence on the degradation of the floristic landscape in the study areas, with often lasting ecological consequences. These fires can alter

the composition and structure of plant communities, thus affecting specific and functional diversity. According to a landmark study by Bowman *et al.* [16], bush fires can lead to a reduction in plant species richness, by favouring the dominance of fire-adapted species to the detriment of others. In addition, repeated fires can lead to changes in plant regeneration, disrupting ecological succession cycles [17]; they can impact ecosystem structure, modifying the composition of plant communities and leading to changes in the density and spatial distribution of species [18]. These alterations can have repercussions on the availability of habitats for wildlife, as well as on essential ecological functions such as soil stabilisation, regulation of the water cycle and carbon sequestration [19]. **Figure 9** shows the spatial distribution of bushfires by intensity for the year 2023.

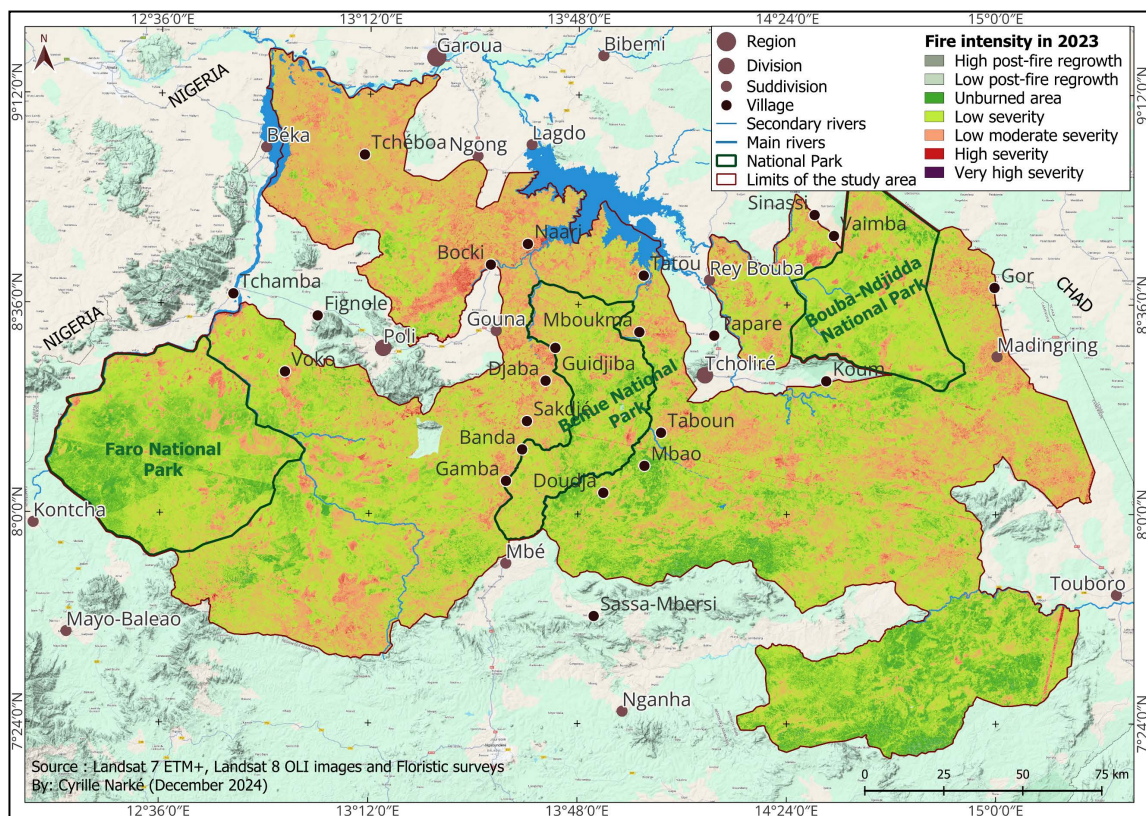


Figure 9. Spatial distribution of bushfires according to their intensity.

Table 2 shows the distribution of areas according to fire severity levels, expressed in hectares and percentages. More than half of the area analysed (51.26%) was unaffected by fire in 2023, indicating good ecosystem conservation. Areas showing improved regeneration cover 29.89% of the area, suggesting favourable conditions for post-fire recovery. Areas affected by fires of low to moderate severity account for 18.78%, indicating limited damage and a degree of ecosystem resilience. Areas seriously affected by fire are very rare (0.07%), which is positive for the health of plant landscapes. However, this situation has a negative impact on the herbaceous cover, as it does not have time to renew itself and provide good

forage for the many herbivores present in the complex.

Table 2. Distribution of bushfires according to intensity on the vegetation cover.

Fire intensity	Area (Hectare)	Percentage
High post-fire regrowth	198,446.22	5.57
Low post-fire regrowth	867,039.12	24.32
Unburned area	1,827,227.07	51.26
Low severity	611,180.01	17.15
Low moderate severity	58,078.44	1.63
High severity	2,569.5	0.07
Very high severity	105.3	0.00
Total	3,564,648.27	100.00

2.4. Consequences of Human Activities on the Landscape of the Complex of Protected Areas Studied

The response to the demographic increase in the cinegetic basin of the North Cameroon region, and the diversification of the population’s survival activities, has resulted in an extension of cultivated areas, widespread environmental degradation and loss of biodiversity. Data on mean species-specific abundance from the Globio 4 model show a progressive loss of biodiversity integrity in the study area (Figure 10).

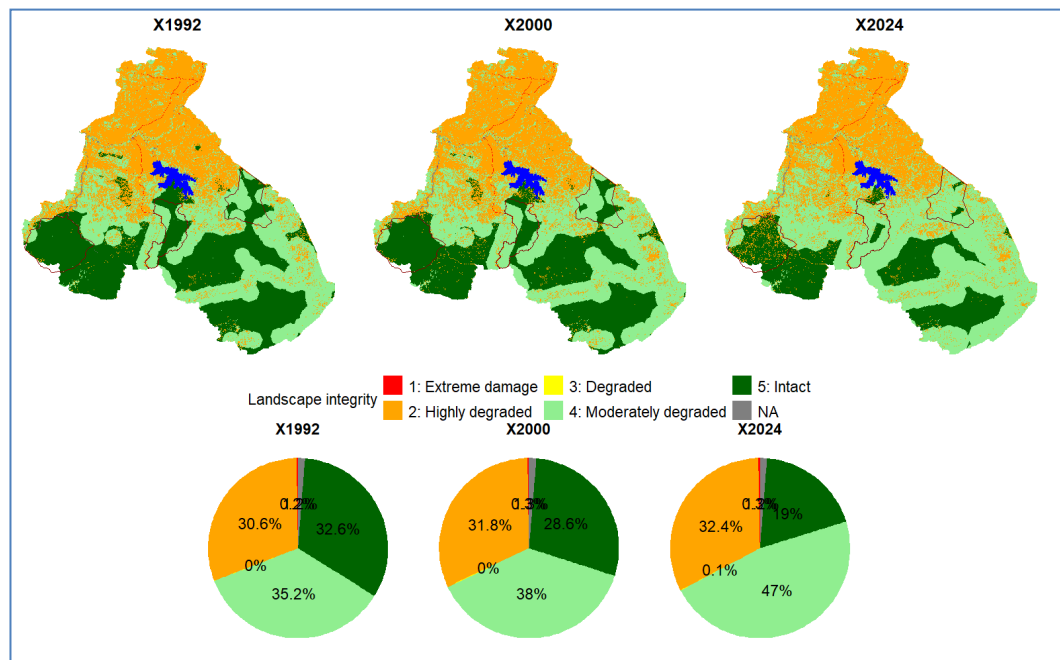


Figure 10. Spatial distribution of the level of integrity of wildlife and plant biodiversity in the landscape.

Analysis of the biodiversity index over time reveals a loss of biodiversity integrity

over time due to strong anthropogenic pressure through uncontrolled bush fires, the unprecedented advance of the agricultural front, transhumance and mining. Over 70% of those surveyed said that the density of vegetation cover had fallen sharply, and was increasingly fragmented. **Figure 10** shows the extent of human activity on natural ecosystems and their biodiversity. There has been a sharp decline in intact landscapes in favour of severely degraded landscapes between 1992 to 2024. The most remarkable development is that of moderately and severely degraded areas, which have risen from 35.2% in 1992 to 38% in 2000 and 47% in 2024.

3. Interpretation and Discussion

The results of this study show a significant degradation of the vegetation cover in the protected area complex, mainly due to human activities such as agro-pastoral activities, bush fires and artisanal mining. Analysis of satellite data and floristic surveys have revealed a shift in natural landscapes towards more or less anthropised formations such as shrub savannahs, fields and fallow land. According to Achard *et al.* [20], the fragmentation of natural habitats due to agricultural expansion is one of the main causes of biodiversity loss in tropical regions; Hansen *et al.* [21] associates deforestation and forest degradation with unsustainable practices such as mining. Kimmins [14] states that the spatial distribution of woody species also varies according to natural or anthropogenic disturbances. Ganota [4] points out that the demand for land for agro-pastoral activities has continued to grow exponentially. Agriculture is a vital source of subsistence for these populations. Over the years, these vast areas of savannah have been transformed into agricultural plots, which has had an impact on the natural environment. Analysis of the woody structure has shown signs of natural regeneration. Chazdon [22] notes that natural regeneration can play a crucial role in restoring degraded ecosystems, provided that disturbance is limited. However, surveys of local stakeholders revealed a high dependence on natural resources for livelihoods [23]-[25].

4. Conclusion

The study of the influences of human activities on the vegetation cover of the protected area complex revealed significant and multifaceted impacts on ecosystems, with important implications for biodiversity conservation and the sustainability of these ecosystems. The results show that agriculture, gold mining and logging are the main causes of vegetation cover degradation, leading to habitat fragmentation, loss of biodiversity and alteration of ecosystem structure. Although some species show a good capacity for regrowth, sustainable management is needed to maintain the balance between fodder supply and the conservation of biodiversity in local ecosystems. These observations underline the urgent need to put in place essential initiatives to preserve ecosystems and ensure their resilience in the face of growing human pressures. In short, this study highlights the need for an integrated approach to preserve the plant cover and biodiversity of the protected area complex. A combination of technological monitoring, ecological restoration and inclusive policies,

as advocated is essential to reconcile conservation and development.

Authors Contribution

Narké Jean Cyrille, the main author, was responsible for collecting and processing the data and writing the article, while the supervisors, Aoudou Doua Sylvain and Mbamba Mbamba Jean Paul Kevin, helped with the design and proofreading of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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