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Spatio-temporal Dynamics of Natural Rangelands Exploited by Transhumance Cattle Herds in the Classified Forest of Upper Alibori, Northern Benin

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Abstract

The natural rangelands of the Classified Forest of Upper Alibori (CFUA) are subject to strong anthropogenic pressures. One can question the capabilities of the classified forest sustainably support this level of control. The aim of this research is to assess the physiognomy changes recorded in these natural rangelands of this forest from 2000 to 2015. The diachronic approach from the Landsat images ETM + of 2000 and OLI-Tirs of 2015 were used. The transition matrix was produced using the Intersect function of the software ArcGIS 10.1. The results showed a regression of the forest formations in favor of the savannah and anthropogenic formations. The woodland and savannah woodland were the most affected because they almost disappeared in 2015. Its surface passed from 12.7 % in 2000 to 0.99 % in 2015. On the contrary, the agricultural areas (mosaics of fields and fallow land) increased from 15.3 % in 2000 to 33.2 % in 2015. In general, the vegetation of the natural rangelands of CFUA had undergone a major transformation mainly related to agro-pastoral activities and tree logging. Effects on the state of rangelands of transhumant herds in this classified forest have been observed through the degradation of vegetation cover. In a perspective of sustainable management of natural rangelands and securing pastoral resources of this protected area, it is therefore very important to put in place effective strategies for forest management, in order to participate in the restoration of extinct vegetation and the conservation of biodiversity.

Keywords: Alibori; protected areas; Pastoralism; land use; anthropogenic pressure.

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1. Introduction

Protected areas are increasingly frequented by transhumant cattle herds. This phenomenon has grown in recent decades in West Africa [1]. Indeed, current traditional practices no longer make it possible to respond effectively to the problems of feeding and watering animals. The amplitude of movements of transhumant herders has become more important and stays in the host areas are becoming longer [2]. During the dry season, the disappearance of the herbaceous layer containing the main forage grasses of the animals makes it difficult to feed them. In this context, the transhumant herders, concerned about the survival of their animals, fall on the forest species that are exploited as aerial grazing. So, the protected areas, in view of the depletion of the resources of the anthropized zones, are increasingly coveted by transhumant herders [3]. Thus, the pastures cannot regenerate properly leading to rangeland degradation with the appearance of glacis, species unpalatable and invasive, etc. [4]. The land use increasingly is a consequence of the increase in agricultural areas to meet the food needs of an ever-growing human population [5].

The upper watershed of was erected an classified forest and its should contribute to the protection of the Alibori watershed and its tributaries and then to the conservation of biological diversity [6]. The protection of the watershed and the conservation of biodiversity now seem incompatible with its geographical location, surrounded by the municipalities of Gogounou, Kandi, Banikoara, Kerou, Ouassa-Pehunco and Sinende, which are known as major producers of cotton, maize, yam [7]. The agro-pastoral activities and tree logging are more practiced within this forest. Similarly, the Classified Forest of Upper Alibori (CFUA) harbors natural resources coveted by peripheral and non-peripheral communities that make illegal and uncontrolled use of them.

Thus, in order to improve the management of this classified forest and to enable it to ensure these functions of biodiversity conservation, the directorate general of forests and natural resources through the program for the management of forests and riparian territory has endowed this forest with a participatory management plan since 2010. Despite the development of this plan, the CFUA continues to face anthropogenic pressure from a many actors including transhumant herders and agro-pastoralists. Faced with this situation, the dynamics of the natural rangelands of this forest is necessary in order to put in place the strategies for securing and restoring the natural vegetation of this protected area. The aim of this study is to analyze the dynamics of the natural rangelands of the transhumant herds of the FC-AS from 2000 to 2015. It is based on the assumption that the forest formations of these natural rangelands undergo a regressive evolution in favor of anthropogenic formations.

2. Materials and Methods

2.1. Study environment

The classified forest of upper Alibori (CFUA) was created by Decree No. 6459 of August 20, 1955. It covers an area of 250,205.73 hectares and forms a vast area covering six municipalities (Pehunco, Kerou, Banikoara Gogounou, Sinende and Kandi) and straddling the departments of Atacora, Donga, Borgou and Alibori. According to the vegetation map of the forest, this forest presents five strata: woodland, gallery forest, tree and shrub savannah, savannah with agricultural presence and mosaic of crops and fallow. The climate of the area is tropical with two seasons observable during the year: a dry season from November to March and rainy season from April to October. Rainfall is unevenly distributed in time and space with water depths ranging from 900 mm in June to a high of 1316.5 mm in July and August.

The population of the six (6) riparian municipalities to the CFUA is estimated at 808 968 inhabitants made up 50.2 % of women against 49.7 % of men [8]. There are three (03) socio-cultural groups are represented by: Bariba, sedentary Fulani; transhumant Fulani. This population consists of Muslims, animists and Christians.

The CFUA is located in an area of consolidated Precambrian granular rocks. The landscape is dominated by a peneplain made up of successions of low cuts characteristic of Sudanian plains. The soils are ferruginous tropical small leached on granito-gneiss at two micas [9]. The CFUA is full of forest species such as: : *Khaya senegalensis*, *Daniellia oliveri*, *Diospyros mespiliformis*, *Isoberlinia* spp, *Detarium microcarpum*, *Vitellaria paradoxa*, *Parkia biglobosa*, *Vitex doniana*, *Combretum* spp. [10 ; 11].

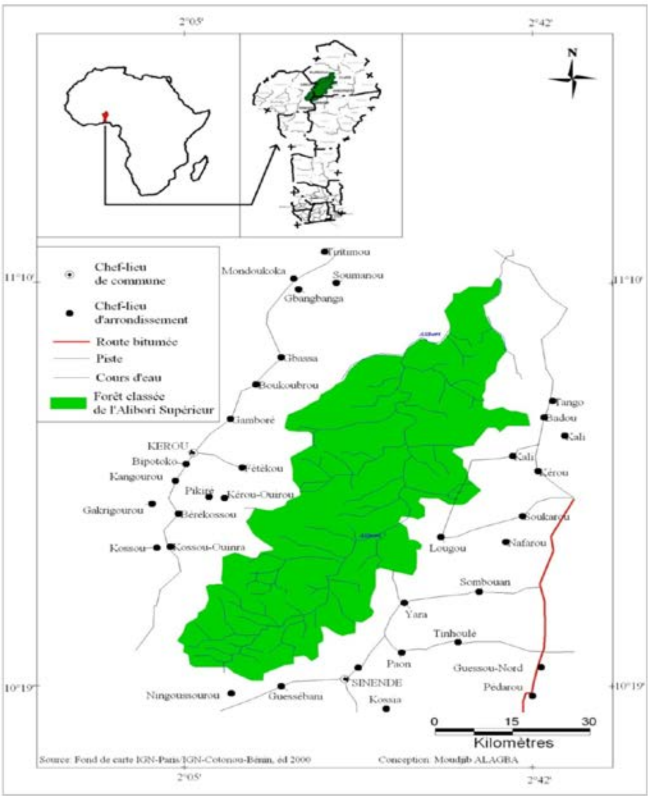

Figure 1: Location of the classified forest of upper Alibori

2.2. Research materials

The scenes of Landsat ETM + images of 2000 and Landsat 8 OLI-TIRS images of 2015, downloaded from eartexplorer.usgs.gov were used. Topographic maps, 1/200 000 IGN, and Bembereke and Kandi leaves were also used.

2.3. Digital processing of satellite imagery and cartography

This part includes: colorful composition, choice of regions of interest and maximum likelihood supervised classification.

- ***Colorful composition***

The colorful composition allowed us to produce color images taking into account the spectral signature of the objects. It served primarily to distinguish the different objects present in the images in order to facilitate the interpretation of the images. In this processing, the bands 4, 5, 3 of Landsat 7 ETM + and 5, 4, 3 of Landsat 8 were used respectively to discriminate between the different land-use units.

- ***Choice of regions of interest***

The regions of interest are sites representative of the numerical characteristics of the classes that define the spectral signatures of each landscape unit. The regions of interest were delimited away from the transition areas to avoid including mixed pixels, that is to say pixels which could be classified into two distinct classes. On the images, the regions of interest are traced to the pixel and well dispersed throughout the study area. These regions are representative of the diversity of each class of landscape unit. The number of regions of interest is all the greater as the class is heterogeneous. The size of the regions of interest must be greater than the location error and less than the object to be detected [12]. It was estimated as follows: $A = P (1 + 2L)$ [7; 13] ; with A = the surface of the regions of interest; P = Dimension of the pixel in meters; L = Precision of the location in meters.

- ***Maximum Likelihood-Supervised Classification***

In supervised classification, the image analyst oversees the pixel categorization process by specifying to the computer algorithm numerical descriptors of various types of land use in the scene. Thus, representative samples of known sites (regions of interest) were used to establish a key numerical characteristic that best describes the spectral attributes for each class type. The interpretation key was based on the GPS points recorded at the level of the various land-use units. In total, 4 common land-use classes were identified in the two images of 2000 and 2015. These are tree and shrub savannahs (TSS); woodland and savannah woodland (WSW); Gallery forests (GF); Fields mosaics and fallow (FMF). Then, the field control was carried out to check the classes of pixels resulting from the classification.

2.4. Statistical analysis of natural rangeland units

- ***Transition Matrix***

The transition matrix revealed the different forms of conversion experienced by the landscape units between two years (2000 and 2015). It consists of x rows and y columns. The number x of rows in the matrix indicates the number of landscape units present in 2000 while the number y columns in the matrix indicates the number of landscape units converted in 2015. As for the diagonal, it contains the areas of the landscape units that remain unchanged. In this matrix, transformations are made from rows to columns. The areas of these different classes of landscape units were calculated from the intersection of the land use maps of 2000 and 2015 using the Intersect function of the Arctoolbox interface of the ArcGis 10.1 software.

- ***Conversion rate***

The conversion rate of a land-use class corresponds to the degree of transformation undergone by that class by converting to other classes [7, 13]. It is therefore the amount of change observed at the level of a land-use unit between 2000 and 2015. It thus makes it possible to measure the degree of conversion from one unit of land use to another unit. It was obtained from the transition matrix according to the following formula [14]:

$$\mathrm{CR} = \frac{\mathrm{V1} - \mathrm{V0}}{\mathrm{V0}} \times 100$$

V0: Surface of the Landscape Unit in 2000;

V1: Surface of the Landscape Unit in 2015 and CR: Conversion rate

3. Results

3.1. Physiognomy of Classified Forest of Upper Alibori in 2000 and 2015

The physiognomy of the vegetation of the natural rangelands of Alibori forest was dominated in 2000 by the tree and shrub savannahs (TSS) and the woodland and savannah woodland (WSW) which occupied 69.2 % and 12.7 % respectively of the surface area (table 1 ; figures 2 and 3). The gallery forest (FG) represented 2.8% of the surface area, were found along permanent streams such as the Alibori and its tributaries. The Field mosaic and Fallow (FMF) occupied 15.3 % of the surface area. In 2015, the vegetation of the natural rangelands of the CFUA was dominated by tree and shrub savannahs (63.2 %). We meet also other vegetation (woodland and savannah woodlands, gallery forests) observed in 2000 (table 1; figures 2 and 3).

Table 1: Surface area of land-use units in 2000 and 2015

	2000		**2015**		**Balance sheet (%)**
LUU	S (km2)	P (%)	S (km2)	P (%)	
GF	5 932	2.8	5 830	2.7	-0,05
WSW	27 519	12.7	2 145	0.99	-11,8
TSS	149 535	69.2	136 436	63.2	-6,1
FMF	33 159	15.3	71 734	33.2	17,8
Total	216 145	100	216 145	100	

LUU– Land use units; **GF** – Gallery forest; **WSW** - Woodland and savannah woodland ; **TSS** - Tree and shrub savannahs; **FMF** – Field mosaic and fallow; **S** – Surface area; P - Percentage

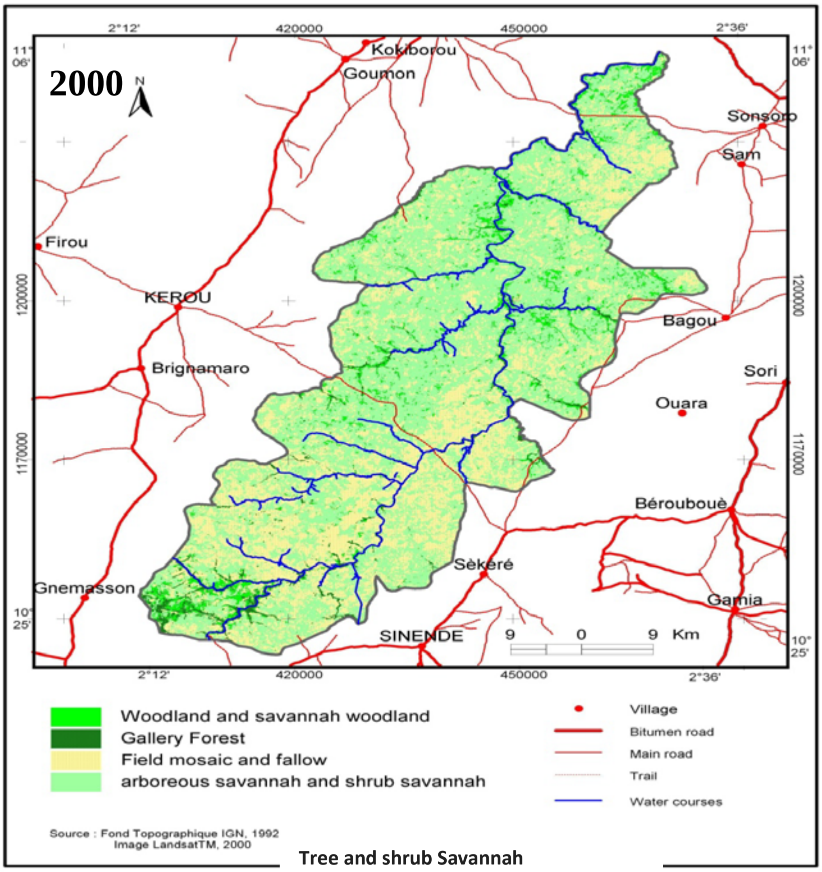

Figure 2: Land use units of the CFUA natural rangelands in 2000

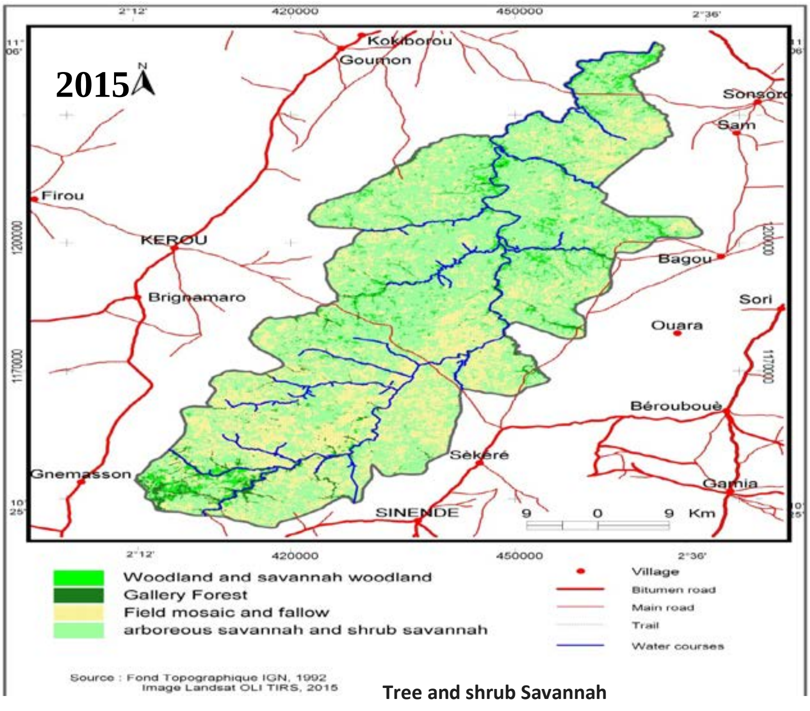

Figure 3: Land use units of the CFUA natural rangelands in 2015

From the examination of table 1 and figure 2, it appears that gallery forest, woodland and savannah woodland, and tree and shrub savannahs have undergone a regressive evolution, while the mosaics of fields and fallows have evolved gradually.

3.2. Dynamics of the natural rangelands of CFUA

The dynamics of the vegetation formations of the rangelands and the mosaics of fields and fallows of Alibori forest from 2000 to 2015 is summarized by the transition matrix (Table 2). In the cells of the rows and columns are respectively the land use units in 2000 and 2015. The conversions are made from rows to columns. The cells of the diagonal correspond to the surface areas of land use that have remained stable from 2000 to 2015. The units that are outside the diagonal represent changes in land use units.

Table 2: land use change transition matrix between 2000 and 2015

	Land uses units in 2015				
Land uses units in 2000	**WSW**	**TSS**	**GF**	**FMF**	**Total surf. area 2000**
WSW	2145	19136	0	6238	27 519
TSS	0	117300	0	32235	149 535
GF	0	0	5830	102	5 932
FMF	0	0	0	33159	33 159
Total surf. area 2015	2 145	136 436	5 830	71 734	216 145

Total surf. area 2000: Surface area of land-use units in 2000 ;

Total surf. area 2015: Surface area of land-use units in 2015;

2145: Surface area remained stable between 2000 and 2015

GF- Gallery forest; **WSW** - Woodland and savannah woodland ; **TSS** - Tree and shrub savannahs; **FMF** – Field mosaic and fallow;

Examination of the transition matrix (Table 2) reveals that all land use units observed in 2000 are also present in 2015. However, in general, natural formations have undergone two conversion modes: savannization and anthropization. The conversion rates (Table 3) provide a better understanding of the different transformations experienced by vegetation from 2000 to 2015.

From the analysis in Table 3, it appears that the highest conversion rate was found in the woodland and savannah woodland with 92.2%, this shows that these land-use units are highly disturbed. By against the tree and shrub savannah and gallery forests have respective low conversion rate of 8.8% and 1.7%, it's relatively stable land-use units.

Table 3: Conversion rates of land-use units between 2000 and 2015

Land uses units	CR (%)
Gallery forest	-1.72
Woodland and savannah woodland	-92.2
Tree and shrub savannahs	-8.8
Field Mosaic and Fallow	116.3

3.3. Conversion forms of vegetation formations of natural rangelands

Between 2000 and 2015, gallery forests experienced a decrease in their surface area, which rose from 5932 km² to 5830 km², ie an average annual rate of regression of 0.05% with a conversion rate of 1.7%. Analysis of the transition matrix shows that 102 km2 of gallery forests have been converted into mosaics of fields and fallow so the gallery forests are undergoing a regressive evolution in favor of mosaics of fields and fallow. This regression of gallery forests is due to tree logging which facilitates the practice of agricultural activities in these formations (figures 4, 5, 6, 7 and 8).

The woodland and savannah woodland also saw a decrease in their surface area from 2000 to 2015. The analysis of the transition matrix shows that 19136 km² and 6238 km² of woodland and savannah woodland have been converted into tree and shrubs savannahs (69.5%) and mosaics of fields and fallow (22.7%) with a total conversion rate of 92.2%. With this regressive trend, it is a vegetation formation is in the process of disappearing. This decline in forests and savannahs is mainly due to agro-pastoral activities and tree logging (figures 4, 5, 6, 7 and 8).

Figure 4: Installation of yam fields in the CFUA

Figure 5: Pasture of cattle herds in the CFUA

Figure 6: Tree logging in the CFUA

Figure 7: Cotton fields in the CFUA

In the same way, tree and shrub savannahs have experienced a regressive evolution of their area from 2000 to 2015, with an annual regression rate of 6.1%. Indeed, their surface area has decreased from 149535 km² in 2000 to 136436 km² in 2015. Indeed, the analysis of the transition matrix reveals that 32235 km² or 21.5 % of the tree and shrubs savannahs were transformed into mosaics of fields and fallow. In addition, the mosaics of fields and fallow land have been extended. Their surface area has increased from 33159 km² in 2000 to 71734 km² in 2015. The annual rate of increase is 17.8 %. These mosaics of fields and fallows constitute areas of grazing in the dry season with the use of crop residues.

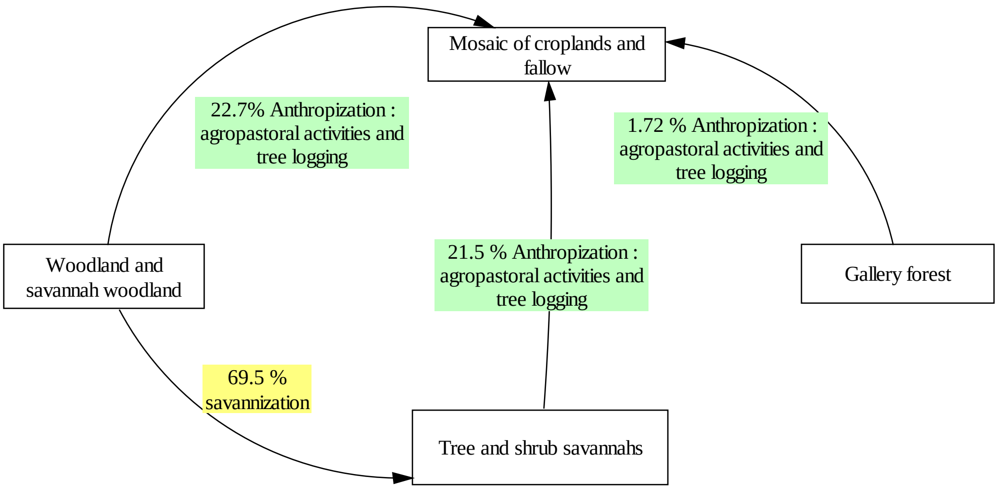

Figure 8: Main rates of change in land-use classes between 2000 and 2015 in the CFUA

4. Discussion

4.1. Dynamics of Land Use

The analysis of the dynamics of land use in the Classified Forest of Upper Alibori of 2000 to 2015 revealed a regression of the natural formations in favor of the mosaics of fields and fallows. In this classified forest there is over-exploitation, deforestation and degradation of rangelands. The practice of activities such as agriculture, livestock, tree logging has been raised by several authors [15 ; 6; 13 ; 16] to explain the degradation of natural formations in the Upper Alibori classified forest.

In addition, mosaics of fields and fallows which serve as grazing pasture in the dry season have increased in surface area. This regressive tendency of natural formations (closed formations) to the benefit of open formations is due to agro-pastoral pressures in general and particularly to the extensive crops of cotton and yam in the 6 riparian municipalities known as major producers in Benin. This extension of fields and fallow land is consistent with the high rate of population growth in these municipalities [17; 18].

Several other researchers [19 ; 15, 20) ; 16 ; 13 ; 21] have come to the same conclusion by confirming that the regressive tendency of natural formations to the benefit of field and fallow mosaics is due to anthropogenic activities. In total, the regressive dynamics of the vegetation cover can be attributed mainly to anthropogenic factors [22].

The forestry administration now exercises only superficial control in the Classified Forest of Upper Alibori [23]. The classified forest of Upper Alibori became the theater of several anthropogenic activities: agriculture, livestock, tree logging, poaching, and vegetation fires [16]. The "tragedy of commons" was gradually established [24], symbolizing the degradation of the environment due to the concurrent use of a resource by several users, each seeking to make the maximum profit.

4.2. Implications for sustainable natural rangeland management

The spatio-temporal dynamics of the natural rangelands of the Upper Alibori forest are generally regressive. Thus, the degradation of vegetation cover has harmful effects on biodiversity

The presence of transhumant herds in this classified forest was noted by several scientific works [25, 16,13] and their damage to pastoral resources through the multiple transhumance itineraries [1], the degradation of soils and vegetation cover [26], as well as a decrease in biomass and the ability to reproduce and regenerate vegetation [27, 28]. Thus, the pastoral resources of this classified forest are threatened [6] and an advanced degradation of the natural rangelands of cattle herds is observed in this agro-pastoral zone [29, 15, 21].

The spatio-temporal dynamics of the forest's paths provide the basis for better exploitation of pastoral resources. The rejuvenation and assisted diversification of these natural pastures could help alleviate the current pressure on the feed timber of rangelands and strengthen their load capacity.

5. Conclusions and recommendations

The analysis of the dynamics of the natural rangelands of the CFUA from Landsat digital satellite imagery revealed a regression of the surface areas of closed formations. Thus, gallery forests, woodland and savannah woodland and tree and shrub savannah have experienced a decrease in their surface area for the benefit of mosaic of fields and fallow with almost total disappearance of the woodland and savannah woodland. The degradation of the vegetation cover therefore has an impact on the exploitation of the pastoral resources of this protected area. The recommendations of this study concern the use of these results as basic tools for sustainable management of transhumance in the upper Alibori forest. Similarly, the continuation of this study to inventory forage species in the different types of natural rangelands of this forest, to evaluate their productivity and identify threatened and / or endangered forage species. In a perspective of sustainable management of natural rangelands and securing pastoral resources of this protected area, it is therefore very important to put in place effective strategies for forest management, in order to participate in the restoration of extinct vegetation and the conservation of biodiversity.

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