



Analysis of Land Cover Change and Its Implication on the Environment around the Dja Biosphere Reserve, Southeastern Cameroon

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Authors' contributions

This work was carried out in collaboration among all authors. Author NLM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors YBPK, MLTA and JTN managed the analyses of the study. Author RKE managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Land cover change is a growing concern around the world. This is especially true for protected areas which are rapidly degrading owing to pressure from anthropogenic activities. The aim of this study was to analyze land cover change for the periods 1980, 2008 and 2020 and its implication on the environment in and around the Dja Biosphere Reserve in south eastern Cameroon. This was done using remote sensing and geographical information systems techniques to quantify and measure the extent of land cover change in the study area for forty years. Household surveys were equally undertaken through the administration of questionnaires to farmers in villages located within the Dja Biosphere Reserve. Collected data was analyzed through the use of GIS software as well as Microsoft Excel. From the land cover maps, four classes were found: dense forest, cultivated

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areas, water surface, and buildings and bare soils. The transition matrix between 1980 and 2008 showed that 6477.81 ha of dense forest was lost to cultivated areas and between 2008 and 2020, 722.84 ha of dense forest was lost. Between 1980 and 2008 cultivated areas lost 0.07% and gain 0.72% between 2008 and 2020. Building and bare soils increase by 0.28% between 1980 and 2020. The Kappa index of agreement was 0.91 % between 1980 and 2008 and 0.88% between 2008 and 2020. Slash and burn agriculture (43.3%), hunting (36.3%) and harvesting of tree-based products (20.3%) were identified by farmers as the human activities with the most negative impact on the reserve. Results revealed that, there are still opportunities to safe this vulnerable reserve from the negative effects of land cover change through the practice of agroforestry.

Keywords: Land; cover; change; GIS; remote sensing.

1. INTRODUCTION

Land cover change denotes a change in certain continuous characteristics of the land such as vegetation type and soil. These changes are responsible for a number of local and global effects, including biodiversity loss, change in radiation balance, decrease in soil and water-holding capacity and its associated effects on human health, and the loss of habitat and ecosystem services [1]. Land cover change science were proposed to better understand the anthropogenic impacts on the earth systems through changes in land management and to observe such changes through satellite imagery, studies of drivers, impacts and modeling the processes of land change, to provide a better picture of the land transition dynamic and scenarios for future changes [2,1]. Land cover changes induced by anthropogenic activities such as the expansion of agricultural lands into natural ecosystems and the harvesting of non-timber forest products is being increasingly recognized as a major driver of global ecosystem changes [2]. With the ever-growing population and the demand for land for the cultivation of food crops in addition to the increase of reserves and protected areas in the study area, land is evidently becoming a valuable natural resource. Land cover change has taken different forms like enhanced vulnerability mainly the reduction in vegetation cover and the degradation of biodiversity [3], adverse impacts on livelihoods [4], and rangeland degradation [5]. The Dja Biosphere Reserve in Cameroon is no exception to land cover change dynamics. This reserve serves as a habitat for a variety of flora and fauna and characterized by forests of exceptional economic and social value – supplying several subsistence and commercial products [6]. However, the integrity of the Dja Biosphere Reserve is being affected by the exponential demand for forest resources by the local population for livelihood sustenance which has

led to the depletion of some forest resources [7]. A land use management plan that takes into account the problems facing the Dja Biosphere Reserve is therefore very important. In this light, land cover maps provide baseline information for activities such as thematic mapping and change detection. Since the local population resident in the Dja Biosphere Reserve depend on its resources for livelihood sustenance, a socio-economic survey was carried out to assess the perspectives of the local population. To examine the level of land cover change around the Dja Biosphere Reserve, monitoring land cover dynamics over a period of 40 years was necessary. This is of critical importance to authorities managing the Dja Biosphere Reserve as it can assist them in generating planning models for the rational and optimal use of land and forest resources around the Reserve. This study was therefore carried out in order to analyze land cover change and its implication on the environment around the Dja Biosphere Reserve.

2. MATERIALS AND METHODS

2.1 Location of Study Area

The Dja Biosphere Reserve is located South and East of Cameroon, between latitude 2°31'0"-3°52'20"N of the equator and longitude 12°20'20"-13°50'40"E of the Greenwich meridian (Fig. 1). It has an area of about 526,000 ha and covers six subdivisions which are: Lomié (east cluster), Somalomo (north cluster), Bengbis and Meyomessala (west cluster), Djoum and Mintom (south cluster). The Dja River forms a natural boundary to the reserve, protecting it to the south, west and north. The climate is of the equatorial type, with four seasons: the rainy season from mid-September to December followed by a three month dry season and then a small rainy season between mid-March and June followed by a short dry season from July to

September. The monthly average temperature lies between 23.5 °C and 24.5 °C and the annual rainfall of 1600 mm [8]. The east and part of the west cluster is made up of red ferallitic soils while the south and part of the west cluster is made up of yellow ferrallitic (lateritic) sesquioxide soils, good for the cultivation of crops like cocoa and coffee. The vegetation of the Dja Reserve is of the Congolese type with evergreen forest belonging to the Guineo-Congolese domain

and it consists of large trees reaching 60 m tall [9].

2.2 Realization of Land Cover Maps around the Dja Biosphere Reserve

This approach consists of: data acquisition, pre-processing and classification chain, production and validation (Fig. 2).

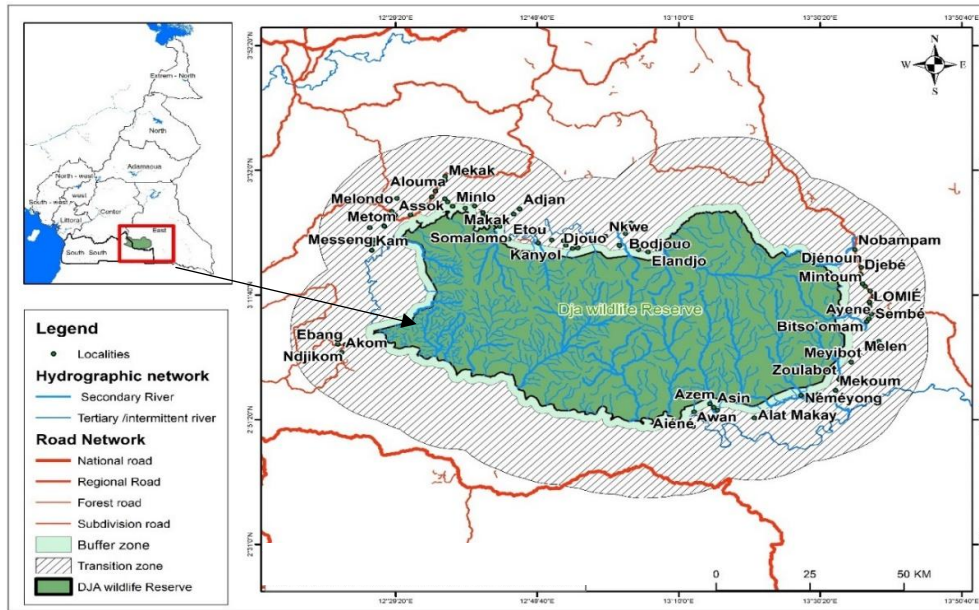


Fig. 1. Location of the Dja Biosphere Reserve

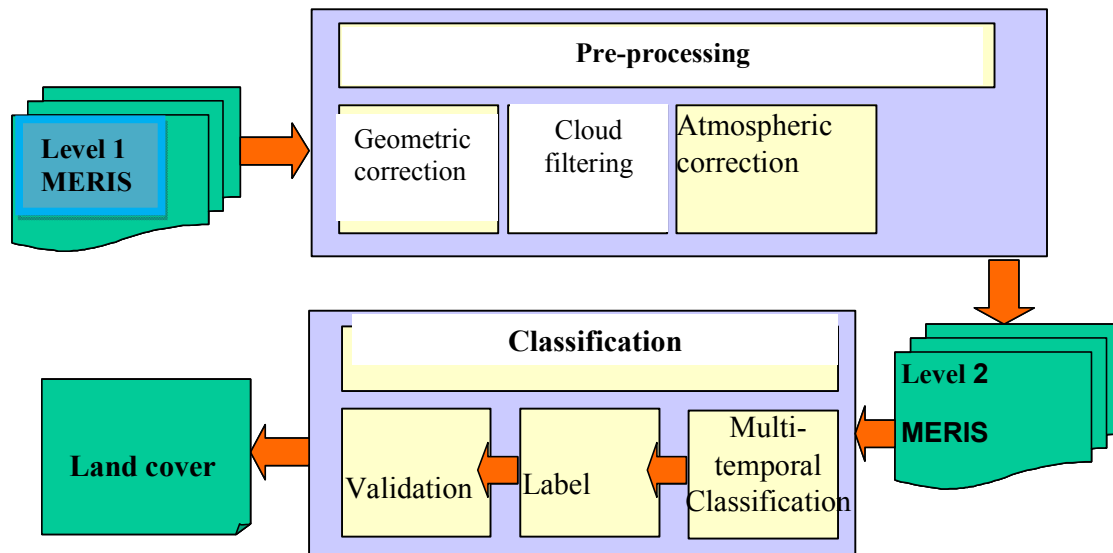


Fig. 2. A classical method for land cover change assessment

➤ Data acquisition

For this study, the satellite data used were MERIS (medium resolution imaging spectrometer) sensor images with a resolution of 300 m pixels. These images were acquired for the periods 1980, 2008 and 2020 and were used to draw up the various land cover maps. This sensor is composed of five CCD (Charge Couple Device) arrays and has a bandwidth of 1150 km.

➤ Pre-processing

The pre-treatment was performed following these steps which are: Geometric correction of the input data to obtain a geo-localization accuracy of one third of the pixels, cloud filtering, land/water reclassification and atmospheric corrections.

➤ Satellite image classification

The land cover classification was aimed at transforming the reflectance of the surface. This was conducted following the steps below:

- (i) A classification algorithm to define homogeneous land cover objects based on one (or at most two) multispectral reflectance composite (s);
- (ii) A land cover discrimination algorithm consisting of iterative multidimensional clustering techniques;
- (iii) A labeling procedure based on reference classifications such as the GLC (global land cover) 2000 regional products and then adapted to MERIS. Validation was carried out through field visits. The aim was to compare the processed images with the large landscape in the study area.

Change detection analysis involves finding the type, amount and location of land cover changes over time [10]. Among change detection approaches, post-classification comparison (PCC) was used in this study to identify changes in land cover. The change assessment was applied to the classification results of individual images from the best performing SVM ('Séparateur à Vaste Marge') model in order to identify change trajectories of two respective dates: 1980-2008 and 2008-2020.

Kappa indices were used to verify the quality of the treatments. The Kappa index lies on a -1 to 1 scale, where 1 is a perfect agreement, 0 is exactly what would be expected by chance, and negative values indicate agreement less than chance [11]. This index, higher than 0.81

assumes that, the images were perfectly treated and are interpreted following Table 1.

Table 1. Interpretation of Kappa index

Kappa indices	Agreement
< 0	Less than chance agreement
0.01–0.20	Slight agreement
0.21– 0.40	Fair agreement
0.41–0.60	Moderate agreement
0.61–0.80	Substantial agreement
0.81– 0.99	perfect agreement

2.3 Collection and Analysis of Socio-economic Data

Household surveys and direct observations were used in the identification of factors influencing dynamics in land use/land cover in the Dja Biosphere Reserve. Household surveys were done through the administration of semi-structured questionnaires to farmers living in the vicinity of the reserve. Through simple random sampling, a total of 320 household heads were surveyed in the study area. Questions were framed to acquire information on income-generating activities, and human activities impacting negatively on the vegetation cover of the reserve. Focus group discussions with farmers and key informant interviews with resource persons like chiefs, quarter heads and forest and agricultural extension agents were equally conducted to acquire more information on types of land use, settlements and farming practices. Data collected through household surveys, key informant interviews and focus group discussions were triangulated, coded and imputed into Microsoft Excel Spreadsheets for descriptive statistical analysis.

3. RESULTS

3.1 Land Cover Change during the Periods 1980, 2008 and 2020 around the Dja Biosphere Reserve

3.1.1 Land cover classes and dynamics

From the classification of Landsat images for 1980, 2008 and 2020, four main classes were identified namely: dense forest, cultivated area, building and bare soils and water surface (Table 2).

Fig. 3 shows the land cover classes around the Dja Biosphere Reserve for the periods 1980, 2008 and 2020. In 1980, cultivated areas

occupied an area of 49 575.75 ha (1.49%), building and bare soils 21 246.72 ha (0.64%), dense forest covered 3 242 417.56 ha (97.49%) of the surface area of the Dja Biosphere Reserve. In 2008, cultivated areas occupied an area of 1.42% (47 359.29 ha), building and bare soils 0.81% (26 895.72 ha) and dense forest covered 97.43% (3 240 173.37 ha). In 2020, cultivated areas represented 2.14% (71 301.20 ha), building and bare soils 0.92% (30 594.84 ha), dense forest occupied 96.60% (3 212 589.39 ha).

Cultivated areas are highly concentrated in the West cluster of the reserve and in the south cluster mostly in villages situated along the roads (Fig. 4). The dense forest is covered by vegetation of all kinds such as woody trees and shrubs.

3.1.2 Kappa index of agreement (KIA) between 1980 - 2008 and 2008 – 2020

Table 3 presents the Kappa statistics of the various land cover units and represents the extent to which the data collected in this study

are correct representations of the variables measured. An index of 0.8 shows a substantial agreement. The overall KIA was 0.91 between the period 1980 - 2008 and 0.88 for the period 2008 - 2020 indicating perfect agreement. This signifies that there was 0.91 and 0.88 agreement of the data collected and the treatment.

3.1.3 Land cover class between 1980, 2008 and 2020

Dense forest was high in 1980 occupying a total surface area of 3 242 417.56 ha but decreased to 3 240 173.37 ha in 2008 and experiences a further decrease to 3 212 589.39 ha in 2020. Cultivated areas occupied an area of 49 575.75 ha in 1980, decreased to 47 359.29 ha in 2008 and increase to 71 301.20 ha in 2020 (Table 4). Building and bare soils increased from 21 246.72 ha in 1980, to 26 895.72 ha in 2008 and then to 30 594.84 ha in 2020. The land cover categories that have experienced an increased during the period of 40 years are cultivated areas, building and bare soils and those that have decreased are dense forest and water bodies including marshy areas.

Table 2. Existing land cover types around the study area

Land cover class	Description
Cultivated areas	Predominantly made up of cocoa (<i>Theobroma cacao</i>) trees, mixed with forest, and fruit trees, coffee and food crops.
Dense forests	Covered by woody trees with thick canopies.
Water bodies	Made up of rivers, streams and marshy areas.
Building and bare soils	Made up of roads and other infrastructures such as administrative offices. Composed of exposed stones, rocks and exposed soils from human activities containing little vegetation.

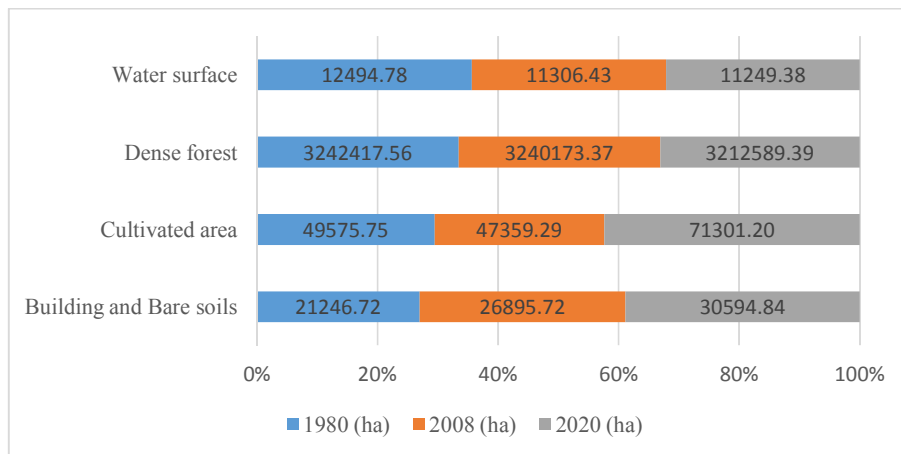


Fig. 3. Land cover change for the periods 1980, 2008 and 2020 around the Dja Biosphere Reserve

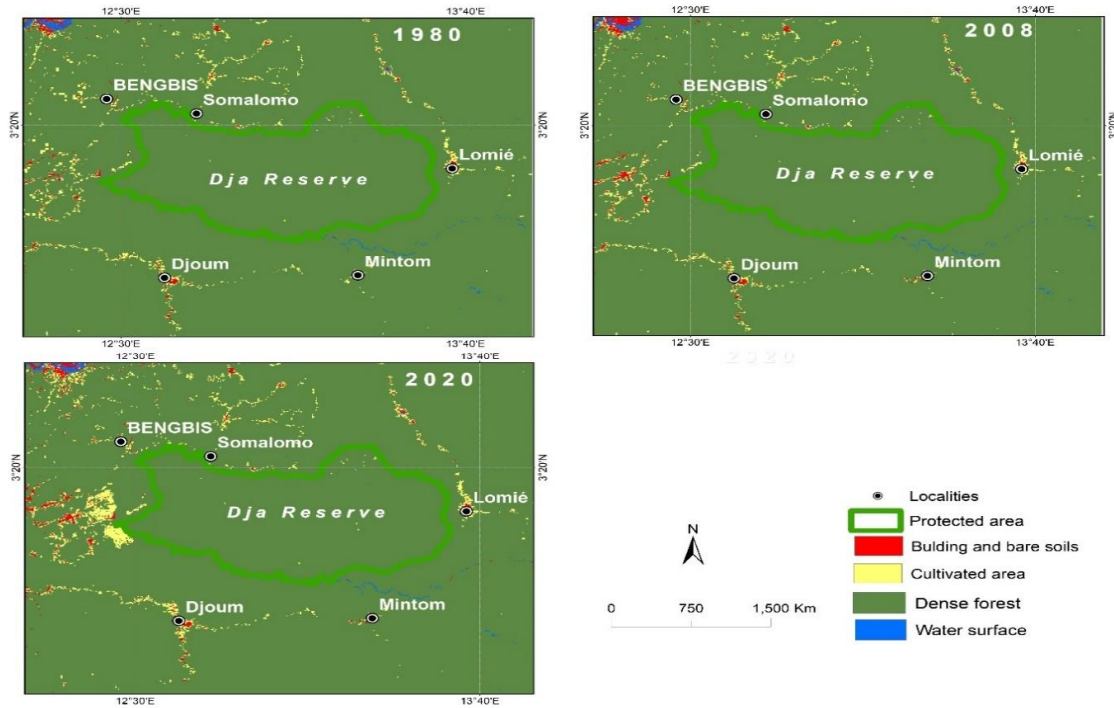


Fig. 4. Distribution of land cover change for the periods 1980, 2008 and 2020

Table 3. Kappa index of agreement from 1980 – 2020

Land cover class	1980 - 2008		2008 - 2020	
	KIA	Appreciation	KIA	Appreciation
Building and Bare soils	0.7886	Good	0.8537	Good
Cultivated area	0.9305	Very good	0.7132	Good
Dense forest	0.9330	Very good	0.9872	Very good
Water bodies	0.9932	Very good	0.9856	Very good

Table 4. Land cover around the Dja Biosphere Reserve between 1980, 2008 and 2020

Land cover class	1980 (ha)	%	2008 (ha)	%	2020 (ha)	%
Water bodies	12 494.78	0.38	11 306.43	0.34	11 249.38	0.33
Dense forest	3 242 417.56	97.49	3 240 173.37	97.43	3 212 589.39	96.60
Cultivated areas	49 575.75	1.49	47 359.29	1.42	71 301.20	2.14
Building and Bare soils	21 246.72	0.64	26 895.72	0.81	30 594.84	0.92
Total	3 325 734.81	100	3 325 734.81	100	3 325 734.81	100

Table 5. Change in land cover between 1980, 2008 and 2008 and 2020

Land cover class	Change between 1980 and 2008		Change between 2008 and 2020	
	CI (ha)	Rate of change (%)	CI (ha)	Rate of change (%)
Building and bare soils	+ 573.9	+ 0.17	+ 3 699.12	+ 0.11
Dense forest	- 2 244.13	- 0.06	- 27 583.98	- 0.83
Cultivated area	- 2 216.46	-0.07	+ 23 941.91	+0.72
Water surface	-1 188.35	- 0.04	-57.05	-0.01

CI = Increase or decrease of a land cover class

3.1.4 Change in land cover class between 1980 – 2008 and 2008 - 2020

Between the period 1980 and 2008, 2 244.13 ha of dense forest was lost representing 0.06% of forest cover and a further decrease of 27 583.98 (0.83%) in 2020 (Table 5). Cultivated areas experienced a decrease of 0.07% between the period 1980 and 2020 and an increase of 0.72% between 2008 and 2020, while building and bare soils increased from 1980 to 2020.

3.1.5 Transition of land cover units between 1980 – 2008 and 2008 – 2020

The values on the diagonal in boxes of Table 6 and Table 7 represent the surface area of land cover classes that remained unchanged during this period and those that were converted to other land cover classes.

Between 1980 and 2008, 32 369.56 ha of dense forests remained unchanged. However, other types of land cover have been converted to this class Such as building and bare soils (4 802.90 ha) and cultivated areas (3 919.10 ha) and also, as a result of the natural regeneration. Natural regeneration of forests can result from self-sown seeds, regeneration from root suckers, and

dispersal of seeds by animals and suitable environmental conditions such as rainfall which favor the regeneration of these plants. In terms of the conversion of land cover classes into cultivated areas, it can be seen that several classes have been converted such as 6 477.81 ha of dense forest and 9.51 ha of building and bare soils. This change is more remarkable at the transition zone of the reserve due to human activities such as extending agricultural lands although inside the reserve, there is a virtually the absence of human activities.

For 2008 and 2020, building and bare soils, dense humid forest and cultivated areas remained stable at 26 153.88 ha, 3 211 866.56 ha and 63 117.52 ha, respectively. Table 7 shows that, several classes were converted into building and bare soils such as 4 336.37 ha of dense forest. However, the most remarkable change is found between dense forests and cultivated areas where 722.84 ha of dense forest was converted to cultivated areas. Also, 19.02 ha of water bodies which include marshy areas were converted to cultivated areas as a result of land reclamation. Water bodies have experience a decreased from 1980 - 2020 due to the destruction of the watersheds by unsustainable human activities.

Table 6. Transition matrix between the period 1980 and 2008

Land cover class	Building and Bare soils (ha)	Cultivated Area (ha)	Dense forest (ha)	Water surface (ha)	Total (ha)
Building and Bare soils	21 246.72	0	0	0	21 246.72
Cultivated area	9.51	59 445.92	6 477.81	76.06	66 009.29
Dense forest	4 802.90	3 919.10	3 233 695.56	0	3 242 417.56
Water bodies	836.59	427.82	0	11 230.37	12 494.78
Total (ha)	26 895.72	63 792.83	3 240 173.37	11 306.43	

Table 7. Transition matrix between the period 2008 and 2020

Land cover class	Building and Bare soils (ha)	Cultivated Area (ha)	Dense forest (ha)	Water surface (ha)	Total (ha)
Building and Bare soils	26 153.88	0	0	0	26 153.88
Cultivated area	0.00	63 117.52	722.84	19.02	63 859.38
Dense forest	4 336.37	24 503.14	3 211 866.56	0	3 240 706.07
Water surface	104.58	114.09	0	11 230.36	11 449.02
Total (ha)	30 594.84	87 734.74	3 212 589.39	11 249.38	

3.1.6 Impact of human activities in and around the Dja Biosphere Reserve

Hunting, harvesting of tree-based products and slash and burn agriculture are the major activities which if not control will lead to degradation of the forest cover of this reserve. Majority of the population of Dja Biosphere Reserve represented by 36.3% depend on hunting as a source of food and income. When they go to the forest to hunt, the cut stems of less than 20 m to established temporal homes and these young stems are also use to prepare traps for animals, all this has negative effect on regeneration of these plants of this reserve. Slash and burn agriculture is a common practice in this area and 43.4% of the population depend solely on this practice. The fell down all the trees and set fire on it to established cassava farms, groundnuts and plantains farms. When fire is used it lead to the destruction of organic matter in the soil, and in turn leads to a decline in the productivity of the vegetation and the crops planted on the burnt soil. Harvesting of tree-based products (20.3%) mostly barks of trees for medicinal purposes is also a cause of the degradation of the vegetation cover due to the use unsustainable harvesting techniques.

4. DISCUSSION

4.1 Land Cover Change around the Dja Biosphere Reserve

The analysis of land cover change around the Dja Biosphere Reserve from 1980 to 2020 shows a decline in some land cover classes and an increase in some classes. From 1980 to 2020, there is a decline in dense forest and an increase in cultivated areas and buildings and bare ground. The transition matrix showed that this decline in dense forest was at the expense of cultivated area mostly at the transition zone, which constitutes a major cause of forest degradation. This forest degradation is accompanied by the loss of biodiversity. Similar results were obtained by Djiongo et al. [12] in the Bouba Ndjidda National Park. They reported a regression in natural plant formations by 13.4% in 26 years at the expense of anthropogenic activities such as crop fields, bare soil, and infrastructure. These results are also similar to those of Temgoua et al. [13] in the classified forest of Djio-li-Kera in southeast Chad and those of Benoudjita and Ignassou [14] in and around the Western Regional Park of Benin, which shows a continuous regression in forest and

savannah at the expense of fallows, crop fields, bare soil and settlements. Reports by Temgoua et al. [15] also showed that in the Ajei community forest in the North West Cameroon, there is a continuous regression in forest cover and a greater part of it is converted to sparse vegetation and bare soils due to grazing of cattles. Studies by Djiongo et al. [12] indicate a decline in forest cover because the population were seriously involve in firewood and charcoal production, livestock rearing, the cultivation of maize, groundnuts, cow pea, millet/sorghum, cassava and yams. All these practices do not favor tree planting but the degradation of forest cover as cultivated areas are increasing. This can be explained by the fact that the population is involved in perennial agroforestry practices which contribute to provide some of the products they obtain from the forests, such as wood. This implies that, the use of agroforestry practices on the buffer zone of protected areas can offer a variety of products and services that meet the demands of the local populations. These benefits will dissuade them from using resources from the protected area. Hunting is one of the major activities which, if not controlled will lead to the degradation of the forest cover of this reserve. When they go to the forest to hunt, they cut tree stems of less than 20 m to establish temporal homes and these young stems are also used to prepare traps for animals. All this has a negative effect on the regeneration of these plants of the reserve. Reports by Tabue et al. [9] for the Dja Reserve indicated that 35,721 stems were destroyed in favor of the construction of temporal homes (commonly called 'cabane') in the forest and to set traps for animals. Hunting can change the abundance of vertebrate predators and seed dispersers, causing species-specific changes in seed dispersers and alteration in the seedling community affecting the reproduction of plants. Wright [16] reported that vertebrates perform important functions in the ecology of forests as herbivores and seed dispersal; hence the extraction of vertebrate species from forest has implications for the conservation of biodiversity that go beyond a simple concern for the species themselves. Slash and burn agriculture negatively degrades the vegetation cover as all trees are fell down and burnt. This is mostly because the population lacks labor and the means to fell down the trees and therefore prefer to set fire on a selected portion before cultivation. Anonyme [17] showed that tropical forests lost 7 million hectares per year and [18] reported that 1% of forests is lost per year in Cameroon in favor of agriculture and forest exploitation.

Harvesting of the barks of the trees usually leads to death of the tree and even loss of the species due to high exploitation and the use of unsustainable harvesting techniques.

5. CONCLUSION

From 2008 to 2020, the rate of decline in forests cover is low, because most cultivated areas are occupied by perennial agroforestry systems which provide some products farmers obtained from the forests reducing their dependence on forest products. As a mitigation strategy to livelihood needs as well as the rehabilitation of degraded land, the conversion of pure cultivated agricultural land into agroforestry is a major opportunity.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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