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Dynamics of Land Use and the Evolution of Agroforestry Practices in the Dja Biosphere Reserve (DBR) Southeast Cameroon

Njini Loveline Munjeb[1], Avana Tientcheu Marie Louise[1], Julius Tata Nfor[2], Yerima Bernard Palmer Kfuban[3], Jean-Michel Harmand[4]

[1]Department of Forestry, Faculty of Agronomy and Agricultural Sciences (FASA), University of Dschang, Dschang, Cameroon
[2]Department of Geography, Planning and Environment, Faculty of Letters and Social Sciences, University of Dschang, Dschang, Cameroon
[3]Department of Soil Sciences, Faculty of Agronomy and Agricultural Sciences (FASA), University of Dschang, Dschang, Cameroon
[4]CIRAD/DP-Agroforestry, Yaounde, Cameroon
Email: njini.loveline@yahoo.com

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Abstract

The study had as objective to investigate the land use/land cover change from 1980 to 2019 in the Dja Biosphere Reserve using GIS and remote sensing techniques and the evolution of agroforestry practices. Semi structured questionnaires were administered to 320 farmers who were randomly selected from 35 villages of the Dja Biosphere Reserve characterized by the presence of agroforestry systems. The land use map revealed six classes which were dense humid forest, perennial crop-based agroforestry practices, river, wetland, built up and bare areas. Between 1980 and 2008, dense humid forest lost −4.9% of its area to the benefits of perennial crop-based agroforestry practices, built up and bare land. Between 2008 and 2019, dense humid forest gain 1.77% of its area due to increase in perennial crop-based agroforestry practices and a subsequent increase in vegetation cover. Perennial crop-based agroforestry practices and built up increase progressively from 1980 to 2019. Farmers perceived hunting (36.3%), slash and burn agriculture (43.3%) and harvesting of tree-based products (20.3%) as the anthropogenic activities impacting the reserve negatively. The evolution of agroforestry practices were observed on the field, but the precise area under agroforestry practices in the study area need to be estimated. 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.

Keywords

Land Use/Land Cover, GIS and Remote Sensing Techniques, Agroforestry,

Dja Biosphere Reserve

1. Introduction

Protected areas such as national parks and reserves are the cornerstone of global biodiversity conservation (UNEP, 2004) and they provide a wide range of biological resources and ecosystem services (Dudley, 2008). Human activities are responsible for the land cover/land use (LCLU) changes in protected areas (Mehari et al., 2019). Particularly, human-induced land cover/land use changes, through activities such as the collection of non-timber forest products, expansion of agricultural lands into the natural ecosystems, are being increasingly recognized as a critical element of global ecosystem changes (Nagendra et al., 2003). The increasing dynamics of land cover/land use takes various forms such as enhanced vulnerability, mainly the reduction in vegetation cover and the degradation of biodiversity (Barana et al., 2016), rangeland degradation (Mohammed et al., 2017), and adverse impacts on livelihoods (Gebreslassie, 2014). This is the case of the Dja Biosphere Reserve in Cameroon which is endowed with forests of exceptional economic and social value, and habitat of a variety of flora and fauna, supplying many commercial and subsistence products (Ashley & Mbile, 2005). Unfortunately, the depletion of these forest resources and increasing demand for forest products, especially by the rural people who depend on forests for their livelihoods, has widened the gap between the demand and the supply of forest products around the DBR, which is affecting the integrity of the reserve (UNESCO, 2011). Therefore, there is the need for a land use management plan that takes into consideration these issues. Base on this, land use and land cover maps establishes the baseline information for activities like change detection and thematic mapping. Considering the fact that the growth of the population of Dja Biosphere Reserve depends on its social and economic development, it is for this reason why socio-economic survey were carried out which include both spatial and non-spatial datasets. To ensure sustainable development in Dja and its peripheral zones, it was necessary to monitor the ongoing processes on land use and land cover pattern over a period of 29 years. This is needed so that the authorities associated with development of DBR generate planning models so that the available land is used in a most rational and optimal way which requires the present and past land use and land cover information of the study area. It is under this premise that, the main aim of the study was to investigate the land use/land cover changes and the evolution of agroforestry practices in the Dja Biosphere Reserve using GIS and remote sensing techniques couple with socio-economic information.

2. Materials and Methods

2.1. Location of Study Area

The Dja Biosphere Reserve is situated in the southeast regions between latitudes

2˚4430'N - 3˚1530'N and Longitudes 12˚430'E - 13˚3930'E of the Greenwich meridian (Figure 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 (Sonke & Couvreur, 2014). 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 (Tabue et al., 2018).

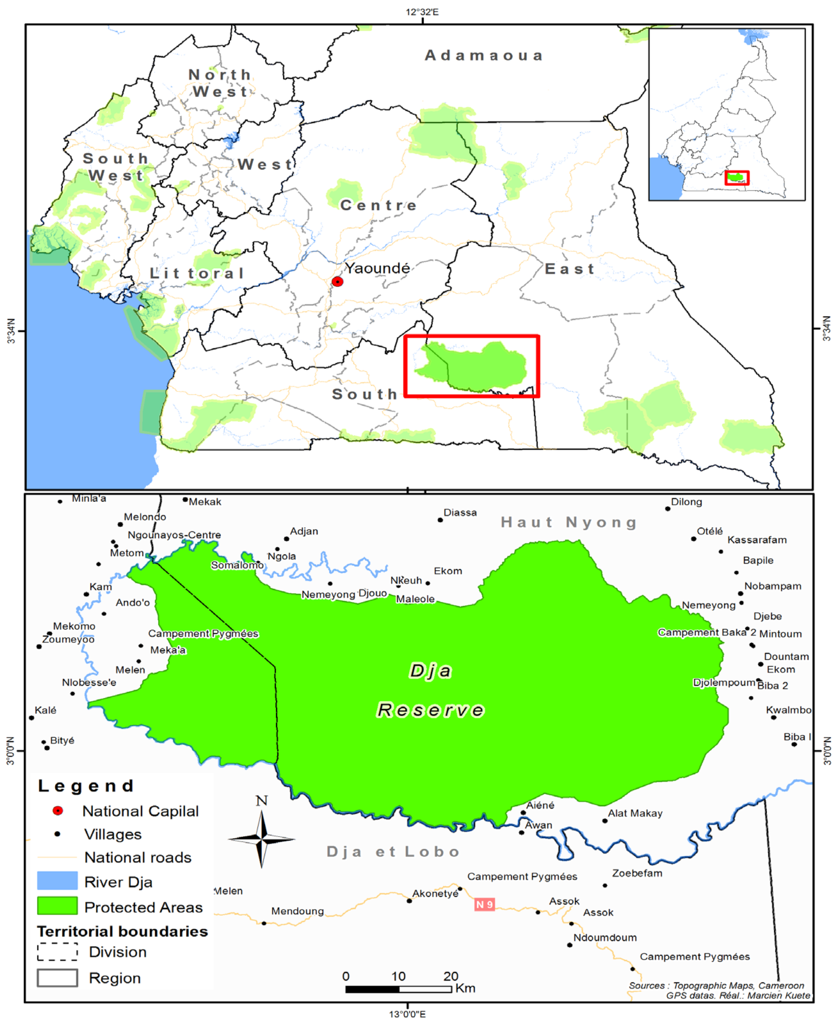

Figure 1. Location of the Dja Biosphere Reserve and its peripheral zones.

2.2. Mapping and Digital Processing of Satellite Images of the DBR

Landsat images were downloaded from the downloaded from the United States Geological Survey (USGS) website (http://glovis.usgs.gov/). Images were selected based on selected dates and quality which were 1980, 2008 and 2019. Delineation of agroforestry areas was based on Advanced Multispectral Scanner (MSS), Thematic Mapper (TM) (Landsat 5 image of 1980), Enhanced Thematic Mapper Plus (ETM+) (Landsat 7 image of 2008), and Operational Land Imager (Landsat 8 image of 2019). All images were geometrically corrected and acquired in level 1T (L1T). These images were acquired during the dry season to ensure that they were cloud free.

2.2.1. Image Preprocessing

Before proceeding with the thematic classification of the satellite images, a series of pre-processing operations were carried out to facilitate their exploitation as follows:

- Combining the bands to obtain a single multispectral image. Landsat images consist of multiple bands in Geotif format and all the bands were combined in ENVI software using the Layer Stacking module.
- Image enhancement to improve the appearance of the images and facilitate visual interpretation and analysis of the scenes. The contrast between the features on the images was improve by adjusting the dynamics of the radiometric values in the frequency histogram. This was accomplish by using the "enhance" module in the ENVI software.
- Extraction of the study area from the multispectral images was obtain, following the administrative boundaries. This was accomplish by using the "subset data from roid" algorithm in ENVI software.
- The radiometric correction was done to increase the reflectance of each pixel of the image using the "Radiometric calibration" algorithm.

The geometric improvement was not necessary because the images obtain have been geometrically corrected on the basis of the UTM WGS84 projection area 32N. However, the other complementary cartographic data (administrative boundaries, GPS data, hydrographic data and roads) were all projected on the UTM WGS84 zone 32N.

2.2.2. Calculation of Indices

This phase served to highlight several land cover units through the reflectance of each pixel of the image. Among others are the NDVI for highlighting the vegetation, the NDWI which highlights the presence of water on a satellite images, the brightness index (IB) highlighted the built-up areas which has the highest reflectance. We also calculated the bare ground index (BSI). The combination of these indices and the creation of a shape file (point) for taking samples from the image provided knowledge of the land use types in the DBR as well as GPS points sampled for processing validation.

2.2.3. Classification

Using ENVI 5.3 image processing software, the digital image classification process included selecting the color compositions (Band 6, Band 5, and Band 3), defining the legend or ROI (Regions of Interest), selecting sample plots describing and providing information about the different classes; and selecting the classification algorithm.

Images were displayed in the three primary colors (red, green and blue) that is, associating each spectral band to a primary color results in a color composite image. The visual interpretation of the images after the color composition allowed the identification of the type of occupation of the soil and thus the delimitation of the sample areas. The delimitation of these sample areas integrated GPS points collected on the field (**Figure 2**). Knowledge of the study area guided the choice which favor the supervised classification, which consists of applying the same treatment to each pixel, independently of neighboring pixels. The Maximum Likelihood (Maximum Likelihood) algorithm was chosen for image classification. It is a method that calculates the probability that a pixel belongs to one class rather than another. Pixels were assigned to the class for which the probability is highest.

2.2.4. Post-Classification

After the supervised classification, it was transferred to post-classification which consisted of validating treatments based on observations through Google Earth and field visits. Once the classification was completed, treatments were carried out to refine, evaluate the accuracy and validate the results. The first treatment consisted of passing the classified image through a 3 × 3 majority filter (isolated pixels are transformed into majority neighboring pixels in a 3 × 3 square around the pixel under consideration. The classification was simplified and freed of isolated pixels, and then the classification was evaluated using an algorithm to calculate the separability index between land cover classes, an algorithm that checks the separation of pixels from one land cover class to another. It varies between 0 and 2 with the value 0 termed poor separation.

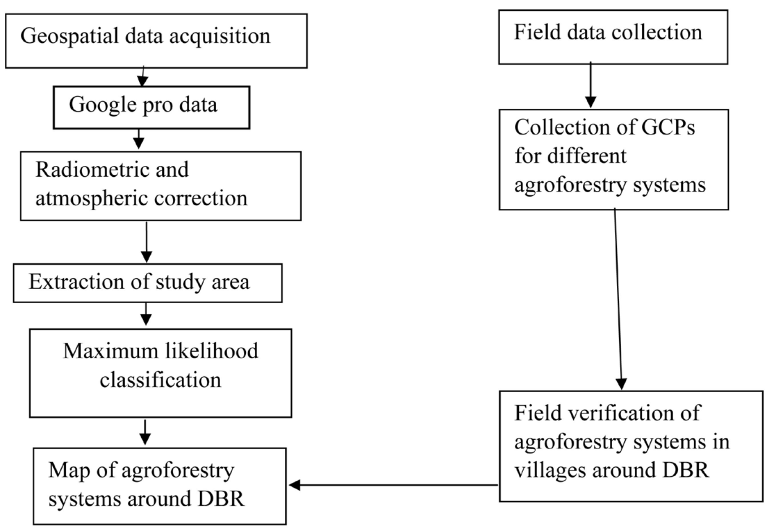

Figure 2. Mapping agroforestry systems around DBR. Source: Adapted from (Mahato et al., 2016).

2.3. Interviews with the Local Population

Semi-structured interviews and direct observations were used to identify the factors affecting the changes in land use/land cover change in the DBR. Three hundred and twenty questionnaires were administered to respondent who were randomly selected from 35 villages of the DBR. Focus group discussions were organized to obtain additional information on settlement, type of land use and farming practices. Questions were administered to household heads who were randomly selected. Issues discussed during the surveys were the socio-economic data such as income-generating activities, and human activities which the perceived negatively affect the vegetation cover of the reserve.

3. Results

3.1. Land Use/Land Cover Change between 1980, 2008 and 2019

From the classification of Landsat images for 1980, 2008 and 2019, six main classes were identified namely: dense humid forest, cropland, build up areas and bare land, wetland and river Dja (Table 1).

In 1980 (Figure 3), perennial crop-based agroforestry practices occupied an area of 5442.48 ha (0.8%), wetland 77,194.89 ha (4.1%), buildup and bare land 789.44 ha (0.1%), humid dense forests covered 923,263.13 ha (94.87%) of the surface area of the reserve and its peripheral zones. In 2008 (Figure 4), perennial crop-based agroforestry practices occupied an area of 2% (20,350.98 ha), wetland 7.7% (77,194.89 ha), buildup and bare land 0.33% (863.55 ha) and humid dense forests covered 89.98% (740,222.00 ha). In 2019 (Figure 5), perennial crop-based agroforestry practices occupied represented 3.2% (31,856.98 ha) of its area, wetland 3.7% (37,199.13 ha), buildup and bare land 0.9% (3414.26), humid dense forests occupied 91.74% (905,677 ha). Perennial crop-based agroforestry practices is highly concentrated in the West and East clusters of the reserve and in the south mostly in villages situated along the roads. The dense humid forest is covered by vegetation of all kinds such as trees and shrubs.

Table 1. Existing land use and land cover types in the study area.

Class name	Description
Perennial crop-based agroforestry practices	Predominantly cover with cocoa (*Theobroma cacao*) trees, mixed withforest, and fruit trees, coffee and food crops.
Wetland	Marshy areas.
Dense humid forests	Covered by woody trees with thick canopies which still possessed their natural state and have not been exploited.
Water bodies	Made up of water
Bare areas	Composed of exposed stones rocks and soils from human activities containing little vegetation.
Built up	Made up of buildings, roads and other infrastructures like administrative offices.

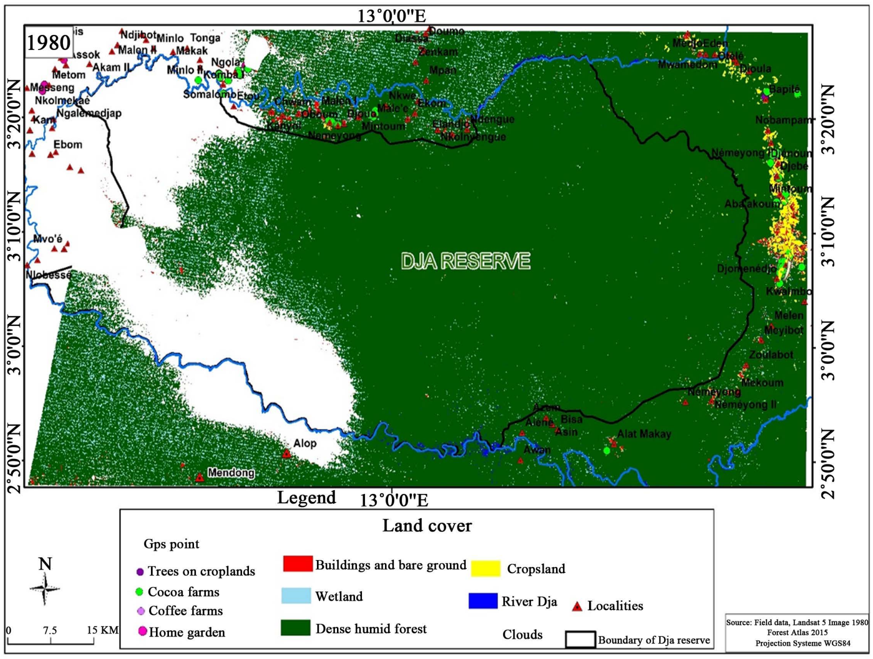

Figure 3. Landuse/land cover maps of 1980.

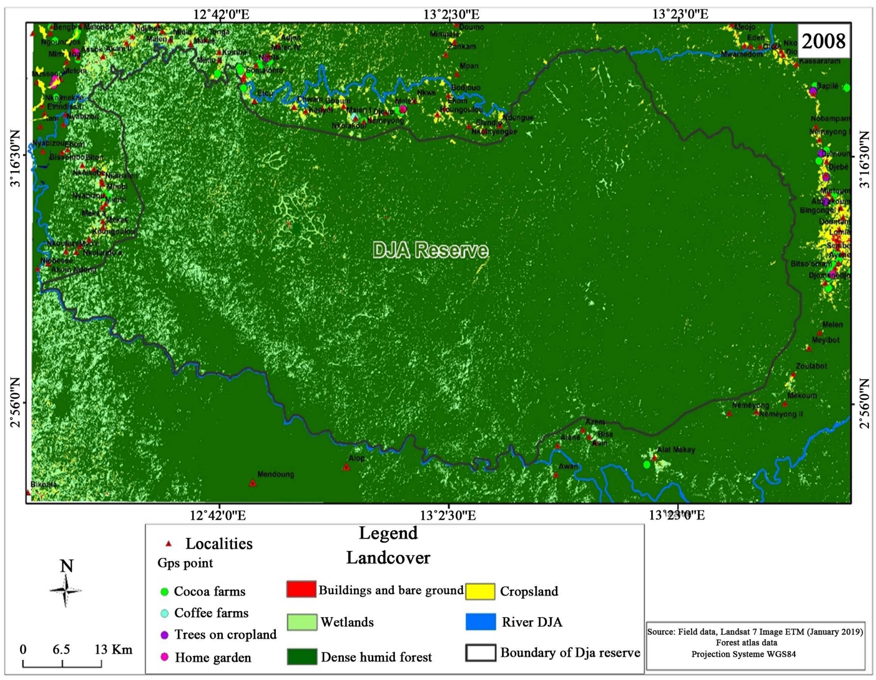

Figure 4. Land use/cover change of 2008.

3.2. Land Use Units between 1980, 2008 and 2019

Dense humid forest was high in 1980 occupying a total surface area of 923,263.13 ha but decreased by 183,041.13 ha in 2008 and an increase of 17,586 ha in 2019. Perennial crop-based agroforestry practices experience the highest increase from 5442.48 ha in 1980 and 31,856.98 ha in 2019 (Table 2). Buildup and bare areas increase from 789.44 ha in 1980 to 3414.26 ha in 2019. The land use classes

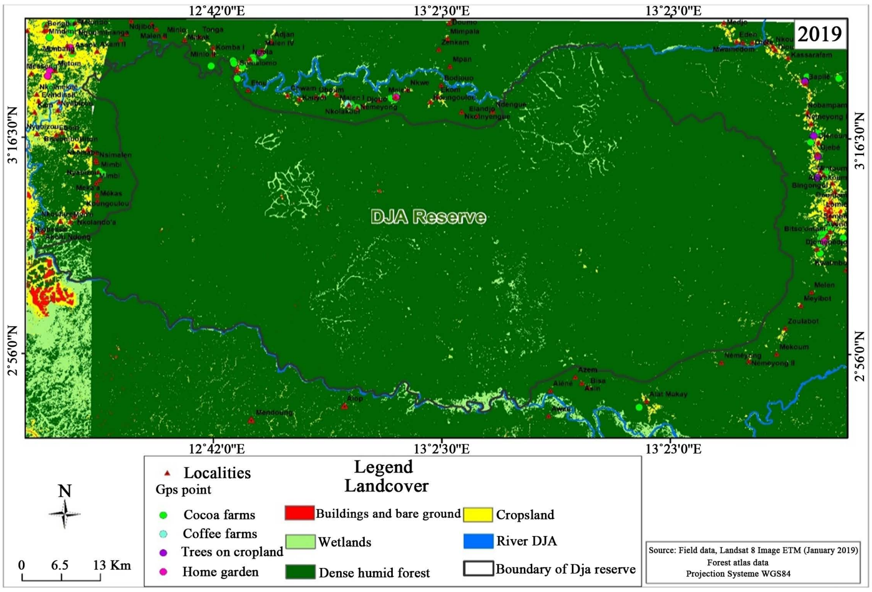

Figure 5. land use/land cover change of 2019.

Table 2. Land use in the DBR and its peripheral zones between 1980, 2008 and 2019.

Land use classes	1980		2008		2019	
	Area covered (Ha)	%	Area covered (Ha)	%	Area covered (Ha)	%
Building and bare ground	789.44	0.085	863.55	0.33	3414.26	0.89
Wetland	31,811.76	4.077	77,194.89	7.67	37,199.13	3.69
Dense humid forest	923,263.13	94.87	740,222.00	89.97	905,677	91.74
River DJA	1980.00	0.253	2,570.78	0.8	10,658.92	1.06
Perennial crop-based agroforestry practices	5442.48	0.697	20,350.98	2	31,856.98	3.17

that have experience progressive change during the period of 29 years are Perennial crop-based agroforestry practices, buildup areas and bare ground and humid dense forest.

3.3. Change in Land Use Units between 1980 and 2008 and 2008 and 2019

Between 1980 and 2008, 183,041.13 ha of humid dense forest was lost represented 4.9% of forest cover lost (Table 3). The forest lost 4.9% of its surface area in favor of perennial crop-based agroforestry practices and buildup areas and bare land respectively.

From 2008 to 2019, humid dense forest gain 165,455 ha of forest lost between 1980 and 2008 representing an increase rate of 1.17%. Perennial crop-based agroforestry practices and buildup areas experienced a progressive increase from 1980 to 2019 respectively. Wetland increase in 2008 and drop in 2019 which is related to the climatic conditions of 2008 which lead to an increase in wetland.

Table 3. Change in land use/land cover between 1980, 2008 and 2008 and 2019.

Land use units	Change between 1980 and 2008		Change between 2008 and 2019	
	CI (ha)	Rate of change (%)	CI (ha)	Rate of change (%)
Building and bare ground	+74.11	+0.26	+2550.71	+0.86
Wetland	+45,383.13	+3.59	−39,995.76	−3.91
Dense humid forest	−183,041.13	−4.9	+165,455	+1.77
Perennialcrop-based agroforestry practices	+14,908.5	+1.30	+11,506	+1.17
River DJA	+590.78	+0.77	+8088.14	+0.26

CI = Increase or decrease of a land use units.

3.4. Impact of Anthropogenic Activities on the Dja Biosphere Reserve (DBR)

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 DBR 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 plot of cassava, groundnuts and plantains. When fire is used it lead to the destruction of organic matter in the soil, and in turn, to a decline in the productivity of the vegetation and the crops planted on the burnt plot. 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.

3.5. Evolution of Agroforestry Practices in the Dja Biosphere Reserve

In the DBR, farmers practice integrated systems including agriculture and agroforestry which was identified as the main source of livelihood for the local population. The DBR which is divided into South, West, East and North clusters had variations in area under cultivation. These cultivated areas were mostly the integration of crops and perennial trees on the same piece of land which can be termed agroforestry. The West and East clusters (Figure 5) had the highest area under perennial crop-based agroforestry practices because these areas were located closer to most roads. The North cluster had the least area under perennial crop-based agroforestry practices due to proximity to the reserve and fuel wood, non-timber forest products were easy for the population to reach and this could be one of the reason for the low area under perennial crop-based agroforestry practices and also inaccessibility of the cluster to major roads and markets.

4. Discussion

Dynamics of Land Use/Land Cover Change

The analysis of land use land cover change of the Dja Biosphere Reserve showed a decline in humid dense forest between 1980 and 2008 at the expense of perennial crop-based agroforestry practices, buildup areas and bare soil. The same result were obtained by (Djiongo et al., 2020) in the Bouba Ndjidda National Park who 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., 2018b) in the classified forest of Djio-li-Kera in southeast Chad and those (Benoudjita & Ignassou, 2017) in and around the W Regional Park of Benin, which shows a continuous regression in forest and savannah at the expense of fallows, crop fields, bare soil and settlements. Report by (Temgoua et al., 2018a) also show that the Ajei community forest in the North West, Cameroon is experiencing an ongoing regression and a greater part of it is converted to sparse vegetation and bare soils due to grazing of cattles. From 2008 to 2019, in the Dja Biosphere reserve, there is an increase in 165,455 ha (1.17%) of the 183,041.13 ha (4.9%) of dense humid forest that was lost between 1980 and 2008. As perennial crop-based agroforestry practices and buildup areas are increasing, the humid dense forest is increasing progressively. This can be explained by the fact that the population are practicing agroforestry which is contributing to the increase in forest cover. This imply that, the use of agroforestry practices on the buffer zone of protected area can offer a variety of products and services that meet the demands of the local populations. These benefits will prevent them from using resources from the protected area. Hunting is one of the major activity which if not control will lead to degradation of the forest cover of this reserve. 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. Report by (Tabue et al., 2018) in the Dja Reserve reported 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 dispersal and alteration in the seedling community affecting the reproduction of plants. Report by (Wright, 2003) that vertebrates perform important functions in the ecology of forests as herbivores and seed dispersal, hence the extirpation 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 degrade the vegetation cover as all trees are fell down and burn. This is mostly because the population lack labor and the means to acquire labor and therefore prefer to set fire on a selected portion before cultivated. Reports (Anonyme, 2016) shows that tropical forests lost 7 million hectares per year and

(Anonyme, 2009) 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 lead to dead of the tree and even loss of the species due to high exploitation. Studies by (Djiongo et al., 2020) showed 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 yam and all these practices do not favor tree planting but the degradation of forest cover. Also as cropland is increasing in the Dja Biosphere Reserve, the farmers turn to depend more on their farms and do not exploit resources from the forest frequently. Between 1980 and 2019, wetland experienced an increase in surface area in 2008. According to (Mitchell, 2013) activities which results in wetland loss include: drained for housing developments and agriculture, unsustainable harvesting of wetland resources such as plants and fishes. All these factors reported by (Mitchell, 2013) as impacting wetland negatively were not observed in the BDR, therefore an increased in wetland area in 2008 can be explained by the fact that 2008 was a humid year and 1980 and 2019 were dry years. During 2008 there was high rainfall which resulted in flooding and an extension of the wetland area.

5. Conclusion

The aim of this study was to investigate land use/land cover changes and the evolution of agroforestry practices in the Dja Biosphere Reserve between 1980 and 2019. The vegetation cover decreases from 1980 to 2008 representing a loss of −4.9% to perennial crop-based agroforestry practices, infrastructure and bare areas, and experienced an increase from 2008 to 2019 representing a gain of 1.77% which was due to the increase of agroforestry practices in the area which led to an increase in vegetation cover. Perennial crop-based agroforestry practices increase progressively from 1980 to 2019 which probably led to an increase in the production of diverse crops and a decrease in pressure on the reserve. Anthropogenic activities which are progressively affecting the reserve negatively are hunting, slash and burn agriculture and harvesting of tree based products. The evolution of agroforestry practices, which are considered to improve the livelihood of the population and to reduce the pressure on natural vegetation cover were observed on the field, but the precise area under agroforestry practices in the study area need to be estimated which will help to determine if the agricultural land in the area is fully under agroforestry. Agroforestry is the key to prosperity for millions of farmers leading to increase income, employment opportunity, and greater food security. 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.

Conflicts of Interest

The authors declare no conflict of interest.

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