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Spatio-Temporal Dynamics of Land Use and Land Cover in the Alibori Basin in Northern Benin Republic (West Africa)

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Abstract

Forest ecosystems of the Alibori basin are subject to multiple anthropogenic pressures witch therefore modify their land use and their land cover. This research aims at analyzing the spatio-temporal dynamics of land use and land cover in the Alibori basin in Northern Benin. The methodological approach used is based on the diachronic analysis of land cover from Landsat 2, 7, and 8 satellite images acquired respectively in 1980, 2000, and 2020, and the evaluation of land cover change parameters (conversion rate, level of deforestation, intensity and speed of change of land cover units). The results obtained reveal that the number of classes has increased from 8 to 9 with the appearance of plantations between 1980 and 2000. Between 1980 and 2020 the basin recorded a degradation of forest formations and an anthrogenization of savannah formations. The intensity and speed of loss of area are quite rapid in dense dry forests, open forests, and wooded savannahs between 1980 and 2020. The average rate of deforestation decreased from 1.27% annually between 1980 and 2000 to 1.26% annually between 2000 and 2020.

1. Introduction

The dynamics of land use and land cover evolution in recent decades, have been characterized by a considerable decline in the area of natural vegetation formations to benefit anthropogenic formations (Diouf et al., 2019; Folahan et al., 2018; Imorou et al., 2017). According to FAO (2018), the main causes of deforestation globally in the world are agriculture (80%) and infrastructure construction (20%). Multiple studies have shown that commercial and subsistence agriculture are the main proximate in Africa, subsistence agriculture and production for local markets are more important (Curtis et al., 2018; De Sy et al., 2019; Gibbs et al., 2010; Kissinger et al., 2012; Rudel, 2013). The growing world population's demand for food, feed, and fiber creates the challenge of enhancing the global agricultural supply without compromising environmental sustainability (Henders et al., 2015). Tropical deforestation causes loss of biodiversity and other ecosystem services, soil degradation, and the disruption of hydrological cycles (Henders et al., 2015).

Because of its location in the Dahomey Gap, Benin has a small dense forest cover (Akoègninou et al., 2006). Like other developing countries, the anthrogenization of forest ecosystems has become a major environmental concern that impacts biodiversity in Benin (Biaou et al., 2019) and this in a worrying way (Agbanou et al., 2018). The results of studies and research on the evolution of vegetation types have revealed that the dynamics of vegetation formations (forest ecosystems) in Benin have a regressive trend in time and space (Benin, 2006; Boko, 2012; Mama et al., 2013; Ousséni et al., 2011).

The Alibori watershed is a semi-arid area where protected areas and the cotton basin are juxtaposed. It is currently the site of a permanent « conflict » between environmental protection and the economic interests of the population (Boko, 2012). The growing demand for agricultural land in the Alibori basin is highlighted by increasing the cotton area in cultivation, which is one of the main factors not only for the degradation of forest resources but also for hydroclimatic changes (Badou, 2016). For Issiaka et al. (2016), the evaluation of the physiognomic changes recorded in these natural routes of 2000 to 2013 reveals a regression of forest formations in favor of savannah and anthropogenic formations in Banikoara and Karimama. The quickest change rate has been recorded at the level of open forests and wooded savannahs. The extent of the loss of forest cover could have an impact on climate regulation, the surface flow and the socio-economic conditions of the rural population that directly depends on it (Vissin, 2007). Despite extensive research (Ousséni Arouna et al., 2016; Bogaert et al., 2011; Kouta & Imorou, 2019; Mama et al., 2013) carried out in this area to alert decision-makers and attract the attention of various actors, nothing seems to slow down the environmental dynamics in progress. It is therefore appropriate to map the spatiotemporal changes in land use in this environment from satellite imagery. In view of the regressive trend that Benin in general and the Alibori sub-basins are experiencing, it is appropriate that the overall spatio-temporal dynamics of the Alibori basin should be properly assessed. Therefore, the aim of this paper is to evaluate the spatio-temporal dynamics of land use and land cover in the Alibori basin.

2. Data and Methods

2.1. Study Area

The geographical framework of this study is the Alibori basin. It is located between 10°04'20" and 12°10'24" North latitude and between 1°52'17" and 3°21'27" East longitude (Figure 1). The area is 13,866.24 km². The Alibori basin has a population estimated in 2022 at 504,262 inhabitants with an average growth rate of 4.8%. The climate is Sudanian with a rainy and a dry season (Badou, 2016; Boko, 2012; Le Barbé et al., 1993).

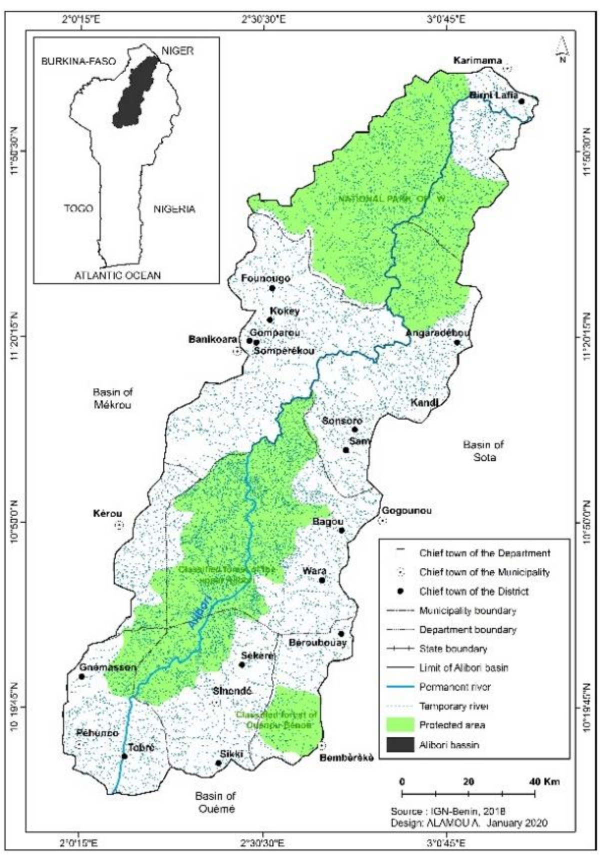

Figure 1. Location of Alibori Basin

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2.2. Data Collection

Two categories of data were used. The first category of data consists of Landsat satellite images covering the Alibori basin (Table 1). These are Landsat images of 1980, 2000, and 2020 downloaded from the USGS website (https://earthexplorer.usgs.gov/).

2.3. Reasons for Periods Choice

In the case of this study, a step of 20 years was preferred for deforestation measures between 1980 and 2020. The reasons underlying this choice are first: deforestation is not perceptible over a short period hence the impacts of ecosystem degradation of ecosystems. Then the year 1980 was chosen because, before this year, the Alibori basin did not have quality image scenes covering the entire sector in one year. Finally in Benin, the 2000s marked the era of transition of decentralized governance with the birth of municipalities and agricultural mechanization.

Table 1. Characteristics of Landsat Images Used

Satellites	Sensors	Reference dates	Path/Rows	Spatial resolution
Landsat 2	MSS	February, 2nd 1980	206/052 et 053	60 m
Landsat 7	ETM	February, 2nd 2000	192/ 052 et 053	30m
Landsat 8	OLI-TIRS	February, 2nd 2020	192/052 et 053	30m

The second category of data, known as "complementary" data, consists of GPS data (field control points) and the topographic base of the National Geographical Institute (2018).

2.4. Data Processing Methods

The digital processing of the satellite images was carried out in two essential stages: pre-processing and processing.

2.4.1. Pre-processing

The downloaded Landsat data have already been geo-referenced. However, verification and geometric correction were done by superimposing the Landsat images with the topographic map of the Alibori basin. The images were classified using the maximum likelihood classification technique with ENVI 5.0 software to identify the land use and the land cover units. There is a correspondence between the planimetric elements (waterways, road network, and protected area) of the topographic map and the images. The images covering only the Alibori basin were extracted to facilitate the processing on the screen.

2.4.2. Digital and statistical processing

The digital processing was done in two steps: the choice of the training sites and the classification method, while the statistical processing consisted of the calculation of the rates from the automatically generated transition matrix.

a. Selection of Training Sites

The training sites represent the digital characteristics of the classes that allow the definition of the spectral signatures of each vegetation type. According to Arouna (2012), training sites are delineated away from transition zones to avoid including mixed pixels, i.e., pixels that could be classified into two distinct classes. In the images, the training sites are plotted to the nearest pixel. They are scattered throughout the study area, representative of the diversity of each vegetation class or other land use unit.

b. Classification Method

It is a pixel-by-pixel classification based on the assumption that the spectral signature of each pixel is representative of the class of vegetation in which it is located. According to Arouna (2012), the adoption of this classification method is indicated in the case of images of different resolution by considering their spatial resolution which supposes that the different details present in the perimeter of a pixel combine to form a relatively unique and homogeneous for this class of vegetation. The method of processing images of different resolutions adopted in the context of this research is the resampling operation which consisted in sampling the pixels of 30 m resolution through the raster tools of the ArcGIS software. The supervised maximum likelihood classification consisted of assigning to each group of pixels the most plausible class based on the spectral similarity between the pixels and the class signature. The set of pixels in each satellite image was classified according to the maximum likelihood algorithm extrapolating the spectral characteristics of the training areas to the rest of the image.

The ground truthing consisted of verifying the pixel classes resulting from the classification. For this purpose, a sample of 15 classes of training areas per unit of land use and land cover was randomly selected. The accuracy assessment of the image classification was based on a confusion matrix. This matrix was automatically generated in ENVI 5.0 software. It has allowed us to evaluate the errors of omission, commission, map validity indices, class purity, and overall classification accuracy.

c. Statistical Analysis of Changes

- **Transition Matrix**
  It is synthetic table that summarizes the different transformations in the state of land use and land cover units in protected areas and village lands in the Alibori basin between 1980 and 2000 and between 2000 and 2020.
- **Deforestation Rate**
  It is calculated from the following formula:

$$\boldsymbol{Tdef = \frac{Def\ (b,n)}{S} x\ 100} \quad \text{.................Eq. (1)}$$

Where, Def (b,n) brut or net deforestation and S natural formation area of forest at years t.

The Pontius Matrix41 program was used to generate two graphs showing the intensities of land use and land cover unit changes based on the transition matrices between 1980 and 2000 on the one hand, and between 2000 and 2020 on the other.

The program "Intensity Analysis03.xlms", has been used to generate statistics for the transitions between each land use and land cover category and the others, according to the time intervals, based on the transition matrices. The same is true for the losses and gains that occurred during transitions between land use and cover units in the Alibori basin.

3. Result and Discussion

The results of this research are presented under three headings: confusion matrix of land use and land cover units, land use and land cover dynamics; analysis of the intensity of changes between 1980 and 2020.

3.1 Confusion Matrix of Land Use Units

The accuracy of the maps derived from the interpretation of satellite images was based on a confusion matrix. Tables 2, 3, and 4 present the confusion matrices for 1980, 2000, and 2020 respectively. An examination of Table 2 shows eight (08) land use and land cover, 90.05% global precision, and weak mutation between the class units. Tables 3 and 4 present nine (09) land use and land cover with the appearance of the plantation. The global precision is respectively 82.4% and 93.07%. In 2020, the high mutation can be noticed in farmlands and follows, woodland, and dense and dry forest. The year 2020 image has the highest global precision while the year 1980 image has the lowest.

Table 2. Confusion matrix for 1980

Classes	FF	FG	WB	SSS	WWS	DDF	SR	AG	Total	PGC (%)
FF	57	0	0	0	0	0	2	3	62	90,05
FG	0	37	0	0	1	2	0	0	40	
WB	0	0	25	1	0	0	0	0	26	
SSS	0	0	0	166	0	0	0	0	166	
WWS	0	0	0	0	41	10	0	0	51	
DDF	0	21	0	1	4	38	0	0	64	
SR	0	0	0	0	0	0	16	2	18	
AG	10	0	0	0	0	0	5	70	85	
Total	67	58	25	168	46	50	23	75	512	

*)LUC: Land Use and land cover Unit; FG: Forest Gallery; DDF: Dense Dry Forest; WWS: Woodland; SSS: Tree and shrub savannas; PL: Plantation; FF: Farmlands and Fallow Land; SR: Rocky Surface; WB: Water Body; AG: Agglomeration.

Table 1. Confusion Matrix for 2000

LUC classes	FF	FG	WB	SSS	WWS	DDF	PL	SR	AG	Total	PGC (%)
FF	403	0	0	0	0	0	0	0	0	403	82,4
FG	0	115	0	0	0	0	0	0	0	115	
WB	0	0	66	0	0	0	0	0	0	66	
SSS	0	0	0	2018	0	0	0	1	0	2020	
WWS	0	0	0	0	112	0	0	0	0	112	
DDF	0	0	0	9	0	174	0	0	0	183	
PL	0	1	0	2	0	0	87	0	0	90	
SR	0	0	0	2	0	0	0	72	0	74	
AG	0	0	0	0	0	0	0	0	317	317	
Total	403	116	66	2031	112	174	87	73	317	3379	

*)LUC: Land Use and land cover Unit; FG: Forest Gallery; DDF: Dense Dry Forest; WWS: Woodland; SSS: Tree and shrub savannas; PL: Plantation; FF: Farmlands and Fallow Land; SR: Rocky Surface; WB: Water Body; AG: Agglomeration.

Table 2. Confusion Matrix for 2020

LUC classes	FF	FG	WB	SSS	WWS	DDF	PL	SR	AG	Total	PGC (%)
FF	3065,55	0,00	0,00	808,94	64,82	3,93	64,16	0,00	60,24	4067,64	93.07%
FG	5,72	7,06	0,00	0,00	0,00	0,00	0,65	0,00	0,00	13,43	
WB	0,00	0,00	1,26	0,00	0,00	0,00	0,00	0,00	0,00	1,26	
SSS	2478,86	0,00	0,00	4832,36	72,37	4,26	13,75	0,00	5,89	7407,49	
WWS	488,01	0,00	0,00	442,97	490,34	3,60	10,48	0,00	0,00	1435,40	
DDF	347,47	0,00	0,00	252,01	13,75	218,52	0,65	0,00	0,00	832,40	
PL	0,32	0,00	0,00	0,00	0,00	0,00	0,33	0,00	0,00	0,65	
SR	0,00	0,00	0,00	0,00	0,00	0,00	0,00	66,79	0,00	66,79	
AG	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	31,1	31,11	
Total	6385,93	7,06	1,26	6336,28	641,28	230,31	90,02	66,79	97,24	13856,2	

*)LUC: Land Use and land cover Unit; FG: Forest Gallery; DDF: Dense Dry Forest; WWS: Woodland; SSS: Tree and shrub savannas; PL: Plantation; FF: Farmlands and Fallow Land; SR: Rocky Surface; WB: Water Body; AG: Agglomeration.

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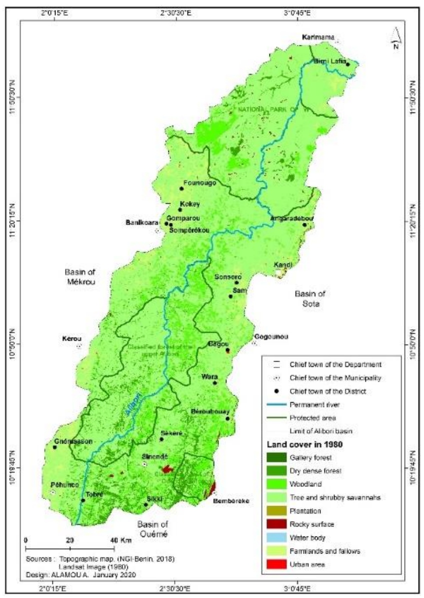
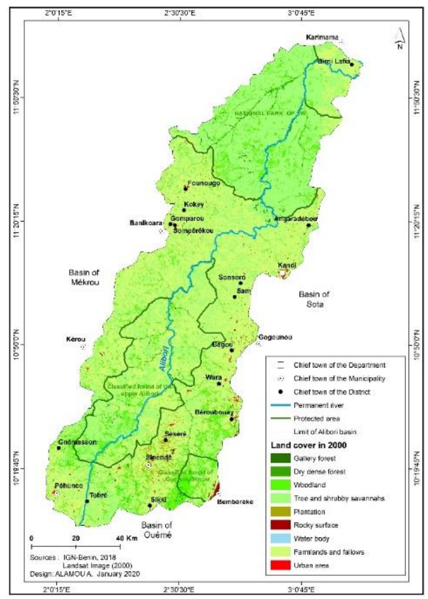
3.1.1. Land Use and Land Cover Dynamics from 1980 to 2020

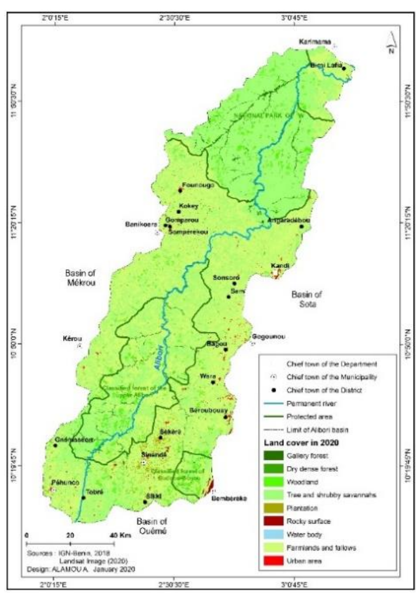
Figures 2 illustrate the states of the land use and land cover units in 1980, 2000, and 2020 respectively. The physiognomy of the 1980 land use and cover map (Figure 2a) shows the dominance of three land use and covers: dense dry forest, woodland, and tree and shrub savannah. The dense dry forest is more represented in the south of the basin, the woodland, and wooded savannah are more localized from the center to the north, while the SSS are found throughout the basin. As for the 2000 survey (Figure 2b), the physiognomy in order of dominance is as follows: farmlands and follows, woodland, and tree and shrub savannah. The farmlands and fallows are mainly present in village territories and on the periphery of protected areas. The woodland and tree and shrub savannah are found in the protected areas of the basin. Finally, the trends in order of dominance on the 2020 map (Figure 2c) are as follows: farmland and fallows and tree and shrub savannah. These two-land use and land covers are more common in village lands and within protected areas, except for Park W.



(a) Land use and land cover in 1980



(b) Land use and land cover in 2000



(c) Land use and land cover in 2020

Figure 2. Dynamics of Land Use and Land Cover from 1980 to 2020

3.1.2. Transition Matrix of Land Use and Land Cover Units between 1980 and 2000

Table 5 presents the transition matrix of land use and land cover units between 1980 and 2000. An examination of Table 5 shows that eight (8) land use and land cover classes were observed in 1980 and nine (9) classes in 2000 with the appearance of plantations class: proof of land use and land cover modification in degradation way. Naturals formations as tree and shrub savannah, woodlands, and wooded savannah have known the important loosed area respectively: 2 910.71 km2. While the anthropogenic formations as agglomerations, farmlands, and fallows have gained area respectively: 8.19 km2 and 3 244.44 km2.

Table 5. Land Use Land Cover Transition Matrix between 1980 and 2000

					2000					
1980	**FG**	**DDF**	**WWS**	**SSS**	**PL**	**SR**	**FF**	**WB**	**AG**	**Areas 1980 (Km²)**
FG	13,43	0,00	0,00	0,00	0,00	0,00	2,29	0,00	0,00	15,72
DDF	0,00	162,05	278,27	282,85	0,00	0,00	93,30	0,00	0,00	816,47
WWS	0,00	4,58	636,42	664,24	0,00	0,00	469,45	0,00	0,33	1775,02
SSS	0,00	69,08	1625,73	5726,51	0,65	0,00	2904,82	0,00	5,24	10332,03
SR	0,00	0,00	0,00	0,00	0,00	66,79	0,00	0,00	0,00	66,79
FF	0,00	5,24	75,95	144,37	0,00	0,00	597,78	0,00	2,62	825,96
WB	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,26	0,00	1,26
AG	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	22,92	22,92
Areas of 2000 (Km²)	13,43	240,95	2616,37	6817,97	0,65	66,79	4067,64	1,26	31,11	13866,24 km²

*)LUC: Land Use and land cover Unit; FG: Forest Gallery; DDF: Dense Dry Forest; WWS: Woodland; SSS: Tree and shrub savannas; PL: Plantation; FF: Farmlands and Fallow Land; SR: Rocky Surface; WB: Water Body; AG: Agglomeration.

3.1.3. Transition Matrix of Land Use and Land Cover Units between 2000 and 2020

Table 6 presents the transition matrix of land use and land units between 2000 and 2020.

Table 6. Land Use Land Cover Transition Matrix between 2000 and 2020

					2020					
2000	**FG**	**DDF**	**WWS**	**SSS**	**PL**	**SR**	**FF**	**WB**	**AG**	**Areas of 2000**
FG	7,06	0,00	0,00	0,00	0,65	0,00	5,72	0,00	0,00	13,43
DDF	0,00	66,79	13,75	112,29	0,65	0,00	47,47	0,00	0,00	240,95
WWS	0,00	3,60	295,30	1164,46	10,48	0,00	1142,53	0,00	0,00	2616,37
SSS	0,00	4,26	272,37	4042,84	13,75	0,00	2478,86	0,00	5,89	6817,97
PL	0,00	0,00	0,00	0,00	0,33	0,00	0,32	0,00	0,00	0,65
SR	0,00	0,00	0,00	0,00	0,00	66,79	0,00	0,00	0,00	66,79
FF	0,00	3,93	64,82	808,94	64,16	0,00	3065,55	0,00	60,24	4067,64
WB	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,26	0,00	1,26
AG	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	31,11	31,11
Areas 2020	7,06	78,58	646,24	6128,53	90,02	66,79	6740,45	1,26	97,24	13856,17

*)LUC: Land Use and land cover Unit; FG: Forest Gallery; DDF: Dense Dry Forest; WWS: Woodland; SSS: Tree and shrub savannas; PL: Plantation; FF: Farmlands and Fallow Land; SR: Rocky Surface; WB: Water Body; AG: Agglomeration.

An examination of Table 6 shows that nine (9) land use and land cover classes were observed. All of the classes continued to record the mutations. Naturals formations as tree and shrub savannah, woodlands and wooded savannah have known the important loosed area respectively: 2 498.5 km2 and 4 067.64 km2. While

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the anthropogenic formations as agglomerations, farmlands and fallows have gained area respectively: 66.13 km2 and 2 672.81 km2. In general, the natural formations of the Alibori basin have regressed by undergoing two modes of conversion: savannization and anthrogenization.

3.1.4. Evolution of Deforestation in the Alibori Watershed between 1980 and 2020

Table 7 shows the deforestation rate in the whole forest units between 1980 and 2000 and between 2000 and 2020 on the other.

Table 7. Deforestation Rate of the Alibori Basin between 1980 and 2020

Forests Units	Areas 1980 (km²)	Areas 2000 (km²)	Areas 2020 (km²)	Tdef (%) 1980-2000	Tdef (%) 2000-2020	Tdef (%) 1980-2020
FG	15,72	13,43	7,06			
DDF	816,47	240,95	78,58	1.27	1.26	1.265
WWS	1775,02	2616,37	646,24			
SSS	10332.03	6817.97	6128.53			

*)FG: Forest Gallery; DDF: Dense Dry Forest and SSS: Tree and shrub savannas

The analysis of Table 7 shows that between 1980 and 2000, the Alibori basin has a deforestation rate estimated at 1.27% per year. During the period, the global change rate has estimated to 25.46% of basin area then 16 549.35 hectares lost per year between 1980 and 2000. For the period 2000 to 2020, there was a continuous loss of forest formations with a rate estimated at 1.26% per year (a slight decline). During 2000 to 2020, the global change rate has estimated to 25.27% of basin area, then 12 241.30 hectares lost per year. Globaly Alibori basin has 1.265% as deforest rate between 1980 to 2020. With this average of deforestation rate, the total area of forest lost annually is estimated to 14 395 hectares between 1980 and 2020.

3.1.5. Intensity Analysis of changes between 1980 and 2020

Figure 3 illustrates the intensities of change of the LUCs between 1980-2000 and 2000-2020.

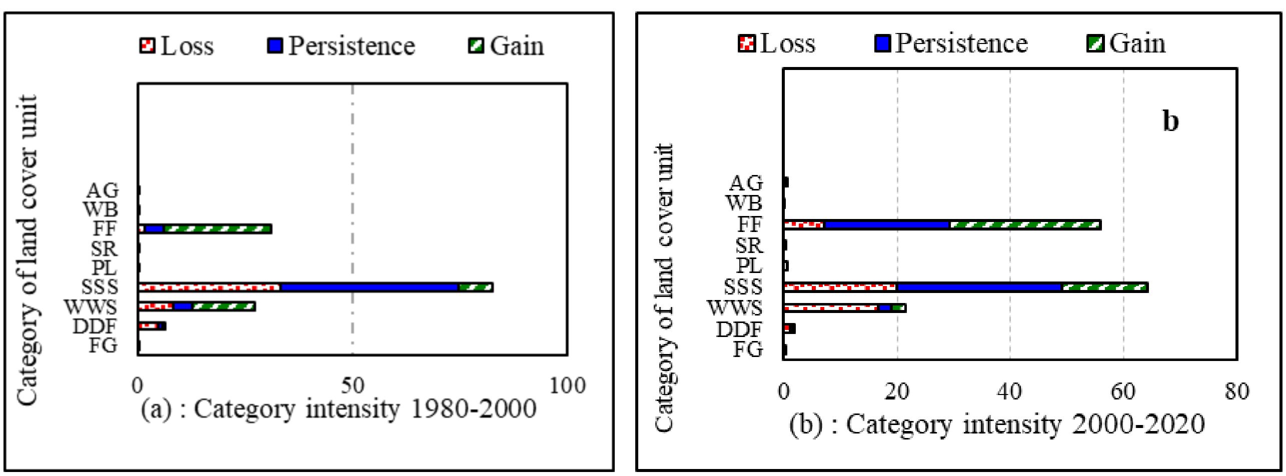

Figure 3. Intensity of Change in Land Use and Land Cover Units between 1980 and 2000

Examination of Figures 3a show that the tree and Shrub Savannah (SSS) have experienced more change with 33% of loss, 41% of stability, and 8% of profit over 82% of the study area between 1980-2000 while during 2000-2020 the same unit have experienced more changes with 20% of loss, 29% of stability, and 15% of profit over 64% of the study area. During 1980-2000, changes were also intense with WWS and FF with respectively 8% and 0.5% of loss, 5% and 4% of stability for 14% and 25% of profit while in period 2000-2020 FF and WWS, with respectively 7% and 17% of loss, 22% and 2% of stability and 27% and 3% of profit. Finally in 1980-2000, the dense dry forests (DDF) with 5% of loss, 1% of stability and no profit while in 2000-2020 DDF were found to have 0.5% of loss, no stability and no profit.

3.1.6. Intensity and speed of land use change between 1980 and 2020

Figure 4 illustrates the speed of change of LUCs between 1980-2000 and 2000-2020.

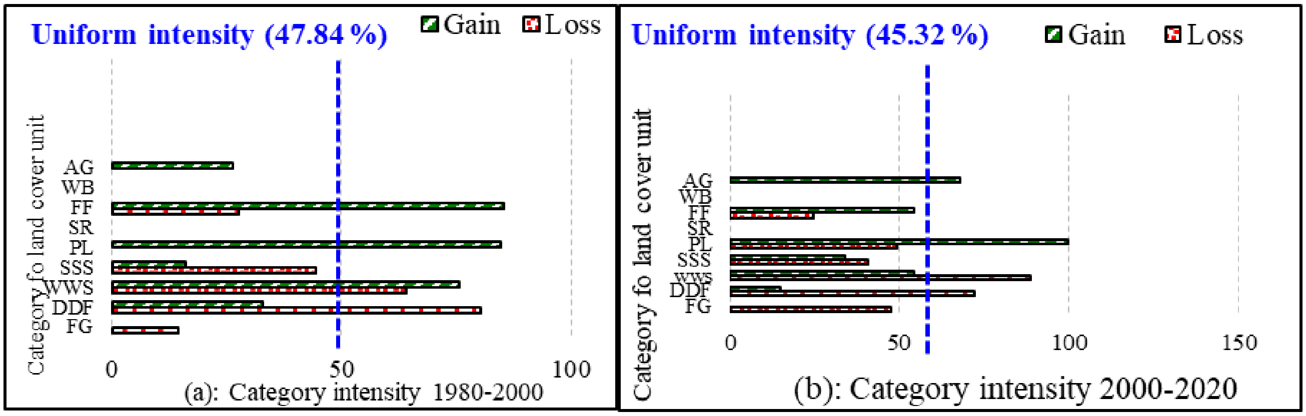

Figure 4. Intensity and speed of changes in land use and land cover units between 1980 and 2000

The observation in Figure 4 shows globally that between 1980-2000 the changes were rapid in four units (DDF, WWS, PL, and FF) while during the period of 2000-2020, the changes have been rapid in six units (forest gallery, dense dry forest, woodlands and wooded savannah, plantations, farmlands and fallows, and agglomerations) out of the nine-land use and land covers in the study area, because their rates of changes are greater than 45.32%. It is therefore perceptible that the natural vegetation types (FG, DDF, WWS, SSS) experienced more rapid or active losses between 1980-2000 with rates of 15%, 33%, 76% and 45% respectively, whereas the anthropogenic units (PL, FF and AG) experienced rapid or active profit with rates of 85%, 85% and 26% respectively. For 2000-2020, is therefore noticeable that the natural vegetation types (forest gallery, dense dry forest, woodlands and wooded savannah and tree and shrub savannah) experienced more rapid or active losses between 2000 and 2020 with respective rates of 47%, 72%, 89%, and 41%, whereas the anthropogenic units (plantations, farmlands and fallows, and agglomerations) experienced rapid or active profit (gain) with rates of 100%, 55%, and 68% respectively. These intensities and rates of change inevitably lead to areas of deforestation in the Alibori basin.

3.2 Discussion

The comparisons of the 1980, 2000, and 2020 land use maps have allowed the assessment of land use and land cover dynamics and deforestation in the Alibori Basin with the global accuracy of image interpretation between 80% and 92%, which reflects the validity of the classification. The result is in accordance with the research of Issiako et al. (2021) who obtained a global accuracy index above 90% for the classification of the images of the forest of upper Alibori (FCAS). The high rates of speeds and intensities of land cover changes between 1980 to 2020 in Alibori basin reflected by rapid gains within anthropogenic formations (plantations, farmlands and fallows and agglomerations) and active losses within natural formations indicate an ongoing deforestation process. These regressive dynamics are explained by the increase in cultivated space and population growth then protected areas are new lands of conquest for farmers because of their fertility. These results are in harmony with those of Boko (2012) who concludes that there is a marked decline in natural vegetation types in favour of an increase in the area of farmlands and fallows in the Alibori basin, and with the results of Issiako et al. (2021) who concludes that there is a 60.21% decrease in natural vegetation types in the FCAS in favour of anthropogenic formations between 2009 and 2020.

The deforestation rate observed in Alibori basin between 1980 and 2020 is 1.265% per year then global change estimated to 25.37% of forests areas. With this average of deforestation rate, the area of forest lost annually is estimated to 14 395 hectares between 1980 and 2020. These results are lower than those of FAO (2010) which estimated that from 1978 to 2010, Benin lost nearly 85% of its dry dense forests and more than 30% of its vegetation cover, and around 50,000 ha of forest are destroyed each year. Other recent studies report a decline in national forest cover, which fell from 31.6% in 1990 to 30.6% in 2015 (Biaou et al., 2019; FAO, 2018). For Djaouga et al. (2021) between 2005 and 2015, the deforestation rate for the entire Alibori department was 1.83% per year, including 0.70% in protected areas. Thus, 14.96% of the total area of the department is affected by deforestation.

The conclusion of this study corroborates the results of the present research. The forests rates approximately equal. But the appreciation of forests areas destroyed in Alibori basin per period showed that the lost area between 1980 - 2000 (16 549 hectares annually) is 1.35% important than 2000-2020 (12 241 hectares annually). This rate is less than the rate of Kouta & Imorou (2019)whose found that the proportion of the area of the forest landscape in the cotton basin of northern Benin experienced a regression of 2.52 times between the periods 2000-2016 and 1986-2000. According to the results of Imorou et al. (2019)the deforestation rate for the whole cotton basin between 2000 and 2015 is estimated at 2.94%. To Ahononga et al. (2020) the deforestation rate is estimated at 2.94% in the Sudanian zone between 2005 and 2015.

Other similar studies in part of the basin, or in the region have shown that the regression of vegetation types is in favour of anthropogenic formations such as farms and fallows, bare soil, and settlements. Based on diachronic studies (Avakoudjo et al., 2014; Djaouga et al., 2021; Issiaka et al., 2016; Issiako & Arouna, 2018; Kouta & Imorou, 2019) respectively in Benin's Park W, Karimama District, Sudano-Guinean Zone, Alibori Upper Basin and Cotton, there is a correlation between the economic activities of the study area and vegetation regression.

4. Conclusion

The mapping of the dynamics of land use and land cover revealed that the basin is increasingly undergoing spatio-temporal changes both at the level of village lands and protected areas. The vegetation types in the Alibori basin are undergoing a regressive dynamic in favour of anthropogenic formations which therefore has led to deforestation. This research has shown that the Alibori Basin is experiencing strong deforestation at the profit of anthropogenic formations. The anthropization of the protected areas is brought about by progressive colonization from village lands and peripheries (between 1980 and 2000) to the interior (between 2000 and 2020). Today, these protected areas are heavily anthropized. The results of this analysis call on the communal and central authorities to develop or implement an inclusive land-use planning policy for all the Alibori basin municipalities.

5. References

Agbanou, T. B., Abdoulaye, D., Bogo, G. A. S. O., Paegelow, M., & Tente, B. (2018). Variabilité pluviométrique et son impact sur le couvert végétal dans le secteur Natitingou-Boukombé au nord-ouest du Bénin. *Afrique Science*, *14*(3), 182–191.

Ahononga, F. C., Gouwakinnou, G. N., Biaou, S. S. H., & Biaou, S. (2020). Vulnérabilité des terres des écosystèmes du domaine soudanien au Bénin de 1995 à 2015. *Bois & Forêts Des Tropiques*, *346*, 35–50.

Akoègninou, A., der Burg, W. J., & der Maesen, L. J. G. (2006). *Flore analytique du Bénin* (Issue 06.2). Backhuys Publishers.

Arouna, O. (2012). Cartographie et modélisation prédictive des changements spatio-temporels de la végétation dans la Commune de Djidja au Bénin: implications pour l'aménagement du territoire. *Doctorat Unique Université d'Abomey-Calavi (Bénin)*.

Arouna, Ousséni, Etene, C. G., & Issiako, D. (2016). Dynamique de l'occupation des terres et état de la flore et de la végétation dans le bassin supérieur de l'Alibori au Benin. *Journal of Applied Biosciences*, *108*, 10543–10552.[Crossref]

Avakoudjo, J., Mama, A., Toko, I., Kindomihou, V., & Sinsin, B. (2014). Dynamique de l'occupation du sol dans le Parc National du W et sa périphérie au nord-ouest du Bénin. *International Journal of Biological and Chemical Sciences*, *8*(6), 2608–2625. [Crossref]

Badou, D. F. (2016). Multi-model evaluation of blue and green water availability under climate change in four-non sahelian basins of the Niger River Basin. *Published PhD Thesis*, 1–155.

Benin, O. F. C. I. N. (2006). Modélisation de la dynamique de l'occupation des terres dans le département des collines au Bénin. *Télédétection*, *6*(4), 305–323.

Biaou, S., Houeto, F., Gouwakinnou, G., Biaou, S. S. H., Awessou, B., Tovihessi, S., & Tete, R. (2019). Dynamique spatio-temporelle de l'occupation du sol de la forêt classée de Ouénou-Bénou au Nord Bénin. *Conférence OSFACO: Des Images Satellites Pour La Gestion Durable Des Territoires En Afrique.*

Bogaert, J., Barima, Y. S. S., Ji, J., Jiang, H., Bamba, I., Mongo, L. I. W., Mama, A., Nyssen, E., Dahdouh-Guebas, F., & Koedam, N. (2011). A methodological framework to quantify anthropogenic effects on landscape patterns. *Landscape Ecology in Asian Cultures*, 141–167.

Boko, G. J. (2012). Trajectoires des changements dans l'occupation du sol: déterminants et simulation, cas du bassinversant de l'Alibori (Bénin, Afrique de l'ouest). *Doctoral Thesis: 291*.

Curtis, P. G., Slay, C. M., Harris, N. L., Tyukavina, A., & Hansen, M. C. (2018). Classifying drivers of global forest loss. *Science*, *361*(6407), 1108–1111.

De Sy, V., Herold, M., Achard, F., Avitabile, V., Baccini, A., Carter, S., Clevers, J. G. P. W., Lindquist, E., Pereira, M., & Verchot, L. (2019). Tropical deforestation drivers and associated carbon emission factors derived from remote sensing data. *Environmental Research Letters*, *14*(9), 94022.[Crossref]

Diouf, J., Mbaye, M. S., Camara, A. A., Dieng, B., Diouf, N., Sarr, M., & Noba, K. (2019). Structure et dynamique de la flore et la végétation de la réserve spéciale botanique de Noflaye (Sénégal). *International Journal of Biological and Chemical Sciences*, *13*(3), 1458–1472.[Crossref]

Djaouga, M., Arouna, O., Zakari, S., Kouta, S., Moumouni, Y. I., Mertens, B., Imorou, I. T., & Thomas, O. (2021). Cartographie de la déforestation dans le département de l'Alibori (nord du Benin) grâce aux images satellitaires SPOT. *Revue Française de Photogrammétrie et de Télédétection*, *223*, 200–216.

FAO. (2010). Evaluation des Ressources Forestières Mondiales. In *Rapport principal*.

FAO. (2018). *La situation des Forêts du Monde.*

Folahan, S. O. N., Dissou, E. F., Akouehou, G. S., Tente, B. A. H., & Boko, M. (2018). Ecologie et structure des groupements végétaux des écosystèmes de la Lama au Sud-Bénin. *International Journal of Biological and Chemical Sciences*, *12*(1), 322–340.[Crossref]

Gibbs, H. K., Ruesch, A. S., Achard, F., Clayton, M. K., Holmgren, P., Ramankutty, N., & Foley, J. A. (2010). Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. *Proceedings of the National Academy of Sciences*, *107*(38), 16732–16737.[Crossref]

Henders, S., Persson, U. M., & Kastner, T. (2015). Trading forests: land-use change and carbon emissions embodied in production and exports of forest-risk commodities. *Environmental Research Letters*, *10*(12), 125012. [Crossref]

Imorou, I. T., Arouna, O., Houessou, L. G., & Sinsin, B. (2017). Contribution of sacred forests to biodiversity conservation: Case of Adjahouto and Lokozoun sacred forests in southern Benin, West Africa. *International Journal of Biological and Chemical Sciences*, *11*(6), 2936–2951.[Crossref]

Imorou, I. T., Arouna, O., Zakari, S., Djaouga, M., Thomas, O., & Kinmadon, G. (2019). Évaluation de la déforestation et de la dégradation des forêts dans les aires protégées et terroirs villageois du bassin cotonnier du Bénin. *Conférence OSFACO: Des Images Satellites Pour La Gestion Durable Des Territoires En Afrique*.

Issiaka, N. T., Arouna, O., & Imorou, I. T. (2016). Cartographie de la dynamique spatio-temporelle des parcours Naturels des troupeaux transhumants dans les Communes de Banikoara et de Karimama au Bénin (Afrique de l'ouest). *European Scientific Journal*, *12*(32), 251–268.[Crossref]

Issiako, D, & Arouna, O. (2018). Dynamique de l'occupation des terres avant et après l'élaboration du plan d'aménagement participatif de la forêt classée de l'Alibori Supérieur au Nord-Benin. *Actes de La Conférence Scientifique Internationale OSFACO: Images Satellitaires Pour Un Meilleur Aménagement Des Territoires et Une Gestion Durable de La Biodiversité*, 193–2010.

Issiako, Dramane, Arouna, O., Soufiyanou, K., Imorou, I. T., & Tente, B. (2021). Prospective mapping of land cover and land use in the classified forest of the upper alibori based on satellite imagery. *Geoplanning: Journal of Geomatics and Planning*, *8*(2), 115–126. [Crossref]

Kissinger, G. M., Herold, M., & De Sy, V. (2012). *Drivers of deforestation and forest degradation: a synthesis report for REDD+ policymakers.*

Kouta, S., & Imorou, I. T. (2019). Forest landscape dynamics in the cotton basin of North Benin. *International Journal of Forest, Animal and Fisheries Research*, *3*(6).

Le Barbé, L., Alé, G., Millet, B., Texier, H., Borel, Y., & Gualde, R. (1993). Les ressources en eaux superficielles de la République du Bénin. *Monographies Hydrologiques ORSTOM*, *11*.

Mama, A., Sinsin, B., Cannière, C. de, Bogaert, J., & others. (2013). Anthropogenic effects and landscape dynamics in the Soudanian zone of North Benin. *Tropicultura*, *31*(1), 78–88.

DOI: 10.14710/geoplanning.10.1.11-22

Ousséni, A., Ismaila, T., Paul, D. C., Brice, S., & others. (2011). Comparative analysis of local populations' perceptions of socio-economic determinants of vegetation degradation in sudano-guinean area in Benin (West Africa). *International Journal of Biodiversity and Conservation*, *3*(7), 327–337.

Rudel, T. (2013). *Defensive environmentalists and the dynamics of global reform*. Cambridge University Press.

Vissin, E. (2007). *Impact de la variabilité climatique et de la dynamique des états de surface sur les écoulements du bassin béninois du fleuve Niger*. Université de Bourgogne.