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Spatio-temporal dynamics and habitat fragmentation within a central region of Togo

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Abstract

This study assessed the spatial change processes underway in the landscape of Centre-Togo where the production of charcoal and purely extensive and ancestral agricultural activities are taking a worrying rise. The data used are mainly Landsat satellite images (30 m resolution) of 1987, 2000, and 2017 year's. The supervised classification by maximum likelihood and the calculation of landscape metrics made it possible to quantify the dynamics of land use and to detect the spatial transformations that have occurred over 30 years, using Qgis 2.18 and Fragstat 4.2 softwares. From a diachronic analysis of land use maps, it appears that between 1987 and 2017, dense dry forests, clear forests and wooded savannahs decreased by 2.71% and 2.97% respectively. Unlike these plants grouping, tree-shrub savannahs, mosaics of farm-fallow-agroforestry parks and urban areas have progressed respectively by 4.27%, 393.77% and 192.24%. From 1987 to 2000 at the landscape level, the number of fragments (NP) and patch density (PD) increased for the class of clear forests and wooded savannahs, farm-fallow-agroforestry parks and human settlements, whereas at the class level, it decreased for tree-shrub savannas. The spatial transformations underway are the fragmentation, isolation, dissection and perforation of natural vegetation classes. Faced with this observation, it is essential to define development and management plans for plant communities.

Keywords: Biodiversity conservation, connectivity, fragmentation, landscape metrics, patch, Togo

Introduction

The spatial and structural characteristics of tropical forests are constantly being altered under the effect of natural hazards, urbanization interventions imposed by soaring demography (Barima et al., 2009; Weaver, 2013; Sadda et al., 2016). These structural modifications require changes in land use, degraded forest areas, lead to the loss of biomass and accentuate deforestation (Sist et al., 2012; Badji et al., 2014; Koné et al., 2014). The inadequate use of natural resources generates environmental problems (floods, landslides, soil erosion and compaction, deforestation, etc.). These recurring problems, coupled with the negative effects of climate change, lead to the loss of the resulting natural habitats and their biodiversity, forest emisson and the rise in temperatures.

Globally, there has been a decline in terrestrial forest cover, which decreased from 31.6% in 1990 to 30.6% in 2015 (FAO, 2018). The degradation and the deforestation are a source of imbalances in forest ecosystems and prevent the sustainable management of their resources (Sist et al., 2011). In sub-Saharan Africa, natural forests are subject to the same types of pressure, going from 30.6% to 27.1% between 1990 and 2015 (FAO, 2018), thus compromising their sustainability

(Fahrig, 2003). In a context of sustainable management of forest resources, several initiatives and applications are available at the national and international levels (OGM, 2014). Despite all these initiatives, it is clear that the implementation remains ineffective.

In Togo, the forest cover is for the most part degraded and fragmented (Adjonou et al., 2010b; Folega et al., 2014; Folega et al., 2020) despite its forest cover estimated at 24.24% (MERF, 2016). In the specific case of forest lands in the Central Region, there is strong pressure on forest lands due to the urbanization process and the extension of agricultural areas. The human population growth coupled to the degradation of productive soils and overgrazing cause strong fragmentation of the landscape with the consequence of a very significant reduction of forest lands, the loss of habitat and the disappearance of certain species. This seriously affects the productivity of ecosystems and agrosystems, and thus reduces the income of already vulnerable rural populations. All this inexorably contributes to the degradation of natural plant formations granting to secondary formations, bare soils, and infrastructure (Atsri et al., 2018; Diwediga et al., 2018; Kaina et al., 2018).

In a world where natural resources are finite, but where basic human needs are unlimited, it is urgent to consider their sustainable use. Temporal changes in land use remain an equally important component in achieving the Sustainable Development Goals (Özşahin & Atasoy, 2014) and current land use is essential for any planning (Gülersoy, 2014). Unfortunately, to date, there is a lack of information at the regional level on the evolution of the landscape of Central Region (the fragmentation of the vegetation cover, the dynamics of the landscape and the state of the vegetation) involving the remotely sensed data including Landsat images, which is the most economical and practical solution (Oszwald et al., 2011). some researches on the subject at the prefecture and / or protected area scale were achieved in recent past (Adjonou et al., 2010a; Koumoi et al., 2013; Folega et al., 2015; Atsri et al., 2018). However, there are very few studies devoted to the analysis and assessment of landscape ecology in the Central region. With increasingly rapid changes in land use forms in response to strong population growth, there is necessity to understand through landscape indicators how the landscapes are impacted by human activities in the future. Consequently, sustainable policies of rural and peri-urban territories in Centre-Togo require a better knowledge of the current states of the different land use units.What is the land use dynamics of the Central Region over the time series from 1987 to 2017 in relation to human threats? What are the spatial indices responsible for changes in land use and changes in land use units? Answers to these questions will provide basic scientific information that can guide the sustainable management of this anthropized landscape which is highly dependent on the ancestral farming practices of the population.

The study aims to improve knowledge of past and current dynamics in land use and land use change in the Central Region using satellite data. Specifically, it: (i) assess the land use dynamics of 1987-2017, and (ii) characterize the spatial structure of the landscapes of 1987, 2000 and 2017 in the Central region of Togo.

Materials and methods

Study area

Togo is a West African country of 56,600 km^2. It is located between 6°06'-11°08 'North latitude and 0°09'-1°49' East longitude. It is subdivided into five economic and administrative regions which are Maritime, Plateaux, Centrale, Kara and Savanes. Located in central Togo, the Central Region covers an area of approximately 13,182 km², between parallels 8° and 15° north latitude and 0° 15' and 1° 35' east longitude. It is the second-largest economic region in Togo after the Region of Plateaux with a very representative ethnic diversity that derives its income from agriculture, breeding, hunting and trade. Administratively, this region has five (5) prefectures (Figure 1). It is bordered to the North by the Kara Region, to the South by the Plateaux Region, to the East by Benin and to the West by Ghana. The Central Region is crossed by three ecological zones (Ern, 1979), including ecological zones II, III, and IV of Togo (Figure 1).

The relief is made up of an alternation of plains, valleys and plateaus dominated by old rugged massifs with fairly contrasting aspects which vary according to the ecological zones. The main soils encountered are: tropical ferruginous soils, vertisols, ferralitic soils, less developed soils and hydromorphic soils (Lamouroux, 1969). The climatic regime is of the Sudano-Guinean type. The variations vary between 1000 mm and 1400 mm. It belongs to the Sudanese-Guinean type transition zone (White, 1986). There are semi-humid forests, dense forests, dry forests, clear forests and wooded savannas with Isoberlinia spp, etc. Gallery forests line the rivers. Vegetation is strongly threatened by agricultural pressure, excessive deforestation for energy and timber needs, annual bush fires and migratory flows of transhumants.

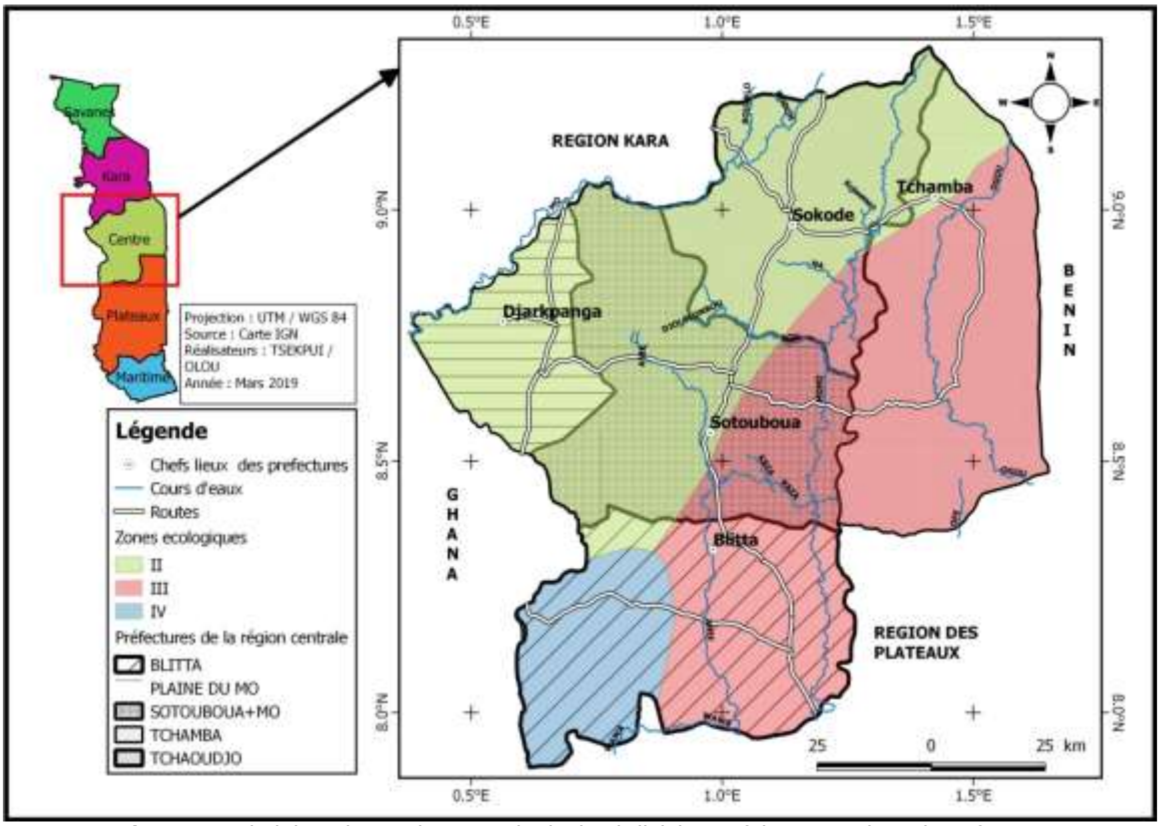

Figure 1: Administrative and agroecological subdivisions of the Central Region of Togo

Data collection

Satellite data collection

High-resolution satellite data (30 m) from LandSAT / USGS (figure 1) sensors from 1987 (Landsat 5, TM), 2000 (Landsat 7, ETM +) and 2017 (Landsat 8, OLI-TIRS) were used to analyse the land use changes. These satellite images were downloaded free of charge from Earthexplorar/USGS websites via https://earthexplorer.usgs.gov/. The downloaded images had undergone atmospheric corrections using the DOS1 (Dark Object Subtraction 1) correction of QGIS 2.18. The DOS1 correction improves the estimate of the reflectance of the land surface on satellite images (Congedo, 2016) to facilitate their interpretation. The choice of images was based on four (4) criteria: spatial extent, resolution, years and seasons of shooting (Dimobe et al., 2017). These Landsat-type images had been used successfully in previous research for mapping land use dynamic (Oszwald et al., 2011; Dimobe et al., 2017).

Ground control data collection

The ground control points (figure 2) made using a GPS (Global Positioning System) receiver with 5 m precision is an essential step in any remote sensing work. It makes it possible to inform the successions of the landscape components. On a land use map of the 2017 Landsat 8 image, we generated ground truth points according to the spectral signatures to be verified along the paths travelled in order to refine the classification of land use units (Dimobe et al., 2017).

Landscape metric

The study of the spatiotemporal dynamics of land cover is not limited only to the analysis of classification from multi-date images. It can be completed and enriched by the analysis of landscape metrics to quantify and qualify the human impact on landscape forms (Elmi Ali, 2016). Numerous landscape indices were used to quantify the structure and organization of a landscape (Skupinski et al., 2009). To quantify the landscape structure of Central Togo, the diagnosis focuses land use and land cover change. At the global scale of the landscape and at the scale of the patch, of the same category as the patch, the indices were calculated to validate the detection of the changes observed between the three dates (1987, 2000 and 2017). These indices are constructed from the combination of variables that characterize the distribution of different land use modes and the complexity of the spatial arrangement in space.

Data Analysis

Image classification

The ISODATA (Iterative Self-Organizing Data Analysis Technique) clustering algorithms, thanks to its power of

further refinements in terms of cleavages and mergers of similar pixel groups, were retained for pre-classification (Jensen & Lulla, 1987). The pre-classification is made at a convergence threshold of 95% and at a maximum of iterations of 10. The thematic classes generated made it possible to collect ground truths, dendrometric, ecological and floristic data. Then, the method known as directed classification with the maximum likelihood algorithm (Folega et al., 2014; Polo-Akpisso et al., 2016) was used for the refinement and validation of classified Landsat images. This algorithm requires the use of a large number of ground control points and the consideration of a maximum training area called ROI (Region Of Interest) in the QGIS 2.18 software. Its advantage is that it provides for each pixel, in addition to the class to which it has been assigned, an index of certainty linked to this choice (Toko Mouhamadou et al., 2012). The number of land use form classes obtained after this post-classification have undergone treatments such as filtering and recoding. The results adjusted by the data of field truths made it possible to group together certain classes to define and prioritize the land use units according to the methodological approach of the classification of land uses and typologies of plant formations in Togo (Anonymous, 2015) adopted for the national forest inventory. For the image of Landsat 8 of the year 2017, the defined land use units amount to six (6) which are dense dry forests and galleries, clear forests-wooded savannahs, wooded-shrub savannahs, farms-fallow and agroforestry parks, water bodies and urban areas. From the thematic dataset collected in the field and the Landsat 8 image from 2017, a mapping of land use for the years 2000 and 1987 was carried out. And, by spectral correspondence, the images of 1987 and 2000 were processed. The statistics of land cover classes using an Excel spreadsheet followed by the diachronic analysis (progression or decline) of each form of land use of 1987, 2000 and 2017 were calculated. These data make it possible to understand the landscape changes due to the different forms of land use in the said region.
The variation in the area of a form of land use between two dates (years) given by $\Delta U = U2-U1$ makes it possible to appreciate the direction of change between the two dates:

if $\Delta U = 0$, we conclude that there is stability;
if $\Delta U < 0$, we conclude that there is a decrease in this unit;
if $\Delta U > 0$, there is an extension of this unit.

The rate of change (Ta) of a given unit of occupation between two years X and Y, expressing the proportion of each unit of natural vegetation that changes annually is calculated from the following formula (Abba, 2013):

$$Ta = [((SY - SX)\ /SX)\ * 100]\ /I \qquad (1)$$

Where, SX = area of a vegetation unit in year X, SY = area of the same vegetation unit in year Y, and I = number of years between years X and Y.

The level of deforestation was evaluated from the annual deforestation rate "Defb" calculated by the formula proposed by Puyravaud (2003):

$$Defb = \frac{1}{t2-t1} ln\left(\frac{A2}{A1}\right) \qquad (2)$$

Where t2-t1 represents the time interval in which we want to assess changes in land use. A1 and A2 represent the sum of the proportion of natural plant formations (dense dry forests and galleries, clear forests and wooded savannahs, wooded and shrub savannahs) of each year.

Accuracy assessment

To assess the accuracy assessment of the cartographic products, the data from the ground control points were compared with the classified data (figure 2). The accuracy index of the vegetation map for 2017, 2000 and 1987 is assessed using a confusion matrice or contingency table obtained from ground truth data records and representative of each land use class. Based on this confusion matrice we calculated errors of omission (EO), commission errors (EC), class purity indices (CPI) and map validity indices (CVI). Two levels of precision were calculated: the overall precision which characterizes the proportion of well-classified pixels and the Kappa coefficient which characterizes the ratio between the well-classified pixels and the total of the probed pixels. The Kappa coefficient provides information on the agreement between the data to be classified and the reference data (Congalton, 1991).

Landscape metrics

In order to calculate landscape metrics, the land cover maps of 1987, 2000 and 2017 were imported into the Fragstat 4.2 software (McGarigal & Marks, 1995; McGarigal, 2002; Germaine & Puissant, 2008) and the following metrics were quantified.

Class level metrics

To assess landscape composition we calculated:

(a) Number of patches (NP) which provides information on the fragmentation of a class between two periods. The increase in the number of patches of a class may be due to the fragmentation of that class (Davidson, 1998).
(b) Patch density (PD): equals the number of patches of land use class (ni) divided by the total landscape area (A) (in m^2).

$$PD = \frac{ni}{A}(10000) * (100) \qquad (3)$$

(c) Total area (CA) of a class j (in ha) is obtained by the formula:

$$CA = \sum_{j=1}^{n} a_{ij}\ (\frac{1}{10000}) \qquad (4)$$

(d) Class percentage of landscape (PLAND). PLAND measures the proportion of the landscape occupied by land use types. PLAND gives an idea of the dominance of types of occupation

$$PLAND = Pi = \frac{\sum_{j=1}^{n} a_{ij}}{A} * 100 \quad (5)$$

(e) Largest Patch Index (LPI): LPI measures the area of the largest patch for each type of land use. Large values of LPI indicate a strong dominance of a single patch.

$$LPI = \frac{\max(aij)}{A} * (100) \quad (6)$$

Where aij = area (m²) of the i-th patch of class j and A = total landscape area (m²).

(f) Patch cohesion index (COHESION)

$$COHESION = \left[1 - \frac{\sum_{j=1}^{m} Pij}{\sum_{j=1}^{m} Pij\sqrt{aij}}\right]\left[1 - \frac{1}{\sqrt{A}}\right] * (100) \quad (7)$$

Where Pij = perimeter of the i-th patch of class j (in terms of the number of cells surface), aij = the area of the i-th patch of class j (in terms of the number of cells) and A = total number of cells in the landscape.

Landscape level metric

The selected metrics for the analysis of the landscape configuration are:

(a) Number of patches (NP)
(b) Patch density (PD)
(c) Largest Patch index (LPI)
(d) Shannon's Diversity Index (SHDI)

$$SHDI = -\sum_{i=1}^{m} (P_i lnP_i) \quad (8)$$

SHDI takes into account the number of elements in the landscape as well as their relative abundance. The value of SHDI will depend on the number of classes present, their relative proportions (Pi = aij/A) and the base of the logarithm.
(e) Landscape total area (TA) occupied by the class j (in ha) was calculated according to the equation below where A was the area of the i-th patch in the class j:

$$TA = \sum_{i=1}^{n} A_{ij} \quad (9)$$

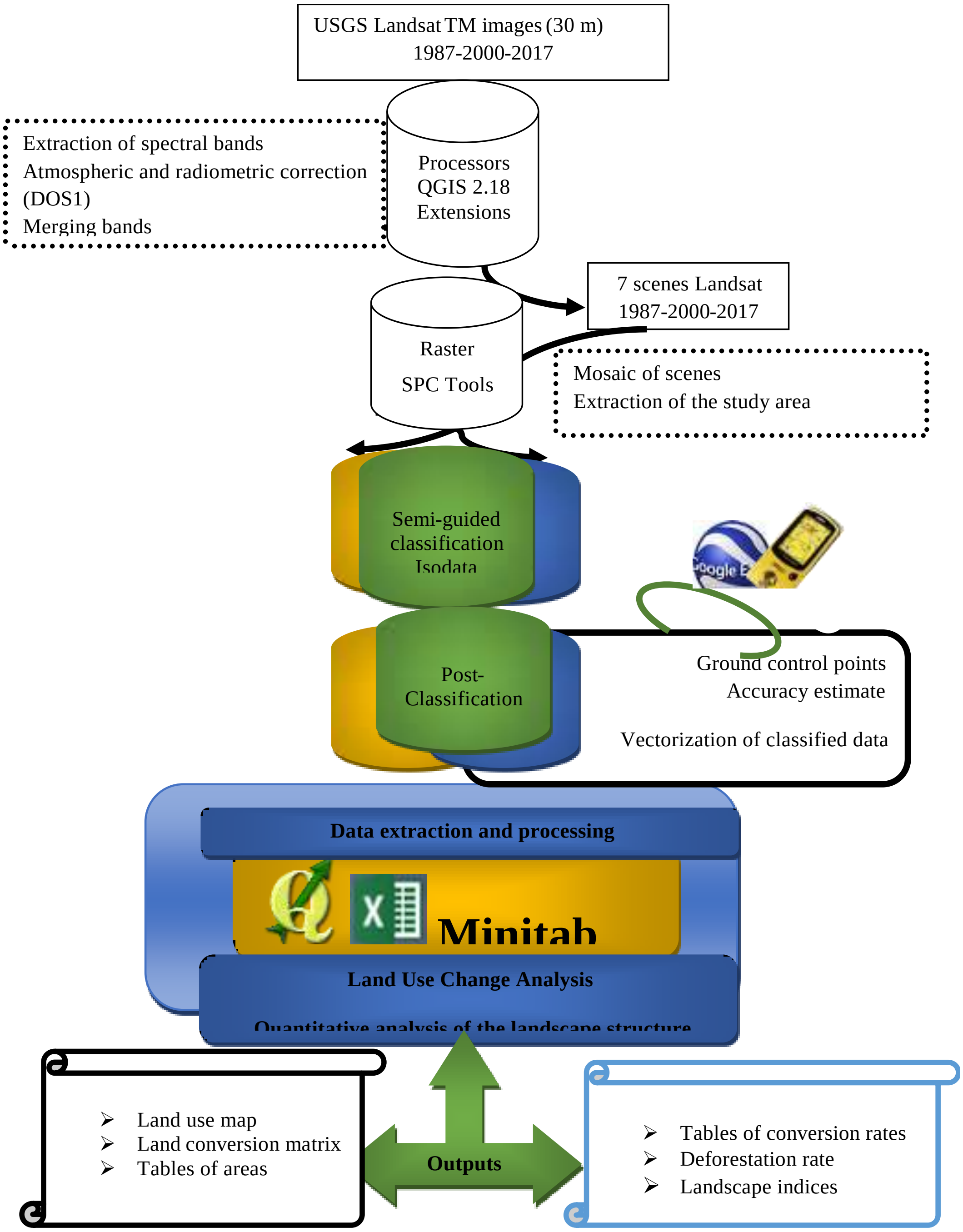

Figure 1: General methodological approach

Results

Land use and land cover dynamics

Mapping of land use forms in the study area

The evolution of the different forms of land use and occupation as well as the modalities of transitions between the different thematic classes from one year to another were analysed successively from 1987 to 2000, from 2000 to 2017 and from 1987 to 2017. The dynamics of plant formations and other units of land occupation and use from 1987 to 2017 are synthesized by the average annual rate of spatial expansion or regression. The individual class area and change statistics for the three study dates are summarized in table 1. It appears that the central region has become too anthropized with many changes and mutations within land occupation units. The analysis of the transition matrice of the land use maps developed (Figure 2, Table 1) showed a regression of all natural plant formations in Centre-Togo and this regression is more marked by the degradation of dense dry forests and galleries, clear forests-wooded savannahs, tree-shrub savannahs for the benefit of agrarian and human settlements.

In 1987, dense dry forests and galleries (625046.40 ha or 47.68%), and clear forests and wooded savannahs (603 744.35 ha or 46.06%) dominated the mapped area. Tree-shrub savannahs and farms-fallows and agroforestry parks respectively represented 73,940.63 ha (5.64%) and 8002.46 ha (0.61%) of land use and land cover change. Human settlements and water bodies were almost invisible over the entire area due to the heavy vegetation cover.

In 2000, dense dry forests and galleries (218,579.59 ha or 16.68%), and clear forests and wooded savannahs (253,414.62 ha or 19.33%) decreased in favour of tree-shrub savannahs (661,186.19 ha or 50.44%), farms-fallows and agroforestry parklands (176,762.27 ha or 13.48%) and human settlements (875.40 ha or 0.07%).

In 2017, there was a sharp increase in the area of farms-fallows and agroforestry parks (953,332.31 ha or 72.73%) throughout the region at the expense of dense dry forests and galleries (117,809.72 ha or 8.99%), clear forests and wooded savannahs (66,234.75 ha or 5.05%) and tree-shrub savannahs (168,643.01 ha or 12.87%).

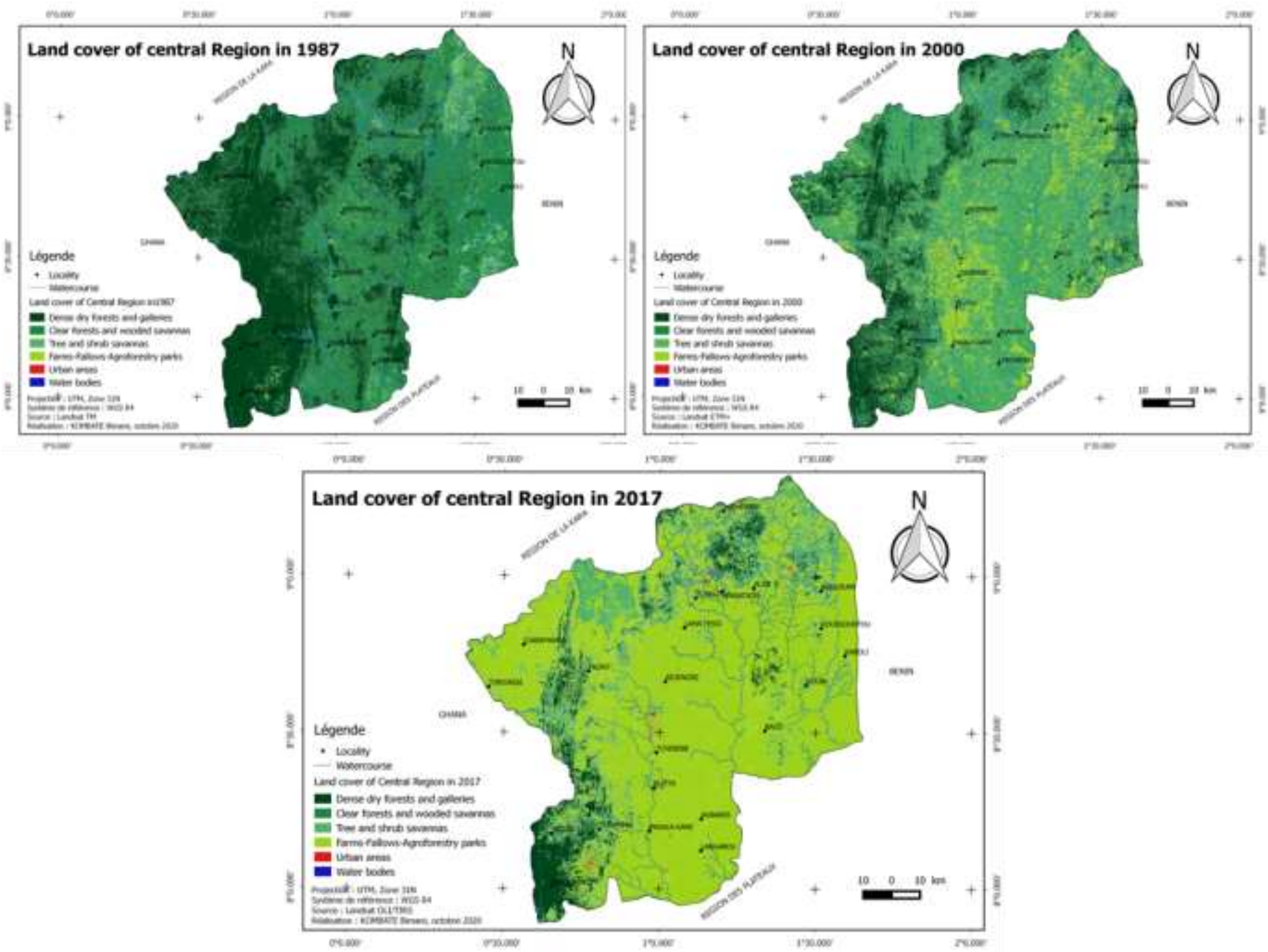

Figure 2: Land cover of Centrale Region in 1987, 2000 and 2017

Table 1: Spatio-temporal dynamics of land use in 1987, 2000 and 2017

	LULC (1987)		LULC (2000)		LULC (2017)		Evolution rate (%)			Deforestation rate (%)		
	Area (ha)	Proportion (%)	Area (ha)	Proportion (%)	Area (ha)	Proportion (%)	1987-2000	2000-2017	1987-2017	1987 - 2000	2000 - 2017	1987 - 2017
DfG	625 046.40	47.68	218 579.59	16.68	117 809.72	8.99	-5.00	-2.71	-2.71	1.07	6.87	4.36
CfWs	603 744.35	46.06	253 414.62	19.33	66 234.75	5.05	-4.46	-4.34	-2.97			
TSS	73 940.63	5.64	661 186.19	50.44	168 643.01	12.87	61.09	-4.38	4.27			
FFA	8 002.46	0.61	176 762.27	13.48	953 332.31	72.73	162.22	25.84	393.77			
Ua	81.60	0.01	875.40	0.07	4 787.43	0.37	74.83	26.29	192.24			
Wb	3.17	0	0.55	0	11.40	0	-6.36	116.40	8.64			
Total	1310818.62	100.00	1310818.62	100	1310818.62	100						

LULC: Land use/land change; DfG: Dense dry forests and galleries; CfWs**:** Clear forests or wooded savannas; TSS: Tree savannas or shrub savannas; FFA: Farms-Fallow and Agroforestry Parks, Ua: Urban area ; Wb: Water bodies.

Accuracy assessment

Overall accuracy is important in assessing classification. For the three classified satellite images, the overall accuracy obtained are respectively 77.35% (1987), 84.04% (2000) and 87.84% (2017) with the Kappa coefficient greater than 70% for the three dates (Table 2). This means that that the classification is good.

Table 2: Summary of the accuracy assessment of the classifications images

	Products	Global précision (%)	Coef Kappa (%)
Landsat Imagery	RC_2017_30m	87.84	83.66
	RC_2000_30m	84.04	78.86
	RC_1987_30m	77.35	70.21

Spatiotemporal quantification of deforestation and the rate of change of LULC

The rate of deforestation of natural plant formations in the whole region is 1.07% between 1987 and 2000, 6.87% between 2000 and 2017 and 4.36% between 1987 and 2017. The rates of change in land use for the periods from 1987 to 2000, 2000 to 2017 and from 1987 to 2017 are presented in Table 1. The analysis of this table shows that in 13 years (1987 to 2000), farms-fallow and agroforestry parks, human settlements and tree-shrub savannahs have experienced annual spatial growth of 162.22%, 74.83% and 61.09% respectively. On the other hand, the dense dry forests and galleries, the clear forests and wooded savannahs experienced an annual spatial regression of 5.00% and 4.46% respectively.

In the second diachrony (2000-2017), the farms-fallows and agroforestry parklands and human settlements experienced an annual spatial progression of 25.84% and 26.29% respectively. In contrast, the dense dry forests and gallery forests, clear forests and wooded savannahs, and the tree-shrub savannahs fell annually respectively by 2.71%, 4.34% and 4.38%.

The changes in land occupation and use over the 30 years (1987-2017) highlight an increasing gain in anthropogenic formations to the detriment of natural stands. Thus, there is an annual spatial progression of 393.77% for farms-fallows and agroforestry parks, 192.24% for human settlements, 8.64% for water bodies and 4.27% for tree-shrub savannahs. During the same period, the dense dry forests and galleries, the clear forests and wooded savannahs fell annually respectively by 2.71% and 2.97%.

Change area matrices of land cover

Tables 3, 4 and 5 respectively present the change area matrices of land cover between 1987 and 2000, 2000-2017 and 1987-2017 with their rate of change. The analysis of the change area matrices of land cover showed that the landscape of central Togo has undergone major changes and that all plant formations are exploited for agricultural purposes.

During the period 1987 to 2000, the area remained unchanged (Table 3) is 198,406.94 ha (31.74%) for dense dry forests and galleries, 151,098.53 ha (25.03%) for clear forests-wooded savannahs, 38,800.77 ha (52.48%) for tree-shrub savannahs. All land use and land cover change (LULC) has undergone changes. Significant changes have taken place at the level of urban areas 95.73% followed by water bodies 82.72%, clear forests-wooded savannahs 74.97% and dense dry forests and gallery forests 68.26%.

Between 2000 and 2017, the area that remained unchanged (Table 4) was 94,220.39 ha (43.11%) for dense dry forests and galleries, 29,197.39 ha (11.52%) for clear forests-wooded savannahs, 52,562.84 ha (7.95%) for tree-shrub savannahs and 165,952.877 ha (93.89%) for farms-fallow and agroforestry parks. All LULC have also undergone changes and mutations. Significant changes have taken place at the level of urban areas 95.18%, followed by tree-shrub savannahs 92.05% and clear forests-wooded savannahs 88.48% and dense dry forests and galleries 56.89%.

In 30 years (1987-2017), there have been major changes within the various LULC (Table 5). Significant changes are observed in clear forests-wooded savannahs 98.00% followed by tree-shrub savannahs 84.02%, dense dry forests, and gallery forests 82.61%.

Table 3: Change area matrices of land cover classes in 1987-2000 (area in ha)

LULC	DfG	CfWs	TSS	FFA	Ua	Wb	Grand Total 1987
DfG	**198 406.94**	95 064.27	278 523.61	52 669.44	382.14		625 046.40
CfWs	14 439.46	**151 098.53**	339 766.79	98 050.46	389.11		603 744.35
TSS	5 606.96	6 216.42	**38 800.77**	23 237.72	78.77		73 940.63
FFA	126.23	1 032.04	4 095.03	**2 727.27**	21.90		8 002.46
Ua		3.36		74.75	**3.48**		81.60
Wb				2.62		**0.55**	3.17
Grand Total 2000	218 579.59	253 414.62	661 186.19	176 762.27	875.40	0.55	1 310 818.62
Change in LULC (ha)	426 639.46	452 645.82	35 139.86	5 275.19	78.12	2.62	
Rate of change in LULC (%)	68.26	74.97	47.52	65.92	95.73	82.72	

LULC: Land use/land change; DfG: Dense dry forests and galleries; CfWs**:** Clear forests or wooded savannas; TSS: Tree savannas or shrub savannas; FFA: Farms-Fallow and Agroforestry Parks, Ua: Urban area; Wb: Water bodies.

Table 4: Change area matrices of land cover classes in 2000-2017 (area in ha)

LULC	DfG	CfWs	TSS	FFA	Ua	Wb	Grand Total 2000
DfG	**94 220.39**	29 858.23	32 517.97	61 841.25	141.06	0.70	218 579.59
CfWs	21 229.50	**29 197.39**	77 160.28	124 471.385	1 346.84	9.23	253 414.62
TSS	1 928.88	5 702.33	**52 562.84**	600 297.666	694.06	0.41	661 186.19
FFA	430.51	1 473.56	6 341.55	**165 952.877**	2 563.26	0.51	176 762.27
Ua	0.45	3.22	60.38	769.14	**42.21**		875.40
Wb						**0.55**	0.55
Grand Total 2017	117 809.72	66 234.75	168 643.01	953 332.31	4 787.43	11.40	1 310 818.62
Change in LULC (ha)	124 359.20	224 217.23	608 623.35	10 808.88	833.19	0	
Rate of change in LULC (%)	56.89	88.48	92.05	6.11	95.18	0.00	

LULC: Land use/land change; DfG: Dense dry forests and galleries; CfWs**:** Clear forests or wooded savannas; TSS: Tree savannas or shrub savannas; FFA: Farms-Fallow and Agroforestry Parks, Ua: Urban areas; Wb: Water bodies.

Table 5: Change area matrices of land cover classes in 1987-2017 (area in ha)

LULC	DfG	CfWs	TSS	FFA	Ua	Wb	Grand Total 1987
DfG	108 678.68	50 407.79	107 029.91	357 669.45	1 256.14	4.44	625 046.40
CfWs	6 433.67	12 077.55	48 369.61	534 482.35	2 376.12	5.05	603 744.35
TSS	2 346.47	3 356.67	11 817.47	55 905.63	514.13	0.25	73 940.63
FFA	350.64	392.45	1 425.57	5 259.34	574.47		8 002.46
Ua	0.25	0.19	0.19	14.40	66.56		81.60
Wb	0.01	0.09	0.27	1.15		1.65	3.17
Grand Total 2017	117 809.72	66 234.75	168 643.01	953 332.31	4 787.43	11.40	1 310 818.62
Change in LULC (ha)	516 367.73	591 666.80	62 123.16	2 743.12	15.03	1.53	
Rate of change in LULC (%)	82.61	98.00	84.02	34.28	18.42	48.13	

LULC: Land use/land change; DfG: Dense dry forests and galleries; CfWs**:** Clear forests or wooded savannas; TSS: Tree savannas or shrub savannas; FFA: Farms-Fallow and Agroforestry Parks, Ua: Urban areas; Wb: Water bodies.

Landscape Quantitative Analysis

The landscape is a very dynamic element in constant evolution. The analysis of spatial structure indices (Table 6) at the level class between 1987 and 2017 reveals that the number of fragments (NP) and the patch density (PD) increased for the class of human settlements and decreased for the tree-shrub savannahs. However, a strong increase in patches and in the patches' density was observed between 1987 and 2000 for clear forest-wooded savannahs and farms-fallows and agroforestry parklands to finally decrease slightly between 2000 and 2017. The number of fragments and the patch density for the class of dense dry forests and gallery forests decreased 1987-2000 to finally experience a strong fragmentation of the initial patch between 2000 and 2017. During these three decades, there was a degradation of the natural vegetation marked by the process of spatial transformation. There was merging, creating new patches, increasing or reducing the size of existing fragments. This degradation trend is confirmed by the reduction in the proportion of the landscape occupied by vegetation classes (PLAND), the decrease in the rate of the largest patch index (LPI) of natural formations (30.40% in 1987 to 0, 02% in 2017 for the class of dense dry forests and gallery forests and from 36.87% in 1987 to 1.29% in 2017 for the class of clear forests-wooded savannahs) and their total area (CA) with consequences of increasing the PLAND, LPI (0.002% in 1987 to 40.70% in 2017 for the class of urban areas) and the total area for anthropized formations showing an expansion of these forms of land use during this period. Tree-shrub savannahs compacted between 1987 and 2000 and a single patch occupied 39.74% of the landscape (LPI) in 2000. The effect of human activities on the state of the different types of plant formation is manifested by the degree fragmentation. The degree of occupation of Farms-fallow-agroforestry parks (72.73%) in 2017 shows the importance of man's influence on this landscape through socio-economic activities. The patch cohesion index (COHESION) generally showed the decrease in structural connectivity between vegetation classes. This structural connectivity between vegetation classes is closely related to the fragmentation and the degree of isolation of habitats.

At the overall landscape level of the Central Region (Table 7), the period 1987-2000 is marked by the increase in the number of patches (NP), the density of patches (PD) and the Shannon's diversity index. (DIV_SH). During the same period, the largest patch index (LPI) experienced a decrease in its area from 67.91% to 49.45%. This indicates fragmentation followed by an increase in the heterogeneity of the landscape with perforation or fragmentation of the initial patch between 1987 and 2000.

Results showed a decrease in the number of patches from 2000 to 2017, the patch density and the Shannon's diversity index indicating a simplification of the structure through the reduction of heterogeneity. The largest patch index (LPI) experienced a decrease from 49.95% to 43.92%. This trend towards the homogenization of the landscape is explained by the strong expansion of farms-fallows and agroforestry parklands.

Table 6: Landscape metrics at the class level for 1987, 2000 and 2017

	DfG			CfWs			TSS			FFA			Ua			Wb		
Metrics	**1987**	**2000**	**2017**	**1987**	**2000**	**2017**	**1987**	**2000**	**2017**	**1987**	**2000**	**2017**	**1987**	**2000**	**2017**	**1987**	**2000**	**2017**
NP	39 532	29 315	50 990	45 492	61 251	55 133	42 550	29 382	2 453	8 126	40 159	18 114	28	644	13 153	4	3	3
PD	3.016	2.236	3.89	3.471	4.673	4.206	3.246	2.24	0.18	0.62	3.06	1.38	0.002	0.04	1.003	0.000	0.00	0.000
CA	625 046.40	218 579.59	117 809.72	603 744.353	253 414.621	66 234.74	73 940.63	661 186.19	168 643.01	8 002.45	176 762.27	953 332.31	81.596	875.39	4 787.42	3.173	0.54	11.395
PLAND	47.68	16.67	8.987	46.06	19.330	5.05	5.62	50.44	12.86	0.61	13.48	72.72	0.006	0.06	0.36	0.000	0.00	0.001
LPI	30.40	5.17	0.021	36.87	2.174	1.28	0.61	39.74	0.01	0.01	2.34	1.90	0.002	0.004	40.70	0.000	0.00	0.001
COHESION	99.79	99.70	99.62	99.78	99.71	99.52	99.55	99.79	99.67	98.80	99.68	99.81	88.85	96.53	98.47	43.82	35.04	70.31

Table 7: Landscape metrics at landscape level

	TA	NP	PD	LPI	DIV_SH
1987	1 310 818.62	135 732	10.35	67.91	0.90
2000	1 310 818.62	160 754	12.26	49.45	1.26
2017	1 310 818.62	139 846	10.67	43.92	0.88

Discussion

Spatio-temporal dynamics of land use

The diachronic analysis of Landsat images from 1987, 2000 and 2017 made underline biophysical and anthropogenic processes shaping the quantitative and qualitative changes between the different land use classes in Centre-Togo. By referring to the values of the overall precision between 77.35% and 87.84% and the Kappa coefficient greater than 70% for the three dates, the classifications of images are reliable and statistically acceptable (Pontius, 2000; Dimobe et al., 2017; Folega et al., 2020). This mapping shows that deforestation and degradation seems to be generalizing and affects almost the entire landscape due to the different forms of use to which they are subjected. The central region has undergone profound changes in land use, characterized by a progression of mosaics of fields and fallows and agroforestry parklands to the detriment of natural stands. This conversion of natural stands into an agricultural zone is an extreme phenomenon of irreversible destruction of vegetation. The increase in cultivated areas is the basis of the regressive change in vegetation cover. Similar studies carried out in Togo and downlock countries, in the sub-region and worldwide scale also reported regressive trends of natural stands characterized by a constant increase in anthropogenic formations to the detriment of more or less closed forest formations (Fousseni et al., 2012; Koumoi et al., 2013; Akodéwou et al., 2019, Burkina Faso by Dimobe et al. (2017), Millogo et al. (2017), Tankoano et al. (2016) and Sambare et al. (2010), in Benin by Azandegbe and Imorou (2019), Akognongbe et al. (2016) and Mama et al. (2014a), in Cameroon by Tsewoue et al. (2020), in Niger by Abou-Soufianou et al. (2016) and Abba (2013), in Senegal by Badji et al. (2014), in Côte d'Ivoire by Koné et al. (2014) and Barima et al. (2009), in the United States in the islands of Puerto Rico by Weaver (2013), in the Amazon by Sist et al. (2012). The main causes of this landscape dynamic are anthropogenic and climatic (Adjonou et al., 2010b; Sadda et al., 2016; Folega et al., 2020). Indeed, the evolution of forest stands depends on the intensity of environmental factors and the relationship that humans have with their ecosystem. Deforestation in Centre-Togo is only the result of the strong interaction between natural factors dominated by climate change, anthropogenic factors marked by an intense purely extensive agricultural activity which forces farmers to clear several hectares each year, vegetation fires, charcoal production, local overgrazing exacerbated by cross-border transhumance (Sokemawu, 2008; Koumoi et al., 2017; Amegnaglo et al., 2018); and the economic, social, historical and political context of the country. Mama et al. (2014b) and Sambare et al. (2010) confirm that anthropogenic actions are responsible for the fastest observed changes in ecosystems and for changes in the dynamics of the spatial structure of landscapes in Sub-Saharan Africa.

In addition, socio-political unrest from 1990 to 1993 led to the forced migration of populations to the centre of the country, which invaded previously unoccupied sites or even protected areas suitable for agriculture (Ouro Djeri et al., 2001; Tchamiè & Lare, 2014). These massive displacements of populations towards the centre require new clearing for crops explaining the expansion of 162.22% for the category of farms-fallow-agroforestry parks and 74.83% for urban areas between 1987 and 2000. The installation of new fields is done to the detriment of forest and savannah areas leading to the reduction and the degradation of natural stands. The observed spatial changes also come from a galloping demography coupled with the mismanagement of urban growth which endangers the ecological and landscape balances. According to Koumoi et al. (2013), strong demographic growth can be a driving force for deforestation and land degradation in Centre-Togo. It increased the internal needs of the populations, particularly in timber and services, and in new arable land. This hypothesis seems plausible insofar as, with an average annual growth rate of 2.81%, the population of Centre-Togo has increased from 273,138 inhabitants in 1981 to 617,871 inhabitants in 2010, constituting a density of 47 inhabitants / km2 (INSEED, 2011). According to Karsenty (2012), when the density exceeds 30 inhabitants / km ², the fertility of the land decreases and the fallow tends to disappear. The high spatial mobility of rural populations in search of new fertile land generates increasingly strong land pressures on vegetation, leading to the fragmentation and destruction of potential habitats for the biodiversity conservation.

Landscape Quantitative Analysis

In central Togo, the processes of landscape fragmentation are considerable. This process mainly due to the change of use and allocation of land remains an important factor in the rapid transformation of the composition of the landscape resulting in degradation and destruction of the habitat and the biodiversity. During the three decades (1987 to 2017), the diachronic analysis of Landsat images coupled with the calculation of landscape metrics reveals that anthropogenic pressures have very strongly altered and fragmented natural forest and savannah areas. The current landscapes of the region are dominated by mosaics of farms-fallow and agroforestry parks which represent 72.73% of the area of the region. These rates confirm the influence of man on this landscape, thus causing the loss of forest cover in each diachrony due to the practices of purely extensive and ancestral agriculture, urbanization, overgrazing and the opening up of villages. This finding is similar to the one of Abdou et al. (2019) in the Dosso partial fauna reserve in Niger, by Dimobe et al. (2017) in the Nazinga game ranch in Burkina Faso, by Mama et al. (2013) on the anthropization and dynamics of landscapes in the Sudanian zone in northern Benin and Bamba et al. (2008) on the influence of anthropogenic actions on the spatio-temporal dynamics of land use in the province of Bas-Congo (DRC).

The spatio-temporal dynamic in the landscape is marked by the increase in the number of patches and the decrease in the value of the total area from 1987 to 2017 in the class of dense forests and gallery forests, clear forests-wooded savannahs. According to Bennett and Saunders (2011), this change in natural vegetation classes is not random; it is typically focused on flatter areas, at lower elevations, and on more productive soils. Bogaert et al. (2011) believe that under the influence of anthropogenic actions, the natural landscape often begins with a perforation or a dissection increase the accessibility of natural stands because their newly cleared soils are often more fertile. The other tree-shrub savannahs compacted between 1987 and 2000, which explains the decrease in the number of patches and the increase in the total area and the cohesion index. The increase in the number of patches, total area and cohesion index for the urban areas class illustrates the process of creating and enlarging patch in these land use units.

These landscape metrics calculated suggest that the processes of fragmentation of the landscape of Centre-Togo took place through the fragmentation, isolation and reduction of the surface of natural habitats causing the modification of connectivity between habitat patches. Connectivity is a vital part of the landscape structure (Taylor et al., 1993). It helps maintain links and movements between ecosystems, thus facilitating the distribution and conservation of species. The decrease in the patch cohesion index (COHESION) between the classes of vegetation observed in dense dry forests and gallery forests, and in clear forests and wooded savannahs would affect the distribution of species, the structure of natural formations and could be a limiting factor in carbon sequestration in this landscape. Poor connectivity between landscapes can produce species extinction (Fahrig, 2003; Bennett & Saunders, 2011; Lindenmayer & Fischer, 2013). At the level of tree-shrub savannahs, farms-fallows and agroforestry parklands and urban areas, there is an increase in connectivity between the patch of these forms of land use. This testifies that the urbanization is based mainly on isolated patches, disconnected from each other as revealed by Doukari et al. (2016), creating an imbalance in the agro-ecological process (Aguejdad, 2009; Mandal & Chatterjee, 2020). The expansion of cultivated areas and urban sprawl can be explained by the strong demographic growth experienced by this region, but also by the fact that agriculture remains the main economic activity.

At the landscape level, the decrease in the number of fragments between 2000 and 2017 does not mean a reduction in human activities, but could rather be the result of the aggregation or removal of patches or patch that, previously isolated, become connected. This same observation was made by Dimobe et al. (2017) in the Nazinga game ranch in Burkina Faso.

In addition to anthropogenic activities, the dynamics of natural landscapes are also exacerbated by climatic hazards (Badjana, 2010; Amoussou et al., 2014; Diwediga et al., 2018). These anthropogenic and climatic pressures adversely affect the circulation and life cycle of animal and plant species (Ritchie et al., 2009), affecting the structure and the flora diversity of the environment.

Conclusion

This study analyzed the different forms of land use and their probabilities of change from 1987 to 2017; quantified deforestation and landscape metrics in the Central region of Togo. The results of the study indicate that in 30 years, LULC have changed drastically. The result of the detection of the changes shows that the area of forest land has significantly decreased and is being converted to cropland and urban areas. As a result, the area under farms-fallows and agroforestry parklands and urban areas, which respectively occupied only about

0.61% and 0.002% of the landscape in 1987, saw their proportion increased by 72.73% and 40.70% in 2017. Transition matrices show that forest areas are more prone to fragmentation. The fragmentation of patches within land use units threatens potential habitats for biodiversity conservation and creates an agro-ecological imbalance making fertile land very vulnerable. Strong anthropogenic pressures, especially shifting slash-and-burn cultivation practices, have made forest classes more vulnerable to fragmentation. Thus, there is a strong relationship between forest loss, expansion of cultivated land and population growth.

From a sustainable planning and management perspective of plant resources, this study would help in the planning, management and use of land and other natural resources. With the decentralization process underway in Togo, these data can constitute a potential tool at research level, policy formulation level and policy implementation level, which will contribute to good landscape management and natural resources. Good landscape planning would be a source of economic growth and political stability for all stakeholders.

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