

RATE OF LAND COVER CHANGE AND ITS DETERMINANTS IN THE SOUDANO-GUINEA TRANSITION ZONE OF BENIN REPUBLIC

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Abstract

The paper assesses land cover dynamics and its associated drivers in the soudano-guinea transition zone of Benin Republic, using both spatial and non-spatial data. Multispectral and multi temporal Landsat imageries (Landsat TM of 1986, ETM+ of 2000 and OLI-TIRS of 2013) were used for the analysis of land cover dynamics through a supervised classification. Logistic Multiple Regression model is used to analyse the relationship between the rate of land cover change and nine explanatory variables considered as potential factors of land cover change rate. Land cover change rate was estimated to an average of -4.34% annually. This rate appears higher than the national rate estimated at -1.2% by Food and Agriculture Organization (FAO). The rate of change classified into four modalities ranging from -8.77 to -1.13, show a gradual decrease towards the northern part of the study area. From the R^2 , it is observed that the nine variables explained about 35.30% of the occurrence of land cover change. Variables such as 'rank of agriculture in the source of income' and 'accessibility' are significantly influencing the rate of land cover change in the study area. The paper further advocates for the need to dwell more on indirect factors which remotely influence environmental dynamics.

Key Words: Land cover, Rate of change, Benin, Logistic multiple regression, Determinants

Introduction

Land Use Land Cover Change (LUCC) highlights the impacts of global environmental change and human interaction with the natural systems (Karanam *et al.*, 2013; Hibbard *et al.*, 2010). Due to the important contributions and role of land in providing environmental goods and services for human sustainability (Showqi *et al.*, 2014), there have been an increased

interest in land use land-cover (Badjana *et al.*, 2015; Lawrence and Chase, 2010). The change observed in Land-cover is one of the most important drivers of global change that affects the climate (Takahashi *et al.*, 2010), the biogeochemical cycles and energy fluxes and thereby the livelihoods (Melillo *et al.*, 2003). The change in land cover is influenced by ecological mechanisms, physical components of the environment

and socioeconomic interactions (Were *et al.*, 2014; Kanianska *et al.*, 2014; Hu *et al.*, 2012).

There have been some studies on land cover dynamics in the climatic transition zone of Benin. For instance, RIVERTWIN project developed and implemented an Integrated Regional Model which indicated that land use/cover data are useful in environmental resources assessment and planning (European Research Area, 2004). Within the framework of this project, Igue *et al.* (2012) developed a Soil and Land Resources Information System in which 17 land cover classes were generated. However, the factors responsible for land cover dynamics were not considered.

Also, IMPETUS Benin project for Oueme basin investigated the relationship between spatio-temporal vegetation dynamics and hydrological cycle between 1986 and 2002. The report of the project revealed threefold causes of land cover change including agricultural colonization, logging and growth of settlements (IMPETUS West Africa, 2003). In the context of this project, Thamm *et al.* (2005) reported that agricultural land was extending while dense forests were reduced from 11% to 6% between 1986 and 2001. Orekan (2007) traced these changes to population growth, migration and change in climatic conditions while Do *et al.* (2014) used a diachronic analysis to show a loss of 87% in forested zones, 48% in savanna and 39% in cropland. However, the spatial coverage is the upper Oueme Catchment area which is not included in this study area.

Other studies have also drawn attention to land cover change in the study area. For example, Oloukoi (2013) analysed the socioeconomic and ecological scenario of land cover change in the central part of Benin. However, the study did not use statistical model to show the contribution of the drivers in land cover change.

The present paper therefore analyses the types of drivers and their contribution to land cover dynamics in the soudano-guinea transition zone of Benin Republic. The research questions include: what is the rate at which the land cover is changing annually? What are the main and significant driving forces of the observed changes?

Study Area

The soudano-guinea transition zone of Benin covers mainly the Central part of the country. The area under this study extends between 7°30' and 9°00' of North latitudes and between 1°38' and 2°46' of East longitudes (figure 1). It is located in the transition climatic zone between the sub-equatorial or guinea and sudanian climates (Afouda, 1990). The rainfall pattern is straddling on the bimodal distribution of the South and the unique rainfall modality of the North. The total annual rainfall varies between 900 and 1200 mm. Temperature and its monthly mean values oscillate between 24 and 32°C. Vegetation presents various types of formations from dense forest to farmlands and fallow lands.

The study area occupies a large part of Oueme river basin as studied within the framework of the RIVERTWIN project (Keyzer *et al.*, 2007).

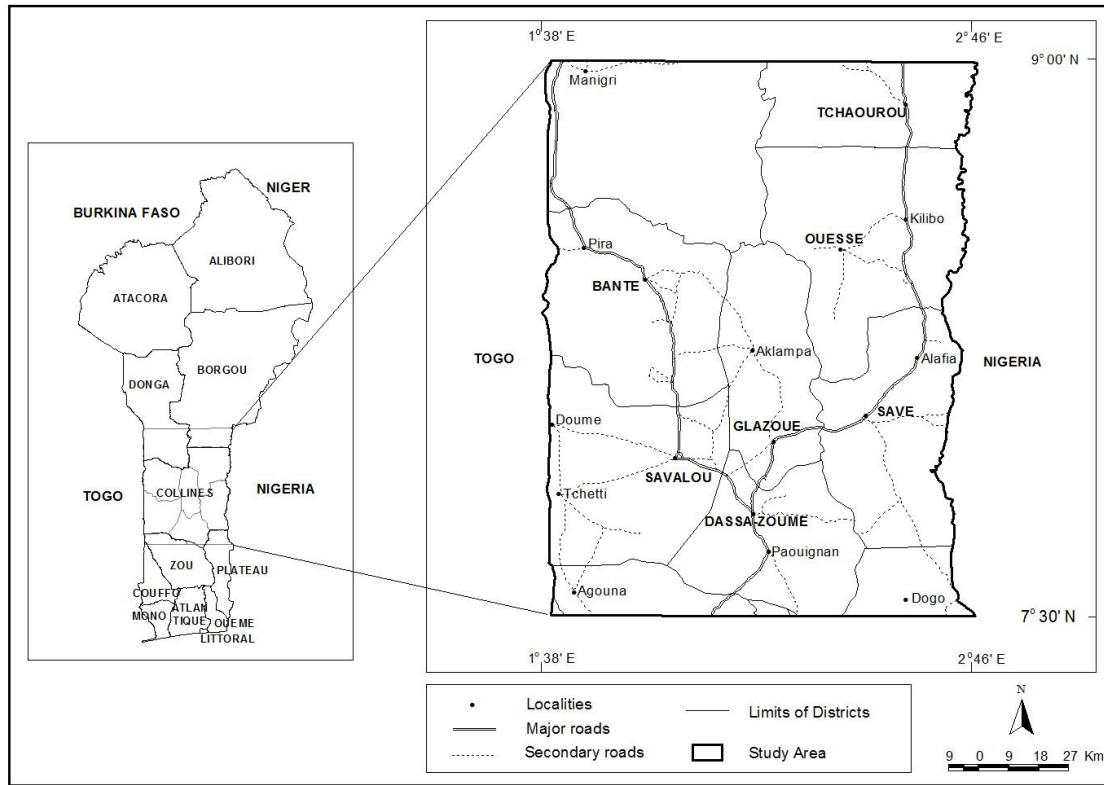


Figure 1: The Study area

Research Methodology

Data Types and Sources

Both spatial and non-spatial (socio-economic) data were used in this study (table 1). Spatial data were collected from existing clearinghouses and mapping agencies while non-spatial data were

gathered from a household survey and some national institutions. They are population data, numbers and names of villages by municipality and agricultural statistics of the central Benin between 1998 and 2010.

Table 1: Data characteristics

Data	Sources	Types
Land cover information	Landsat TM 1986, ETM+ 2000 and OLI-TIRS 2013, ground truthing 2013	Spatial
Soil data	Soil map of Benin, sheets of Abomey and Save at 1/200000, ORSTOM, 1975	Spatial
Topographic map sheet of Save, Sokode, Zangnanado and Abomey	Topographic maps of 'Afrique Occidentale Francaise' at 1/200000	Spatial
Population data	National Censuses 2002 and 1992, INSAE	socio-economic
Agricultural statistics	Ministry of agriculture	socio-economic
Agricultural systems data	Socio-economic survey	socio-economic
Land use information	Socio-economic survey	socio-economic

The household survey was carried out in 68 settlements out of 337 of the study area and the questionnaire was administered in 430 households. Municipalities whose settlements were selected for the investigations were indeed recognized as the major areas of agricultural production in Benin and as places that feature high pressure on forest resources.

Research approach

The satellite images used for the extraction of land cover information were geometrically checked and corrected through georeferencing and resampling. Their contrast was enhanced and color composites including both false color and pseudo natural color carried out.

A supervised classification using Maximum Likelihood Algorithm in ENVI 4.2 software package was performed on the images. Land cover types identified are: dense forest, light forest, woody and shrub savannah,

gallery forest, water bodies, settlements, bare land and exposed rocks, farmlands and fallows. They were confirmed, assembled according to their spectral properties and the results were validated after a thorough ground truthing exercise during which at least 30 GPS (Global Positioning Systems) points in each category of land cover were checked.

The formula used for the calculation of the rate of change for each land cover type is presented as follows (Puyravaud, 2003).

$$T = (1 / (t_2 - t_1)) \times \ln(S_2 / S_1)$$

; t is the number of years of evolution, ln the logarithm, S₁ and S₂ the areas of a land cover type in years t₁ and t₂.

In all the nine land cover maps sheets covering the study area (figure 2), the average rate of change of land cover types varied between -8.7 and -1.13 % (table 2).

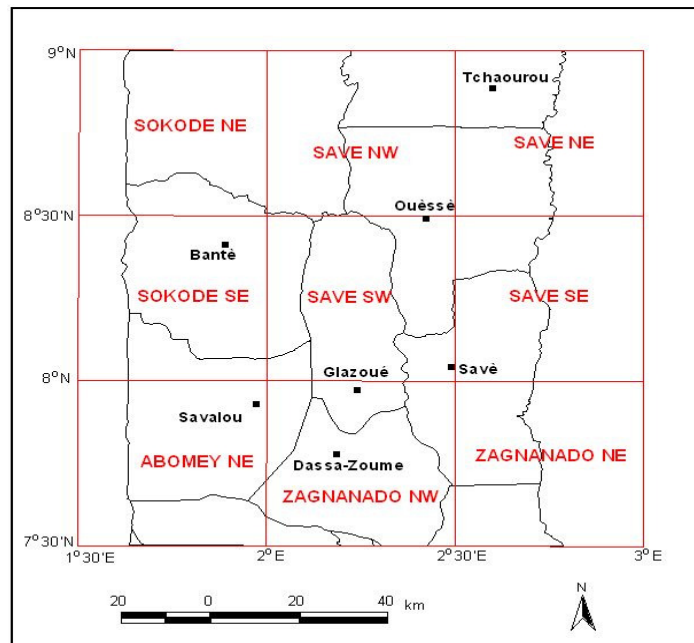


Figure 2: Gridding of the area of study in 30' by 30' sheets

Table 2: Rates of Land cover change between 1986 and 2013

Sheets	1986-2000	2000-2013	Average rate of change
Abomey NE	-2.68	-6.9	-4.79
Save NE	-0.79	-6.59	-3.69
Save NO	3.14	-9.21	-3.035
Save SE	1.67	-8.62	-3.475
Save SO	5.22	-10.62	-2.7
Sokode NE	-0.65	-1.6	-1.125
Sokode SE	-0.17	-8.25	-4.21
Zagnanado NE	-1.14	-14.29	-7.25
Zagnanado NO	-0.21	-16.4	-8.77
Average	0.49	-9.16	-4.34

The rate was transformed into a categorical variable due to its continuous nature. Four major intervals were created and a weight ranging from 1 to 4 was given to each. The rate of land cover change was interpolated using Kriging technique in order to appreciate the spatial configuration and trend in the study area.

Logistic Multiple Regression (LMR) model is adopted to test the relationship between the rate of land cover change

and independent variables considered as potential factors of land cover change (Tayyebi *et al.*, 2014; Li *et al.*, 2013; Martinez *et al.*, 2011; Mitsuda and Ito, 2010). It involves a mathematical relationship between a set of independent variables and a dependent condition (Guo *et al.*, 2016; Mertens *et al.* 2000).

LMR is presented in various forms and can be written as follows (Braak and Looman, 1987):

$$\hat{p} = \frac{\exp(b_0 + b_1X_1 + b_2X_2 + \dots + b_pX_p)}{1 + \exp(b_0 + b_1X_1 + b_2X_2 + \dots + b_pX_p)}$$

Where

\hat{p} is the probability of the dependant variable; $X_0, X_1, X_2 \dots X_p$ are independent variables; and b_0 through b_p are the coefficients of the explanatory variables. The variables are codified and classified in three categories as they are binary, categorical or continuous (Table 2).

Table 2 Description of variables

Variables	Description	Type of data	Mean	Standard deviation	Min	Max
Dependent Variable	Land cover change rate	Categorical	-4.34	2.21	-8.77	-1.13
Explanatory Variables	Accessibility	Binary	0.46	0.50	0.00	1.00
	Land availability	Binary	0.98	0.15	0.00	1.00
	Access to credit	Binary	0.12	0.33	0.00	1.00
	Male labor force	Categorical	1.18	1.34	0.00	7.00
	Female labor force	Categorical	0.91	1.03	0.00	5.00
	Rank of agriculture in the income sources	Binary	0.63	0.48	0.00	1.00
	Population Growth	Continuous	3.69	0.43	2.87	5.42
	Soil fertility	Categorical	2.97	0.51	1.00	5.00
	Distance to markets	Continuous	31.27	86.38	0.02	400.00

LMR model was run in STATA statistical package, version 11.

Results and Discussion

Land Cover Change Process

The dynamics in land cover pattern is characterized by the conversion of land cover types (figure 3). Hence, the area of each land cover type reduced or increased within the time frame of this study. Dense forests lost more than 90% of their initial area of 1986, with an annual rate of regression estimated at 17.07% from 1986 to 2000, and almost 0.1% from 2000 to 2013. The same observation is made with gallery forest which more than 90% of its area was cleared, with an annual rate of regression estimated at 15.8% from 1986 to 2000. Meanwhile, these vegetation formations severely regressed, but they were converted into light forest, farmlands and fallow and then shrub and woody savanna, whose areas witnessed a gradual progression from 1986 to 2013.

We observed two processes: *savanization* and *anthropogenisation*. *Savanisation* is the transition of dense vegetation formation to light forest or

shrub and woody savanna. Between 1986 and 2000, almost 35% of dense forest went through that process. *Anthropogenisation* process is characterized by the extension of farmland and fallows, settlements (Oloukoi, 2013; Orekan, 2007; Mama, 2002). Between 1986 and 2000, the land cover rate of almost 5% is the result of the progression observed in land cover types such as fallow and farmlands, built up areas and savanna. The same observation was made between 2000 and 2013.

From the analysis of land cover change, the annual rate of change approximates -4.34%. The rate appeared very high compared to other regions of the country. The average rate of deforestation according to Global Forest Assessment made by FAO is -1.3% from 1990 to 2000, -1.1% from 2000 to 2010 and -1.2% from 1990 to 2015 (FAO, 2015), confirming that the area is ahead of many other parts of the country in term of deforestation.

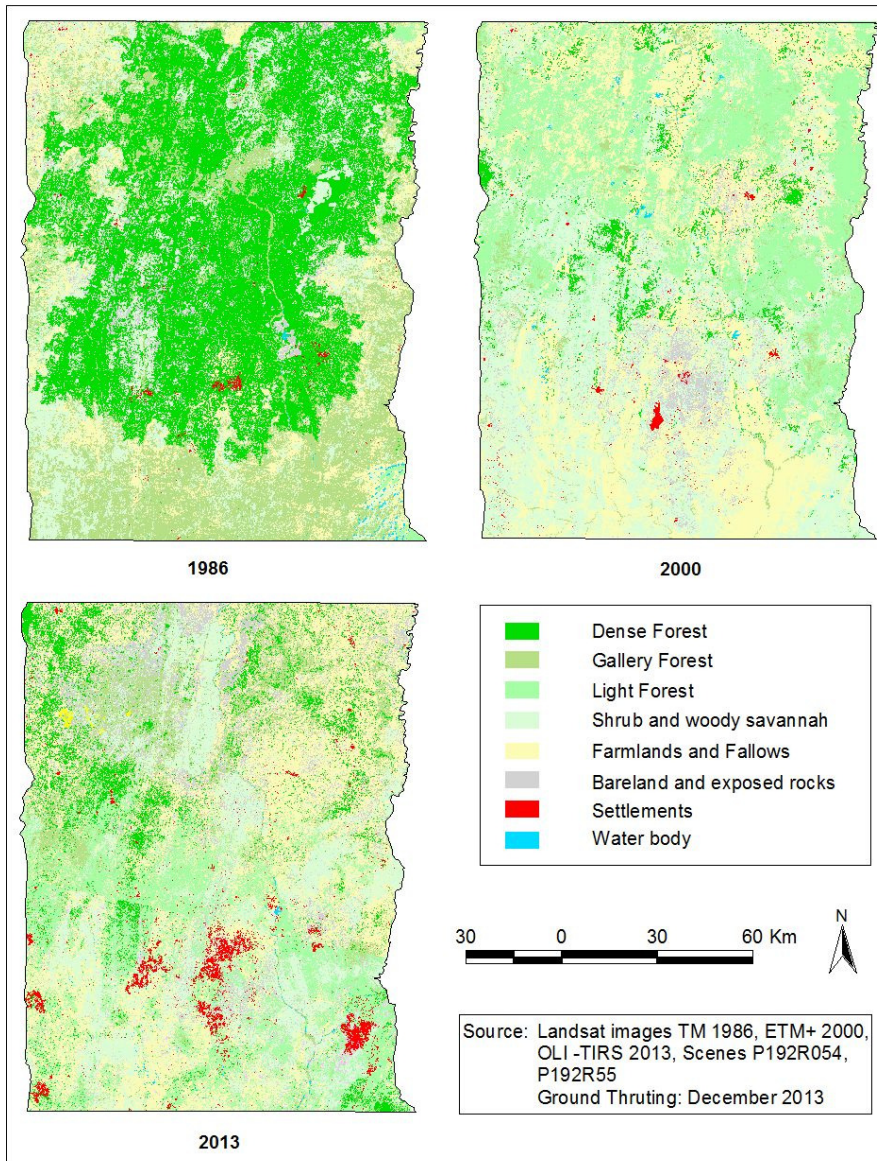


Figure 3: Land cover dynamic process

Determinants of Land Cover Change Rate

Four modalities of land cover change rates were considered in the analysis of the drivers of land cover change. The first modality extends between -4 and -1%, the second covered the rates between -7

and -4%. The third and fourth modalities correspond to the rates of change extending respectively between -8 and -7% and -9 and -8%. It is observed that the rates of land cover change increase towards the southern part of the study area (figure 4).

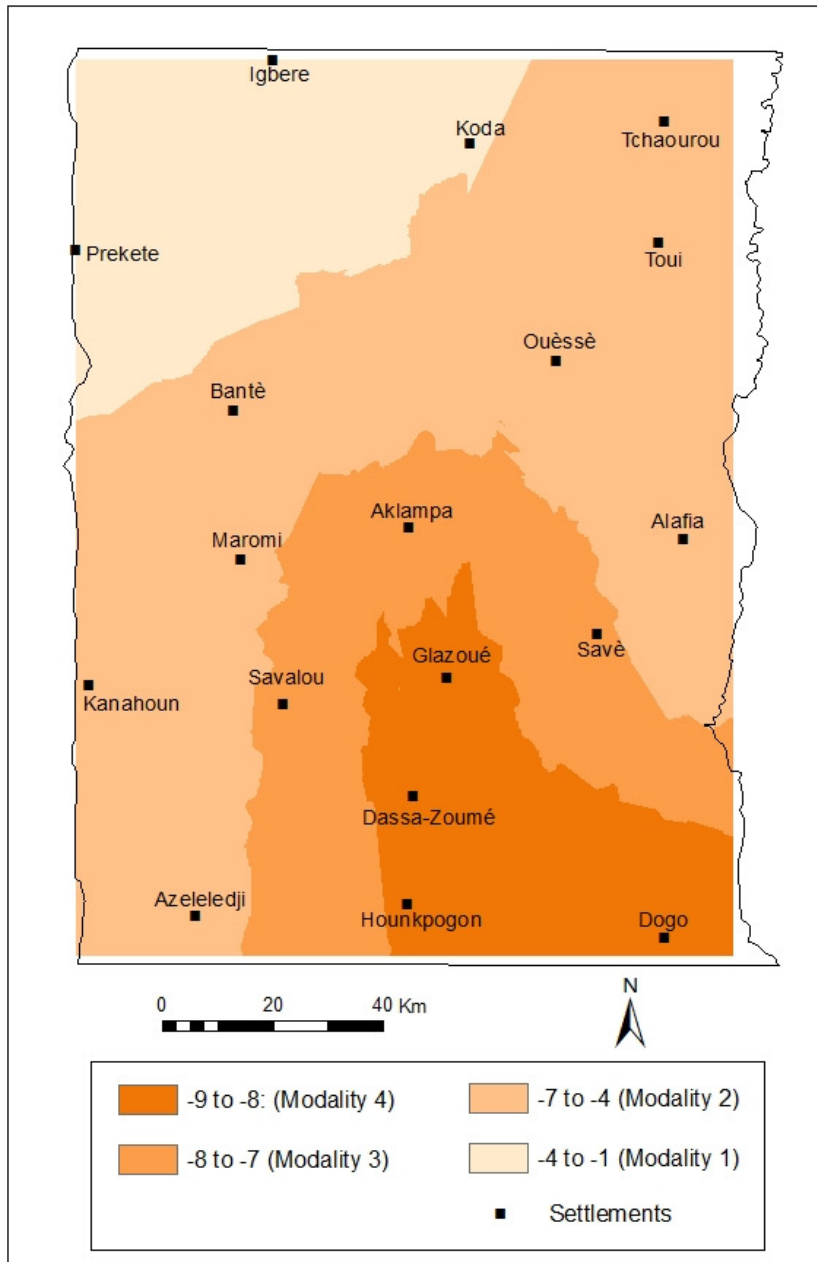


Figure 4: Spatial trend of land cover change rates in the central Benin

Logistic Multiple Regression analysis reveals that the model is significant at 1% threshold with a *Chi Square* (χ^2) estimated at 306.17. All the variables

derived from the model explained about 35.30% (R^2) the rate of land cover change (Table 3).

Table 3: Logistic Multiple Regression (LMR) model output

Variables	Modality 1	Modality 2	Modality 3	Modality 4
Intercept	-19.34(5.649)***	2.704(1.874)	15.819(2.822)***	-2.378(2.769)
Accessibility of villages	1.333(0.506)***	0.445(0.159)***	-0.495(0.210)**	0.809(0.247)***
Land availability	-0.678(0.851)	-0.249(0.278)	0.143(0.360)	0.160(0.450)
Access to credit	-1.150(0.939)	-0.217(0.574)	-0.629(0.791)	-1.438(1.153)
Rank of agriculture in the income sources	1.505(0.452)***	1.183(0.406)***	1.290(0.413)***	1.333(0.414)***
Population Growth	4.646(1.174)***	-0.588(0.380)	-4.837(0.748)***	0.084(0.576)
Soil fertility	-1.561(0.550)***	-0.094(0.340)	0.520(0.383)	-0.433(0.413)
Distance to markets	0.00004(0.003)	-0.001(0.002)	-0.061(0.022)***	0.001(0.003)
Male labor force	0.019(0.336)	0.114(0.182)	0.069(0.221)	0.032(0.242)
Female labor force	-1.383(0.694)**	-0.366(0.237)	0.363(0.281)	-0.234(0.345)
Log likelihood	-280.63028			
Pseudo R ²	35.30			
Chi square (χ^2)	306.17(36)***			
Number of observations	318			

() standard error; **, *** indicate respectively the level of significance at 5% and 1%

In modality 1, land cover change is being significantly influenced by a set of four factors namely: accessibility, rank of agriculture in the source of income, population growth, soil fertility and female labour force. An increase in accessibility by 1 unit multiplies the odds of land cover rate by 1.333 in that modality. Likewise, an increase by 1 unit in the rank of agriculture and in the population growth multiplies the odds of land cover rate by 1.505 and 4.646 respectively. These variables are positive except soil fertility that connotes a negative influence on land cover in that modality. Soil fertility is inversely proportional to the rate of land cover change in that modality. This can be explained by the fact that non fertile soils are not subjected to intense agricultural activities. For years, these soils may be left as fallow lands and they can gain more cover over time.

Modality 2 reveals a set of two factors that explain significantly and positively the rate of land cover change. The factors are accessibility (0.445) and

the priority given to agriculture which has the greatest positive influence (1.183). Four factors influence either negatively or positively the rate of land cover change in Modality 3. For example, accessibility, population growth and Distance to markets have shown a negative influence on land cover rate in that modality while the priority given to agricultural activities in the source of income shows a positive influence. Modality 4 is similar to modality 2 in term of factors explaining changes in land cover. The significant factors in that modality are accessibility (0.809) and rank of agriculture in the source of income (1.333). This modality displays the highest rates of change opining that the influence of factors is strong as shown in their odds values compared to modality 2.

In all the modalities of land cover change rates, it is observed that the coefficients of variable ‘rank of agriculture in the source of incomes’ are positive and significant at 1%. This indicates that the variable influences

positively the changes in land cover in the study area. Hence, as the pressure from agricultural sector increases, the demand in land cover change also augments.

All the factors explained about 35.30% (R^2) the rate of land cover change. This established that there are other factors to explore, especially indirect factors such as political, economical and technological factors. The study also revealed two preeminent factors (rank of agriculture in the source of income and village accessibility) explaining significantly the rate of land cover change.

The pre-eminence of agricultural activity in the study area is confirmed by the extension of farmlands (Badjana *et al.*, 2015; Do *et al.*, 2014). Agriculture is mainly characterized by shifting cultivation associated with bushfire (Thamm, 2008). The average area cultivated per year varies between 0 and 5.33 ha. Majority of farmers (more than 65 %) cultivate between 0 and 1 ha, which confirmed the presence of small scale farmers. Approximately 33 % of farmers cultivate between 1 and 5 ha. Only 2% cultivate more than 5 ha. The two major crops dominating the use of land are cotton and yam. They are associated with other yields such as maize, cassava, groundnuts etc. Cotton crop represents about 13% of the Gross Domestic Product (GDP) and 80% of the agricultural exports which constitute a vital resource for Beninese economy (Wennink *et al.*, 2013). Yam requires a very rich soil for its growth. Firstly, the land must be new or a long fallow which facilitates an important accumulation of organic matter for a good reconstitution of soil (Floquet *et al.*, 2012). Secondly, it

needs a sufficient quantity of water. Farmers are forced to clear new spaces.

Accessibility is a factor that positively influences land cover change. It is considered as the ease with which individuals can reach a place from other locations, using a means of transportation. It depends, on the respective geographical positions of places of origin, the destination and the level of service offered by the modes of transportation (Lee, 1979). In line with this, we considered seasonal practicability of roads from the production spots to the settlements (Muller and Zeller, 2002) and from settlements to markets (Aguiar *et al.*, 2007; Mertens *et al.*, 2002). About 50% of the actors considered the roads to their settlements as good enough to facilitate accessibility to their localities. Producers depend on three specific locations: their residence, represented by the settlement, the production spots (farms, forests exploitation or charcoal production locations) and the places of exchange or distribution of their products (markets). In modality 3, it is observed that a decrease by a unit of distance to market increased the odds of land cover change rate by 0.06 unit. If the conditions of transportation are optimal (good roads, good transportation means, short distances to markets etc.), producers are encouraged to produce more. Thus more pressure is deployed on land resources.

Conclusion

Land cover change assessment confirmed a reduction in dense vegetation formations while other land cover types such as farmlands and savannah witness an expansion within the timeframe of the study. *Savanisation* and

anthropogenisation processes observed are expressed by an annual rate of land cover change estimated at an average lost of -4.34% annually. This rate appears to be much higher than the national rate of 1.2% estimated by FAO in 2015. This indicated that the soudano-guinea transition zone is one of the areas where pressure on vegetation cover is very high in Benin Republic. It is observed that agriculture and accessibility are significantly influencing land cover change in all the four modalities retained. Many of these factors are direct or proximate cause of land cover change. There is still a need to dwell more on indirect factors which remotely influence environmental dynamics. To achieve that, macro and micro economic decisions, infrastructural policies, cultural context and land management policy should be taken into account in future studies.

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