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ANALYSIS OF LANDCOVER CHANGE AND ITS TRAJECTORY IN SUB-SAHARAN WEST AFRICA

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ABSTRACT

The study analysed land cover change and its trajectory in the study area using 300m CCI-land cover data for three epochs (2000, 2005 and 2010) respectively. Five sampling sites were selected and analysed land cover change trajectories. The findings show a continued decline in closed forest and sparse vegetation and increase in cropland; an indication of land degradation. This pattern of land cover change is accelerated by the increasing number of human populations which is estimated to be growing at the rate of 2-3% in Africa by the year 2100. This nature of population growth is expected to increase the size of croplands to support food security, which will exert more pressure on the ecosystem. However, the land cover trajectories presented in the five sampling points does not portray much changes. This can be attributed partly to the temporal extent of the study (15-years) and the spatial resolution of the data. Overall, the land cover change trajectories in the five sampling sites shows that the major changes in the land cover have been caused by human activities and to some extent natural climatic variations especially along the marginal areas, where the size of bare surface have increased. Therefore, there is a need to carry out a comprehensive land cover assessment at local level to ascertain the major local driving forces and biophysical drivers of land cover degradation in the study area.

Keywords: Land Cover; Land Degradation; SDGs; Trajectory, sub-Saharan Africa

INTRODUCTION

Landcover change is one of the major causes of land degradation and desertification, which are adjudged to be among the milestone pillars of the international environment sustainable and development agendas. Specifically, goal number 15 of the recently adopted United Nations sustainable development goals (SDGs) targets on combating desertification and reversing land degradation, especially those manifested from anthropogenic causes (UNCCD, 2015). Environmental problem in the dryland areas is aggravated when land degradation, mostly a human induced process is combined with natural climatic fluctuations (Karlson and Ostwald, 2016).

The end results include among others a temporary or permanent decline in the structure; density; species composition and or productivity of vegetation cover. This result in land cover change which is triggered by land use alterations which may varies significantly from one place to another depending on the prevailing conditions and the extent of man acquisition of natural environment/resources to satisfy his immediate needs, often at the detriment of land cover (Grainger, 1996).

Information about the condition of land cover is of vital importance for many environmental applications. Over the years, interest on the possible connection between environmental changes and land cover change vis-a-vis predominant land uses leading to the change emerged in global environmental literature, with realization that land surface processes influence climate and other environmental changes (Nicholson, 2013; Ibrahim *et al*., 2018). In the mid-1970s, it was recognized that land cover changes modify surface albedo and thus surface-atmosphere energy exchanges, which have direct impact on regional climate. Land cover change alters the partitioning of precipitation into soil water, evapotranspiration and run off. It also affects the biotic diversity worldwide, accelerate soil degradation, and weaken the ability of biological system to support human needs. Land cover change also determines the vulnerability of places and people to climatic, economic and socio-political trepidations (Kasperson and Archer, 2005).

It has been argued that contemporary land cover change is generated principally by human actions directed at manipulating the surface of the earth for his personal benefits, such as agriculture, urbanization, grazing, etc. (Lambin and Geist, 2008). This led to degradation of vegetation cover, which it is also a cause and consequence of climate change (UNCCD, 2015). Due to the immense and multitudes of functions and services land provides to humanity, it is important to study and monitor the state of landcover especially in the extremely degraded areas in Sub-Saharan Africa, where 70% of the population depends on ecosystem services for their survival. In this study an analysis of landcover change in sub-Saharan Africa West was carried out and examined the pattern of landcover change and its trajectory from 2000 to 2010.

MATERIALS AND METHOD

Study Area

The study area is sub-Saharan West Africa, and it covers an area of approximately 6,140,000 km2, an area roughly about one-fifth of the African continent. Specifically, it is located between latitude 4^0N and 20^0N, and between longitude 17^0W and 15^0E (Figure 1). The area is situated between the arid and semi-arid regions of the Saharan desert in North Africa, and humid tropical savanna in the equatorial West Africa down to the Atlantic coast to the south. Hence it is marked by a south-north gradient in surface conditions with nearly zonal uniformity; from the coastal waters of the Gulf of Guinea, to the equatorial rainforests, the grasslands and the savanna of the Sahel. The eastern border is less precisely defined, running approximately from Mount Cameroun to Lake Chad. The vast majority of the land in the area is low-lying at <300m above mean sea level. Isolated mountains exist in several countries along the southern shore. The northern part of the region consists of semi-arid terrain and is known as the Sahel, a transitional boundary between the Sahara Desert and the Sudan savanna.

The region is an area of vegetation, climatic and environmental transitions and it has been intensively studied by environmental scientists. The sub-Saharan West African countries of Senegal, Mauritania, Mali, Niger and Burkina Faso and Guinea-Bissau, which have most of their parts in the Sahel, make up the dry region of West Africa. On the other hand, Nigeria, Benin, Ghana, Togo, Côte d'Ivoire, Liberia, Sierra Leone, Guinea and the Gambia comprises Guinea which is the traditional name given to the area near the Gulf of Guinea, and makes up the humid part of West Africa.

Figure 1: Extent of the study area. (Source: GIS Lab, UMYU, 2020)

Data Sets

The study used climate change initiative land cover data CCI-LC. The data is a product of CCI-LC projects which provides global land cover maps at 300m spatial resolution. Sponsored by European Space Agency (ESA), its aimed to provide multiyear maps for three 5-year epochs centred on the years 2000 (1998-2002); 2005 (2003-2007) and 2010 (2008-2012). We opted to use this land cover data because at the moment, it is the only data archive produced in a repeatable way. It was designed to be globally consistent and regionally-tuned. Today, it is one of the most dynamic products which are in the form of time series span from 2000 to 2014.

The data was tested and validated using both ground and satellites reference data sources. In addition, expert opinions were also used to supplement the ground truth. And the validation was enhanced following the experience gained from the GLC 2000 and Globcover maps project respectively. The accuracy of the data was tested using three complementary approaches that is confidence building procedure; the statistical accuracy assessment and comparison with other global land cover products as well as temporal consistency assessment between the CCI land cover products themselves (ESA, 2014). The data typology was defined based on UN-land cover classification system (UN-LCCS), and it was compatible with the GLC 2000 and Globcover 2005 and 2009 products respectively.

Data analysis

The original CCI-LC came with 23 land cover classes which were reclassified into eight new land cover classes by aggregating the land cover categories which shared relevant and to some extent common characteristics in order to have a limited number of land cover classes within the study area and to minimise data processing time. The original and new land cover classes developed are presented in Table 1.

After the reclassification, new land cover maps for the year 2000, 2005 and 2010 were produced and presented as Figure 2. All the analyses were carried out using Arc GIS.

Change detection

Change detection analysis was carried out to examine the trend of landcover change in the study area from 2000 to 2010. The extents of each landcover categories were calculated and the percentages of each at any given year were computed. The percentage difference between the two or more successive periods was used to examine the trend of landcover change within the study period.

Table 1. List of the original ESA CCI- LC classification and the new classes derived from the aggregation of different landcovers

ESACCI- Land cover classification	Land cover classification used in this study
Cropland, rainfed Crop land, irrigated or post-flooding Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)	Crop lands
Grassland Herbaceous cover Sparse herbaceous cover (<15%)	Grasslands
Shrubland Shrubland deciduous Sparse shrub (<15%) Shrub or herbaceous cover, flooded, fresh/saline/brackish water Mosaic herbaceous cover (>50%) / tree and shrub (<50%) Mosaic tree and shrub (>50%) / herbaceous cover (<50%) Sparse vegetation (tree, shrub, herbaceous cover) (<15%) Tree or shrub cover	Shrub land
Mosaic tree and shrub (>50%) / herbaceous cover (<50%) Sparse vegetation (tree, shrub, herbaceous cover) (<15%) Tree covers, broadleaved, deciduous, open (15-40%)	Sparse vegetation
Tree cover, mixed leaf type (broadleaved and needle leaved) Tree cover, flooded, fresh or brackish water Tree cover, flooded, saline water	Thick Forest
Urban areas	Built up
Bare areas Consolidated bare areas Unconsolidated bare areas	Bare surface
Water bodies	Water bodies

Landcover change trajectory

Five sampling points were selected within the study area and examine the landcover change trajectory at each location. The location of the areas selected is presented in table 2.

The land cover types of each of the five sampling locations were examined for the year 2000, 2005 and 2010 respectively in order to find out the landcover type and its trajectories at each location, which were evaluated to assess the pattern of changes over the study period. This analysis was carried out using R statistical software.

Table 2. Name and location of Sampling locations

Location Name	Latitude	Longitude
Nigeria	12°49'44.4"N	9°17'9.6"E
Burkina Faso	13°33'18"N	1°36'46.8"W
Senegal	14°57'28.8"N	16°0'10.8"W
Ghana	8°1'8.4"N	0°24'46.8"W
Mali	16°11'9.6"N	0°39'39.6"E

RESULTS AND DISCUSSION

Landcover trend and change analysis

In the landcover maps of Sub-Saharan West Africa presented in figure 2, Bare surface makes up the largest percentage of landscape in the area, with 41% each for the year 2000, 2005 and 2010. Cropland makes up the next largest land cover and occurs predominantly in most part of the area especially south of Sahel boundary down to Atlantic coast. The size of the croplands has increased from the year 2000 to 2010, indicating continued demand of agricultural land due to increase in population in the area. Closed forest and sparse vegetation continue to decrease in the study area as shows in table 3.

This comprehensive analysis, of land cover provides both the timing and nature of land cover changes in the study area. Percentage of land cover changes of significant importance to land degradation were highlighted in table 3, and it provides opportunity to clearly see the trend of land cover changes in the area. However, due to the time frame of the analysis of the land cover change covered (only 15 years period) and the size of the study area, the land cover changes were found to be infinitesimal, hence little percentage of change were recorded. And in some cases, such as in urban areas and water bodies' categories, no any change in land cover was recorded from 2000 to 2010. Despite this limitation however, going by the trend of change depicted in the table 3, land cover changes indicate that human activities are expanding at the detriment of natural vegetation cover, meaning more forest and sparse vegetation has been removed at the expense of cropland, an indication of land degradation. The recent forest degradation relates mostly to peasant agricultural system and can be associated to an increasing firewood demand from expanding population in urban areas outside the cities and villages. Similar scenario was documented in southern Chile by Marín *et al*., (2011) and corresponds to the evidence of one of the landscape transformations causes in Czech Republic put forward by Boori and Vozenilek (2014). And in some cases, the decline of economic trees was observed due to agricultural intensification. Far north of the West African Sahel around Sahel-Saharan boundary, bare surface land has increased. This can be attributed to the expansion of degraded lands majorly due to the agricultural abandonment as land become unproductive for agriculture and grazing, forcing farmers to migrate southward. Similar situation has been highlighted over Saharan Africa and many other drylands areas over the globe for several decades (Shalaby and Tateishi, 2007).

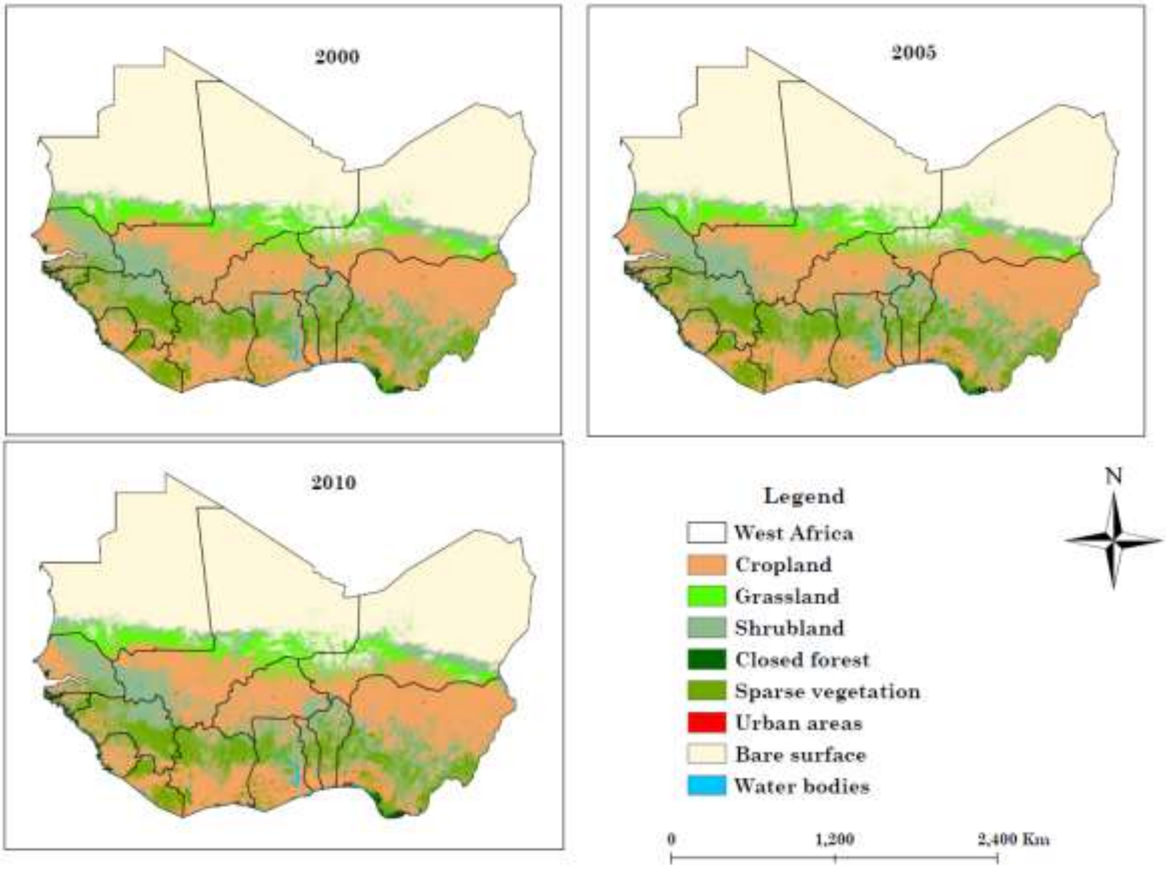

Figure 2: Landcover change map of sub-Saharan West Africa (2000-2010).
Source: Authors Analysis, 2020

Landcover Change Trajectories

Land cover change trajectories in the five study sampling locations for the year 2000, 2005 and 2010 show that land cover types at these locations remained the same from 2000 to 2010. In Nigeria, Burkina Faso and Senegal, the land cover type is cropland and the overall trajectory is also cropland (Table 4). For Ghana, the land cover type trajectory is sparse vegetation throughout the study period. Finally, Mali, which is located northward in the study area, the land cover type was found to be bare surface.

Table 3: Land cover changes in Sub-Saharan West Africa 2000-20

Land covers	2000		2005		2010		Change (%)	Change (%)	Change (%)
	Area (km^2)	percent	Area (km^2)	percent	Area (km^2)	Percent	2000-2005	2005-2010	2000-2010
Cropland	1662497.10	28.0640702	1665308.70	28.1115319	1665602.64	28.1164938	**+0.05**	**+0.0049619**	**+0.0524236**
Grassland	306928.62	5.181161722	306931.86	5.181216415	306931.77	5.181214896	+0.00005	-0.000001519	+0.000053174
Shrubland	904888.71	15.27513057	910579.59	15.37119646	911146.50	15.38076628	**+0.0960**	**+0.00956982**	**+0.10563571**
Closed forest	24155.19	0.407755868	24142.23	0.407537094	24142.23	0.407537094	**-0.000218774**	0.000	**-0.000218774**
Sparse veg.	527163.75	8.898878973	518670.36	8.755504832	517809.60	8.740974624	**-0.1433741**	**-0.0145302**	**-0.1579043**
Urban areas	11355.66	0.191691185	11355.66	0.191691185	11355.66	0.191691185	0.000	0.000	0.000
Bare surface	2448946.08	41.3398584	2448946.71	41.33986903	2448946.71	41.33986903	**+0.00001063**	0.00	**+0.00001063**
Water bodies	37999.26	0.641453089	37999.26	0.641453089	37999.26	0.641453089	0.000	0.000	0.000

Table 4. Land cover change trajectory in the desertified areas

Location	**Land cover type**			**Trajectory**
	2000	**2005**	**2010**	
Nigeria	CL	CL	CL	CL
Burkina Faso	CL	CL	CL	CL
Senegal	CL	CL	CL	CL
Ghana	SV	SV	SV	SV
Mali	BS	BS	BS	BS

Key: CL = Cropland; SV = Sparse Vegetation; BS = Bare Surface

In the first three sampling points, the 2000-2010 land cover change trajectory show stable primary and or secondary agricultural activities. As indicated in table 4, these areas were found to be stable at the expense of natural vegetation in the area (CL-CL-CL). It suggests that these changes were extensively induced by organized human activities. For sampling point in Ghana, which is located mostly is forest and semi-deciduous woodland; the sampling point is under stable sparse vegetation (SV-SV-SV). Finally, the land cover type of the sampling location in Mali is under stable bare surface (BS-BS-BS), and therefore more vulnerable to land degradation and desertification.

However, the land cover trajectories presented in the five sampling points does not portray much change. This can be attributed partly due to the temporal extent of the study (15-years) and the spatial resolution of the data. It has been argued that for any reasonable land cover trajectory to be observed, the data should at least go beyond two decades (Brink and Eva, 2009). Nevertheless, about 60% of all the sampling points fall under CL-CL-CL land cover trajectories. These are areas mostly used by small holder and large-scale farmers for crop production. Cereal crops such as Maize, Guinea corn and millet are the dominant crops produced in the area. These areas fall under Nigeria, Burkina Faso and Senegal. The next trajectory is SV-SV-SV and it was found in Ghana from 2000 to 2010, and finally BS-BS-BS trajectory was found in the most arid zone located in Mali. However, some of the studies which examined land cover change trajectories have documented land cover alterations over three consecutive periods. For instance, the study by Boori and Vozenilek (2014), found alteration in land cover trajectories from 1991 to 2013.

CONCLUSION

The analysis presented in this work shows continued decline in closed forest and sparse vegetation and increase in cropland. This pattern of landcover change is accelerated by the increasing number of human populations which is estimated to be growing at the rate of 2-3% in Africa by the year 2100. This is expected to increase the size of cropland for food security, which will exert more pressure on the ecosystem. Overall, the land cover change trajectories in the five sampling sites shows that the major changes in the land cover have been caused by human activities and to some extent natural climatic variations especially along the marginal areas, where the size of bare surface have increased. Therefore, there is a need to carry out a comprehensive landcover assessment at local level to ascertain the major local driving forces and biophysical drivers of landcover change in the study area. Land use and land cover change processes should be included in the sustainable development agenda, so that the impact of their negative changes can be minimize for the general improvement of the livelihood of the rural dwellers of sub-Saharan West Africa, who rely more on their lands as the means of survival.

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