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Research Article

ASSESSING LAND USE-LAND COVER CHANGES OVER AFRICA (2001-2009) USING GEOSPATIAL TECHNIQUE

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ABSTRACT

Objective: There is the need for Africa as a continent to fight the consequences of Ecosystem changes to have a sustainable development that is all encompassing. As a result, this study was geared toward making Africa fight the causes and respond to the various changes for the needed development.

Methods: The study used combined Terra and Aqua MODIS combined land level 3/level 4 yearly tiled products of 2001, 2005 and 2009 data in geographic information systems environment to assess the Ecosystem status for the three dates, and the changes that have taken place over the period. The study also predicted the ecosystem situation from 2010 to 2020 using Markov Chain analysis.

Results: The result shows that barren lands decreased at an annual rate of 0.74% between 2001 and 2005 while it increased at an annual rate of 0.1% from 2005 to 2009; savanna lands increased at annual rate of 0.71% from 2001 to 2005 but decreased by annual rate of 0.1% between 2005 and 2009; farmlands decreased annually by 0.05% in the period 2001-2005 but increased annually by 0.09% between 2005 and 2009; forest decreased annually by 1.1% between 2001 and 2005 but increased at a marginal annual rate of 0.01% within 2005 and 2009; wetlands increased annually by 1.12% between 2001 and 2009 and also increased significantly by annual rate of 3.06% within the period 2005-2009; water bodies decreased at an annual rate of 0.61% between 2001 and 2005 and also decreased by annual rate of 0.42% between 2005 and 2009.

Conclusion: There is the need to strengthen environmental governance and promotion of capacities to do that effectively and promote sustainable management of African natural resources for the improvement of the economy of the continent in a sustainable way. Enlighten the populace about knowledge on natural resource conservation and management, and most importantly there is a need for synergy in the management of the various ecosystems in the continent.

Keywords: Assessment, Change, Ecosystem, Land cover, Land use, MODIS.

INTRODUCTION

This paper looks at the Ecosystem which is used interchangeably as land use (Lu)-land cover (LC) types in Africa from two perspectives. The first perspective looks at the major land use-LC types (primary classes) that are divided into six categories, namely Barren lands, savanna lands, farmlands, forest lands, wetlands, and water bodies. The second perspective explores the various subunits under the primary classes which are barren or sparsely vegetated, urban and built-up, Closed shrub lands, grasslands, open shrub lands, savannas, woody savannas, cropland mosaics, croplands, deciduous broadleaf forest, deciduous needle leaf forest, evergreen broadleaf forest, evergreen needle leaf forest, mixed forest, permanent wetlands, snow/ice, and water bodies.

LC refers to the physical cover on the land (the layer of soils and biomass) including natural vegetation, crops and artificial constructions that cover the land surface (Campbell, 1996; Anderson *et al.,* 1976, Weng, 2000) [3,1,12]. Land use is defined as "the arrangements, activities and inputs people undertake in a certain LC type to produce, change or maintain it" (FAO/UNEP, 1999) [4]. The United Nations Food and Agriculture Organization Water Development Division explains that Land use concerns the products and/or benefits obtained from the use of the land as well as the land management actions (activities) carried out by humans to produce those products and benefits.

LC change refers to complete or partial replacement of one cover type by another. Land use change includes the modification of LC types such as intensification of agricultural use, without changing its overall classification (Verburg *et al*., 2000) [10]. Changes in the LC are either caused by changes in land use, climate change or natural hazards (like forest fires or droughts, for instance).

Assessing land use-LC and the changes helps policy makers, planners to reduce human impact on the environment that leads mostly to the deterioration of earth system processes with a view to plan and embark on the potential for ecological restoration through effective and efficient land management (Victor and Ausubel, 2000) [11].

MODIS data have been used by several authors and are found to be good for LC and vegetation mapping (Borak *et al*., 2000; Fensholt, 2004; Hansen *et al.*, 2003; Townshend and Justice, 2002; Zhan *et al.,* 2000) [2,5,6,9,13]. Sedano *et al.,* 2005 [8] in their study, "LC assessment with MODIS imagery in southern African Miombo ecosystems" affirmed that the analysis of their results shows that LC classifications from MODIS images can provide good quality results, with some cases presenting overall accuracies around 0.89, and individual accuracies of over 80% for every single LC type. In the light of this, the study aimed to assess and map the land use-LC of Nigeria for 2001, 2005 and 2009; determine the changes that have taken place between 2001 and 2009; and on the basis of the changes project what the situation will be from 2010 to 2020 and the likely implications. The study was to enable the plan to establish African Ecosystem Research Network having known the status of the land use and LC for about then years. The result would enable researchers to know the land use and LC types that need attentions and the type of attentions needed.

METHODS

The study used combined Terra and Aqua MODIS combined land level 3/level 4 yearly tiled products of 2001, 2005 and 2009 satellite imagery downloaded from http://ladsweb.nascom.nasa.gov. These dates were selected based on the fact that it was a continental analysis and the need to use MODIS for the analysis as earlier stated based on its high-

level accuracy and amenability for regional analysis. As at the time of the research, the most recent MODIS data were for 2009. All the data were carefully selected to cover the same season; this is because there was a need to minimize disparity that could affect the analysis because of effect of seasonal changes. The 2001 data captured on 15/05/2001, the 2005 data were of 10/05/2005, and the 2009 data were of 09/05/2009. The data were cloud free.

The data were processed using raster based image processing program. Preliminary analysis of the data processing starts with the geometric correction, radiometric correction, the preparation of the composite image, and supervised multispectral classification (Lillesand and Kiefer, 1979) [7].

Interpretation of the MODIS data for 2001, 2005 and 2009 produced the first set of results which are the land use, and LC data for years 2001, 2005 and 2009, respectively. The land use and LC data interpreted from the MODIS data sets were integrated into a common multi-temporal spatial database to generate land use and LC change analysis (LULCC). The results which represent the second set of analysis are LULCC data for years 2001-2005, 2005-2009 and 2001-2009. The comparison of the land use LC statistics assisted in identifying the change between 2001 and 2009.

Mapping and statistics of LC types in 2001, 2005, and 2009 were done using Arcgis 9.2 (ESRI, Redlands, CA, USA). The magnitude change in land use-LC types was calculated using Formula 1 while the annual change was calculated using Formula 2.

Magnitude change (C)=Magnitude B-Magnitude A (1)

Annual change=100/4*C/B (2)

Where, A is the magnitude for the base year, B is the magnitude for the second year, and C is the magnitude change.

The Markov Chain model was used to predict the LC change based on aggregated LC of Africa. As a result of the area transition matrix of LC from 2001 to 2009, the transition probability matrix was generated, and therefore the land use-LC category from 2010 to 2020 was predicted annually.

RESULTS AND DISCUSSION

Land use-LC status

Results for the status of the land use-LC classes for 2001, 2005 and 2009 were generated and are presented in Table 1. The maps for the land use-LC for 2001, 2005 and 2009 are presented in Figs. 1-3, respectively.

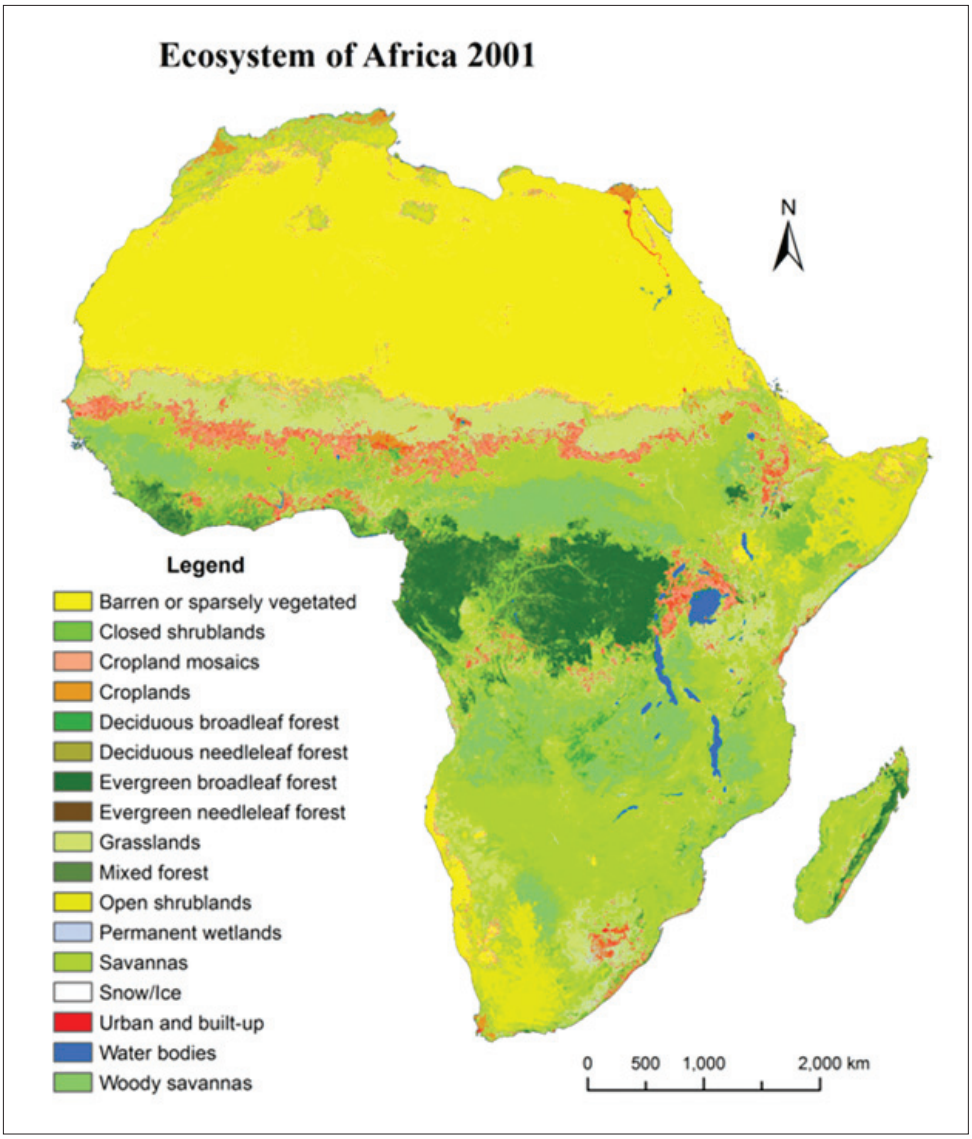

Fig. 1: Land use-land cover of Africa 2001. Source: Geographic information systems analysis, 2012

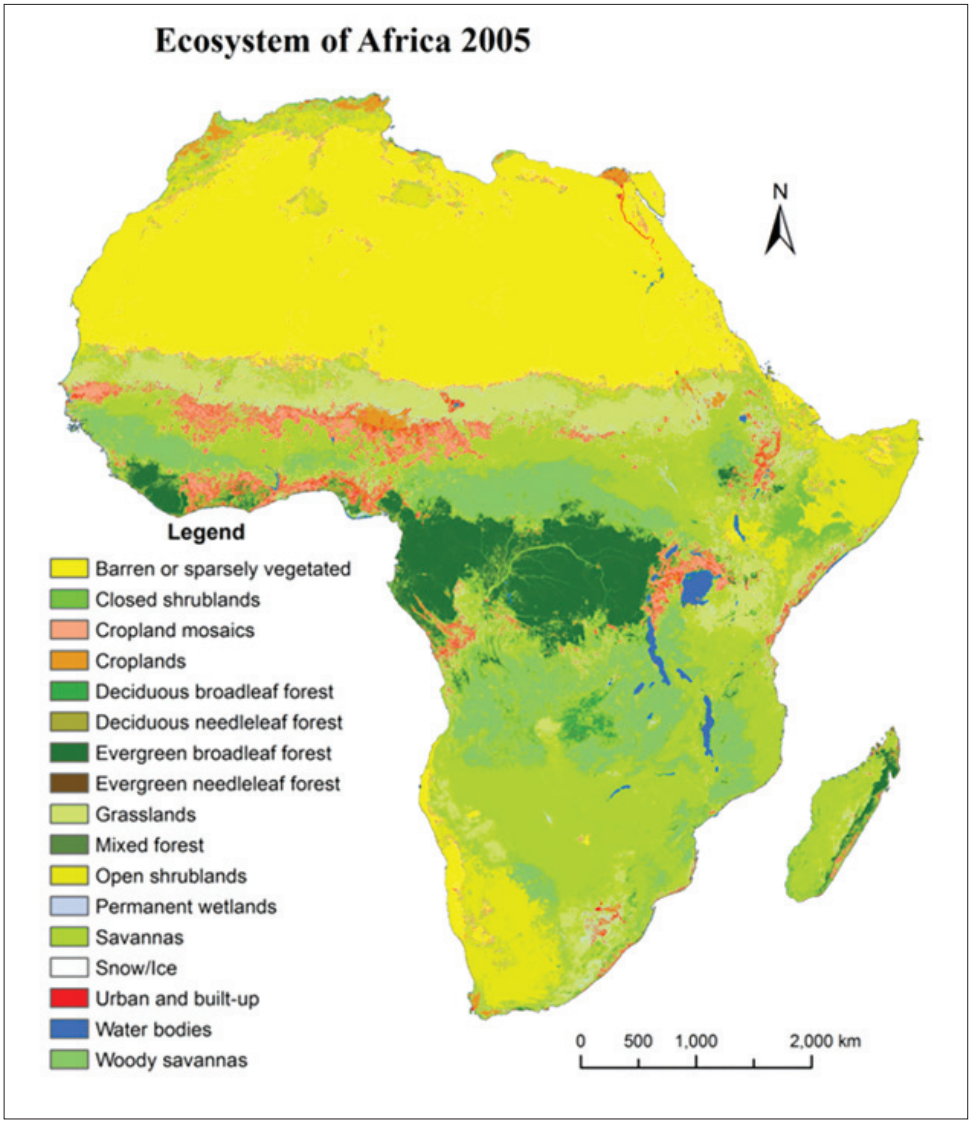

Fig. 2: Land use-land cover of Africa 2005. Source: Geographic information systems analysis, 2012

From Table 1 and as depicted in Figs. 1-3, it can be observed that Barren or sparsely vegetated area covered 975825084.2 ha (32.58%) in 2001, decreased to 946920778.7 ha (31.61%) in 2005 and increased slightly to 950623855.5 ha (31.74%) in 2009. Urban and built-up area was 4019805.645 ha (0.13%) in 2001, decreased to 4019011.408 ha (0.13%) in 2005 and remained constant at 4019805.645 ha (0.13%) in 2009. On the overall, the barren land (Barren or sparsely vegetated area; and urban and built-up area combined) was 979847401.4 ha (32.71%) in 2001, decreased to 950940584.3 ha (31.75%) in 2005 but increased slightly to 954642866.9 ha (31.87%) in 2009.

The savanna land use-LC as a whole was 1474552957 ha (49.23%) in 2001, increased to 1516508467 ha (50.63%) in 2005 and decreased to 1510416067 ha (50.43%) in 2009. The various categories that made up the savannah land use-LC are closed shrub lands which were 51680685.53 ha (1.73%) in 2001, 44118603.92 ha (1.47%) in 2005 and 47314420.79 ha (1.58%) in 2009. Grasslands was 262650084.6 ha (8.77%) in 2001, 266635394.6 ha (8.90%) in 2005 and 273390767.4 ha (9.13%) in 2009. Open shrub lands was 243492871.3 ha (8.13%) in 2001, 282325119 ha (9.43%) in 2005 and 263544996.6 (8.80%) in 2009. Savannas was 432966522.5 ha (14.45%) in 2001, 438161047.8 ha (14.63%) in 2005 and 443376416.3 ha (14.80%) in 2009. The Woody savannas were 483762792.9 ha (16.15%) in 2001, 485268301.5 ha (16.20%) in 2005 and 482789466 ha (16.12%) in 2009.

The farmland land use-LC was 213689467.9 ha (7.13%) in 2001, 213258798.2 ha (7.12%) in 2005 and 213998533.5 ha (7.14%) in 2009. The specific breakdown is cropland mosaics which was 165221965.1 ha (5.52%) in 2001, 151864915 ha (5.07%) in 2005 and 146576691.3 ha (4.89%) in 2009. The croplands was 48467502.78 ha (1.62%) in 2001, 61393883.17 ha (2.05%) in 2005 and 67421842.17 ha (2.25%) in 2009.

The forest land use-LC was 288134555.5 ha (9.62%) in 2001, 275443119 ha (9.20%) in 2005, and 275593101 ha (9.20%) in 2009. The components are deciduous broadleaf forest which was 2799707.212 ha (0.09%) in 2001, 25511453.48 ha (0.85%) in 2005, and 21749989.55 ha (0.73%) in 2009. Deciduous needle leaf forest was 33615741.43 ha (1.12%) in 2001, 15541.28794 ha (0.003%) in 2005 and 15541.28794 ha (0.001%) in 2009. Evergreen broad leaf forest was 33572.6165 ha (0.001%) in 2001, 249063414.1 ha (8.32%) in 2005, and 252791520.1 ha (8.44%) in 2009. Evergreen needle leaf forest had 251205514.5 ha (8.39%) in 2001, 118362.7924 ha (0.004%) in 2005, and 258835.4282 ha (0.01%) in 2009. Mixed forest had 480019.7252 ha (0.02%) in 2001, 672268.0329 ha (0.02%) in 2005, and 777214.6583 ha (0.03%) in 2009.

The water bodies had 24278840.44 ha (0.81%) in 2001, 23688056.84 ha (0.79%) in 2005, and 23290036.74 ha (0.78%) in 2009. The

Table 1: Land use-land cover distribution for 2001, 2005 and 2009

Primary class	Secondary class	2001		2005		2009	
		Area (Ha)	Percent	Area (Ha)	Percent	Area (Ha)	Percent
Barren	Barren or sparsely vegetated	975825084.2	32.58	946920778.7	31.61	950623855.5	31.74
	Urban and built-up	4022317.151	0.13	4019805.645	0.13	4019011.408	0.13
	Total	979847401.4	32.71	950940584.3	31.75	954642866.9	31.87
Savanna	Closed shrub lands	51680685.53	1.73	44118603.92	1.47	47314420.79	1.58
	Grasslands	262650084.6	8.77	266635394.6	8.90	273390767.4	9.13
	Open shrub lands	243492871.3	8.13	282325119	9.43	263544996.6	8.80
	Savannas	432966522.5	14.45	438161047.8	14.63	443376416.3	14.80
	Woody savannas	483762792.9	16.15	485268301.5	16.20	482789466	16.12
	Total	1474552957	49.23	1516508467	50.63	1510416067	50.43
Farmlands	Cropland mosaics	165221965.1	5.52	151864915	5.07	146576691.3	4.89
	Croplands	48467502.78	1.62	61393883.17	2.05	67421842.17	2.25
	Total	213689467.9	7.13	213258798.2	7.12	213998533.5	7.14
Forest	Deciduous broadleaf	2799707.212	0.09	25511453.48	0.85	21749989.55	0.73
	Deciduous needle leaf	33615741.43	1.12	77620.57625	0.003	15541.28794	0.001
	Evergreen broadleaf	33572.6165	0.001	249063414.1	8.32	252791520.1	8.44
	Evergreen needle leaf	251205514.5	8.39	118362.7924	0.004	258835.4282	0.009
	Mixed	480019.7252	0.02	672268.0329	0.02	777214.6583	0.03
	Total	288134555.5	9.62	275443119	9.20	275593101	9.20
Wetlands	Permanent wetlands	14846888.6	0.50	15511085.47	0.52	17409505.31	0.58
	Total	14846888.6	0.50	15511085.47	0.52	17409505.31	0.58
Water bodies	Snow/ice	22367.43375	0.001	22174.24095	0.001	3498.936374	0.0001
	Water bodies	24256473.01	0.81	23665882.6	0.79	23286537.8	0.78
	Total	24278840.44	0.81	23688056.84	0.79	23290036.74	0.78
	Grand total	2995350111	100	2995350111	100	2995350111	100

Source: Geographic information systems analysis, 2012

Table 2: Change in secondary land use-land cover types (2001-2009)

Primary class	Secondary class	2001-2005 change		2005-2009 change	
		Magnitude (Ha)	Annual %	Magnitude (Ha)	Annual %
Barren	Barren or sparsely vegetated	−28904305.5	−0.74	3703076.8	0.10
	Urban and built-up	−2511.51	−0.02	−794.237	−0.01
Savanna	Closed shrub lands	−7562081.61	−3.66	3195816.87	1.81
	Grasslands	3985310	0.38	6755372.8	0.63
	Open shrub lands	38832247.7	3.99	−18780122.4	−1.66
	Savannas	5194525.3	0.30	5215368.5	0.30
	Woody savannas	1505508.6	0.08	−2478835.5	−0.13
Farmlands	Cropland mosaics	−13357050.1	−2.02	−5288223.7	−0.87
	Croplands	12926380.39	6.67	6027959	2.45
Forest	Deciduous broadleaf	22711746.27	202.80	−3761463.93	−3.69
	Deciduous needle leaf	−33538120.85	−24.94	−62079.29	−19.99
	Evergreen broadleaf	249029841.5	185441.19	3728106	0.37
	Evergreen needle leaf	−251087151.7	−24.99	140472.64	29.67
	Mixed	192248.3077	10.01	104946.63	3.90
Wetlands	Permanent wetlands	664196.87	1.12	1898419.84	3.06
Water bodies	Snow/Ice	−193.19	−0.22	−18675.30	−21.06
	Water bodies	−590590.41	−0.61	−379344.8	−0.40

Table 3: Change in primary land use-land cover distribution (2001-2009)

Land use	Year			
	2001-2005 change		2005-2009 change	
	Magnitude (ha)	% Annual	Magnitude (ha)	% Annual
Barren	−28906817.1	−0.74	3702282.6	0.10
Savanna	41955510	0.71	−6092400	−0.10
Farmland	−430669.7	−0.05	739735.3	0.09
Forest	−12691436.5	−1.10	149982	0.01
Wetlands	664196.87	1.12	1898419.84	3.06
Water bodies	−590783.6	−0.61	−398020.1	−0.42

Source: Geographic information systems analysis, 2012

breakdown of the water bodies had Snow/Ice cover of 22367.43375 ha (0.001%) in 2001, 22174.24095 ha (0.001%) in 2005, and 3498.936374 ha (0.0001%) in 2009. The main water bodies (secondary class) covered 24256473.01 ha (0.81%) in 2001, 23665882.6 ha (0.79%) in 2005, and 23286537.8 ha (0.78%) in 2009.

The permanent wetlands was 14846888.6 ha (0.50%) in 2001, 15511085.47 ha (0.52%) in 2005, and 17409505.31 ha (0.58%) in 2009.

Change analysis in land use-LC types 2001-2009 (Table 2)

From the change analysis Table 3, it is observed that barren lands decreased in magnitude of 28906817.1 ha at an annual decrease rate of 0.74% between 2001 and 2005 while between 2005 and 2009, it increased with a magnitude of 3702282.6 ha at an annual increase

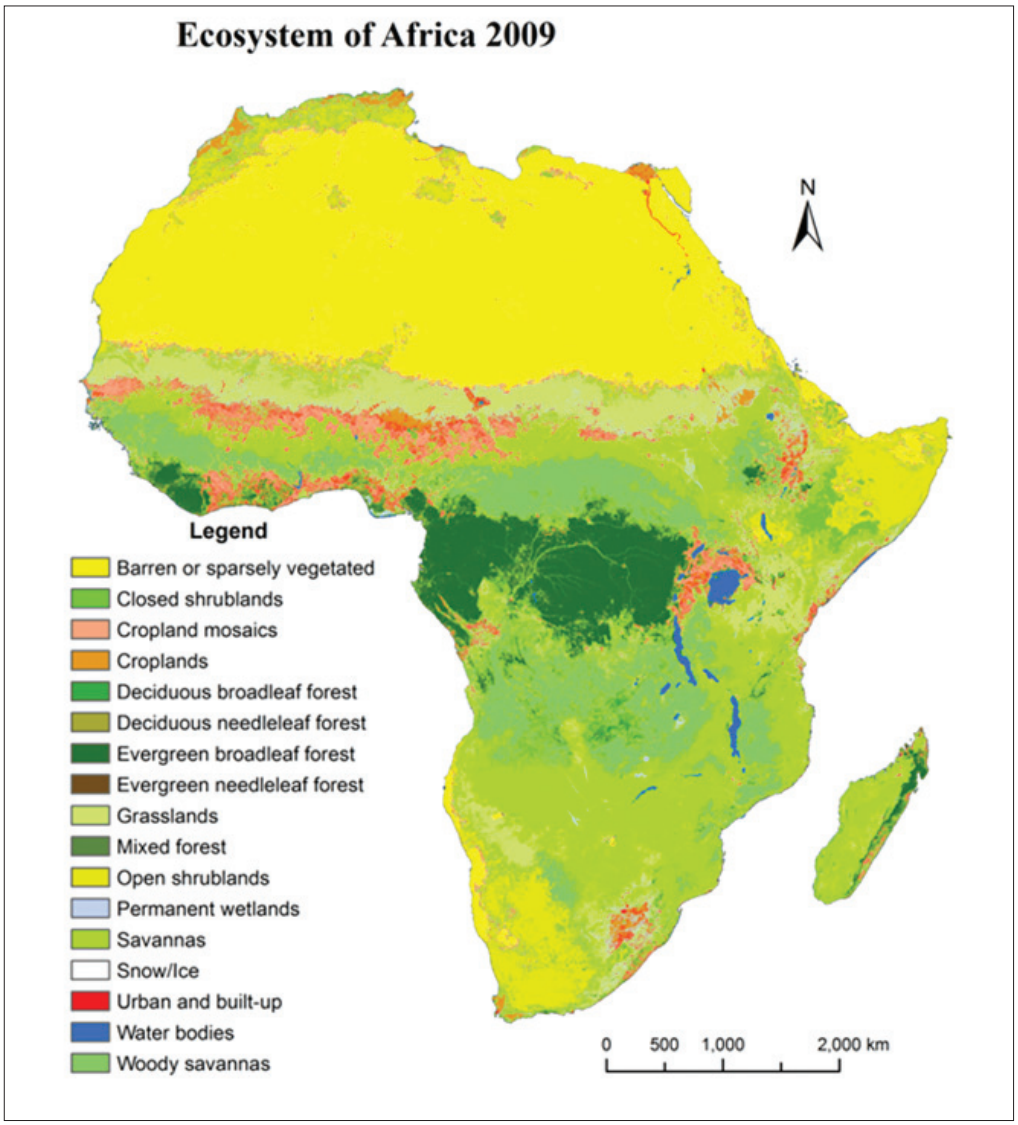

Fig. 3: Land use-land cover of Africa 2009. Source: Geographic information systems analysis, 2012

rate of 0.10%. This increase could be as a result of increase in built-up and devegetation resulting from several factors such as an increase in agriculture, lumbering, and deforestation activities.

The savannah land use-LC gained in magnitude to the tune of 41955510 ha at an annual rate of 0.35% from 2001 to 2005. This is basically as a result of forest loss during the same period as shown in Table 3. However, from 2005 to 2009, savannah decreased in magnitude by 6092400 ha at an annual rate of 0.05%. This also coincided with the gain forest ecosystem as can be seen in Table 3.

Farmland land use-LC decreased by 430669.7 ha at an annual rate of 0.004% between 2001 and 2005 but increased by 739735.3 ha which is an annual rate of 0.01% from 2005 to 2009. The increase could be as a result of the various programs of the governments and organizations in Africa to increase food production to meet the high increase in food demand by the increasing African population.

The forest land use-LC decreased with a magnitude of 12691436.5 ha at an annual rate of 0.12% between 2001 and 2005 due to activities such as lumbering, farming activities, infrastructural development, wood for fire/charcoal, natural fire, and in some cases mining activities. The forest land use-LC, however, gained 149982 ha at an annual increase of 0.0013% from 2005 to 2009. This is probably attributable to several policies and programs at afforestation, reforestation and preserving the forests with serious enlightenment and campaign on the effects of climate change as is widely going on in the continent.

Wetlands land use-LC increased in magnitude by 664196.87 ha with an annual increase of 0.01% between 2001 and 2005. It also gained in magnitude by 1898419.84 ha at an annual increase of 0.02% from 2005 to 2009. This could be linked to the fact that water bodies in Africa are shrinking thereby enhancing the increase in wetlands.

The water bodies in Africa decreased by 590783.6 ha at an annual rate of 0.01% from 2001 to 2005 and further decreased by 398020.1 ha at an annual decrease rate of 0.003% between 2005 and 2009. This decrease area increased the area of wetlands and clearly shows that the effect of climate change in the form of drought is already telling on the water bodies of Africa. Water as a highly strategic resource constitutes a priority concern as it is vital for the sustenance of life and agricultural production.

The future prediction

The land use-LC statistics of the three dates were used to produce the transfer probability with the land use-LC of 2009 taken as the base for the prediction using Markov chain analysis. The resultant result is as shown in Table 4 and Fig. 4.

Table 4: Predicted statistics of the land use-land cover types

Land use-land cover types	Year 2010 (ha)	2011 (ha)	2012 (ha)	2013 (ha)	2014 (ha)	2015 (ha)	2016 (ha)	2017 (ha)	2018 (ha)	2019 (ha)	2020 (ha)
Water	22703729	22151837	21630054	21135965	20667933	20224649	19804942	19407708	19031884	18676440	18340377
Forest	269668355	265056953	261466900	258696354	256593195	255036672	253928243	253186401	252743337	252542526	252536843
Savanna	1531579348	1550137680	1566620140	1581393473	1594724575	1606817104	1617832579	1627902896	1637138055	1645631168	1653461885
Wetland	17729284	17843660	17881609	17895165	17904530	17916877	17934164	17956353	17982732	18012426	18044602
Farmland	214832107	216139462	217638330	219184852	220707569	222172788	223566313	224883846	226125972	227295567	228396463
Barren	938833768	924016999	910109558	897040782	884748789	873178500	862280349	852009386	842324609	833188463	824566421

Source: Geographic information systems analysis, 2012

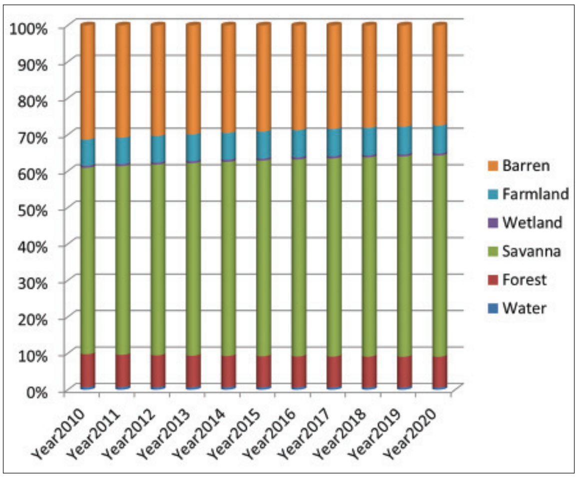

Fig. 4: Predicted land use-land cover 2010-2020. Source: Geographic information systems analysis, 2012

From Table 4 and as depicted in . 4, it can be seen that forest, water bodies, and barren lands will continue to decrease in magnitude if interventions are not done to arrest the situation while wetlands, savannah and farmlands will continue to increase. In view of this, there is the need and urgent concern to continuously monitor the various ecosystems in Africa in other to achieve sustainable development so as to avert the dangerous impacts of the continuous degradation of the land use-LC on the already impoverished society.

CONCLUSION

Significant progress in the quantification and understanding of LULCC has been achieved; however, there is the need to identify conditions for sustainable land use and efficient use of natural resources in the continent. Among other things, it is of most important for effective collaboration, linkages, and coordination among institutions of environmental management to reverse environmental degradation and depletion of natural resources, ameliorate the quality of the living environment, conserve biological diversity, with a view to ensuring a healthy and productive environment; thereby improving the well-being of the ecosystem and the population of the continent. There is the need to strengthen environmental governance and promotion of capacities to do that effectively and promote sustainable management of African natural resources for the improvement of the economy of the continent in a sustainable way. Enlighten the populace about knowledge on natural resource conservation and management, and most importantly there is a need for synergy in the management of the various ecosystems in the continent.

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