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ORIGINAL ARTICLE

Assessing Land Use/Land Cover Dynamic and Its Impact in Benin Republic Using Land Change Model and CCI-LC Products

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Abstract
Accurate information on land use/land cover (LULC) dynamics is necessary for the selection and execution of land use schemes to meet the increasing demands of basic human needs and welfare. This study aims to assess the LULC dynamics and its impacts in Benin using the climate change initiative land cover (CCI-LC) product within a GIS environment. The CCI-LC maps were acquired from the European Space Agency (ESA) for the years 2001, 2008 and 2013. The maps of 2001 and 2008 were used to simulate the LULC scenario for 2013 using Modules for Land Use Change Evaluation (MOLUSCE) available in QGIS software. The predicted result was compared with the observed LULC map of 2013 to validate the model. Finally, based on this, the prediction of future LULC scenario for years 2025 and 2037 was performed. The outcomes of this study revealed the rapid increase of cropland, forest and a considerable reduction of the Savannah land.

Keywords CCI-LC · LULC change · MOLUSCE · Remote sensing · GIS

1 Introduction

Land use/land cover (LULC) change, as one of the major driving forces of global environmental transform processes, is essential to the worldwide sustainable development debate. The observed modifications of the natural landscape of the Earth are generally termed as LULC change (Veldkamp and Lambin 2001; Lambin and Meyfroidt 2010). Moreover, besides the decline in biodiversity, LULC change is regarded as an important component contributing to the current global change (Meyfroidt et al. 2013; Van Asselen and Verburg 2013; Lambin and Meyfroidt 2011; Hibbard et al. 2010; Verburg et al. 2009; Lambin et al. 2003; Turner and Billie 2002; Lambin et al. 2001). According to Lambin et al. (2001), the important key component of Earth system functioning was affected by land use and land cover changes which are so pronounced when brought together globally. The biosphere is influenced in different ways by different anthropogenic activities and land surface changes seem to by far a very old process (Turner and Billie 2001). It is posited that LULC change is the most important indicator of human-induced alteration of the Earth's terrestrial surface. Therefore, land use is known as an important factor (Foley et al. 2005) because of human activities such as agriculture and urbanization that have a considerable impact on the environment. In future, these ongoing changes will lead to an increasing demand of food and energy for the growing population in the world (Schaldach 2006).

In the land change science, the integration of remote sensing (RS) and geographic information system (GIS) has been recognized as a powerful and effective tool for the management of land and other natural resources. Thus, analysing and monitoring LULC changes are vital to scientists, environmentalists, agriculturalist, policy makers and urban planners (Babalola and Akinsanola 2016). In addition, RS technologies facilitate the acquisition of LULC information over large areas at no cost from local to global scales (Mishra and Rai 2016). Therefore, an integrated approach of RS and GIS is the best pathway to extract and examine

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the past and current trends of LULC changes and to predict future scenarios in an efficient manner (Kumar and Shaikh 2013; Youssef et al. 2010; Yang et al. 2008; Mishra and Rai 2016; Mishra et al. 2018).

The transition from rural landscape to urban forms is possible because of the changes in the distribution of the population from village to town and city which contribute to urban growth (Thapa and Murayama 2010). According to the United Nations Framework Convention on Climate Change (2012), Moghadam and Helbich (2013) and Li et al. (2013), the projection by 2050 shows that more than half (72%) of the world's population reside in cities. This large concentration in towns is not without consequences. Thapa and Murayama (2010) confirmed that the urban growth consequence on land use changes is a complex interaction between behaviour and structural factors with the demand, the technological capacity which at the end strains the environment. Increasing urbanization has strong impact on the ecological system catheterized by green spaces within the city which play a decisive role in cleaning the air, adjusting the microclimate, eliminating noise and beautifying the surrounding places (Byomkesh et al. 2012). In addition, socioeconomic processes factor (forest patterns, agricultural, migration and urban sprawl) also contribute to urban growth (Thapa and Murayama 2009). Thus, the land is used for goods and services production and as residential land for those migrating from the village to the city (Lu and Sasaki 2008).

The most important factor in understanding the interactions between anthropogenic activities and the environment is the change in land use and land cover (LULCC) (Dewan et al. 2012). Both human and natural factors contribute to LULCC, the human activity throughout modification in land use/cover in the whole world currently has appeared as the one deeply affecting our ecological systems (Lambin et al. 2001). Thus, the change of land use and cover driven by the socio-economic development results lead to environmental degradation (Grimm et al. 2008). Moreover, forest landscape change due to human activities contributed to carbon flux increasing in the atmosphere which in turn contributed to global climate change (Alves and Skole 1996; Dewan et al. 2012).

In the last decades, Benin Republic experienced rapid population growth and urban expansion. Therefore, understanding the past changes in LULC and predicting the future scenarios are vital for proper land use planning and sustainable management. An increase in human population since 2000 by about 54% from 6.7 million to 10.6 million in 2015 is without precedent (United Nations 2017). The density of the population in 2000 was around 61 inhabitants/km^2 which increased to 94 inhabitants/km^2 in 2015 (INSAE_Benin 2014; United Nations 2017). The vegetation is dominated by forest with two national parks between them and several game reserves and protected areas. Benin (114,673 km^2) is covered by about 21.3%, the equivalent of 2,351,000 ha. Annually, Benin loses an average of 64,700 ha of forest cover and the major changes occurred between 1990 and 2000. This amounts to an average annual deforestation rate of 1.95%. Between 2000 and 2005, the rate of forest change increased from 24.4% to 2.42% per annum. In total, between 1990 and 2005, Benin lost 29.2% of its forest cover, about 971,000 ha (Rhett 2007; Thomson 2007). Many people, particularly rural populations, mostly depend on services provided by the ecosystem (natural resources) and agroecological systems (Schumann et al. 2012).

Several studies were carried on LULC change analysis using an integrated approach of RS and GIS in the last few decades (Mishra and Rai 2016; Babalola and Akinsanola 2016; Issiaka 2016; Oladoye et al. 2014; Srivastava et al. 2013; Houessou et al. 2013; Mishra et al. 2018). Nevertheless, the attention on LULC change studies in Benin Republic was very limited. Most of the previous studies focused on the use of MODIS data with good temporal resolution but a coarse spatial resolution of 500 m. It could not delineate small-scale vegetation areas with accuracy (Oke 1987; Garratt 1990; Agustan et al. 2012; Ozdogan 2010; Muñoz-Robles et al. 2012; Vintrou et al. 2012; Begue et al. 2014; Zhang et al. 2014). The Landsat series satellites images like Landsat 5-TM, Landsat 7-ETM and Landsat 8-OLI offer more opportunities in LULC change studies with the spatial resolution of 30 m. But, the use of Landsat images was restricted due to the frequent cloud cover, and the number of scenes to cover the entire area. Thus, for this study, another product from the climate change initiative and land cover (CCI-LC) was used.

People constantly change the land surface through constructions, agriculture, energy production, and many other activities. Change both in how land is used by people (land use) and in the natural cover of the Earth's surface (land cover) can be described and the future land change can be projected using land change models (LCMs) (NRC 2014). LCMs are primal in trying to understand the ongoing modifications brought onto the Earth's surface and how human beings have been reshaping it in the past and present, and to forecast future landscape conditions, ending with developing policies to manage the resources and the environment at scales ranging from an individual parcel of land to vast expanses of planetary or global forests (NRC 2014). Moreover, land use models are known as the most important subject of LULCC in the recent decade used to predict or explore possible land use change trajectories.

The objectives of this study are: (1) to assess the dynamics of LULC with their related implications on biodiversity, (2) to predict future LULC change scenario in the Benin Republic in 2025 and 2037. This type of analytical study could be used significantly in the sustainable development and management of an area.

2 Study Area

The area for this study is Benin Republic, West Africa (Fig. 1) located at 6°N–12°N, 0.4°E–3°E and an area of 114,673 km^2. The climate in Benin is characterized by three regions: the Sudanian, Sudano-Guinean and Guineo-Congolian region (White and Hopkins 1987; Mayaux et al. 1999). The northern part of Benin Republic has a continental tropical climate with both dry and rainy seasons; and the southern part has a sub-equatorial climate, with two rainy and two dry seasons. The middle of the country experiences a transitional climate. Throughout the year, average rainfall varies between 700 mm (extreme north) and 1500 mm (extreme southeast). In terms of biological resources, the primary forest formations found in Benin are mainly woodlands and Savannahs (centre and northern parts), and semi-deciduous and deciduous rain forests in the southern part (MEHU 2011). The protected areas are divided into two national parks (869,867 ha), three hunting zones (443,679 ha) which belongs to the regional centre of Sudanian endemic (White and Hopkins 1987), 46 classified forests (1,302,863 ha), seven reforestation areas, and sacred forests covering about 0.2% of the territory. The fauna is quite diverse and contains several species of mammals, reptiles, birds, and invertebrates. In terms of biological resources, the primary forest formations found in Benin are mainly woodlands and Savannahs (centre and northern parts), and semi-deciduous and deciduous rain forests (Ministère de l'Environnement et de la Protection de la Nature 2009).

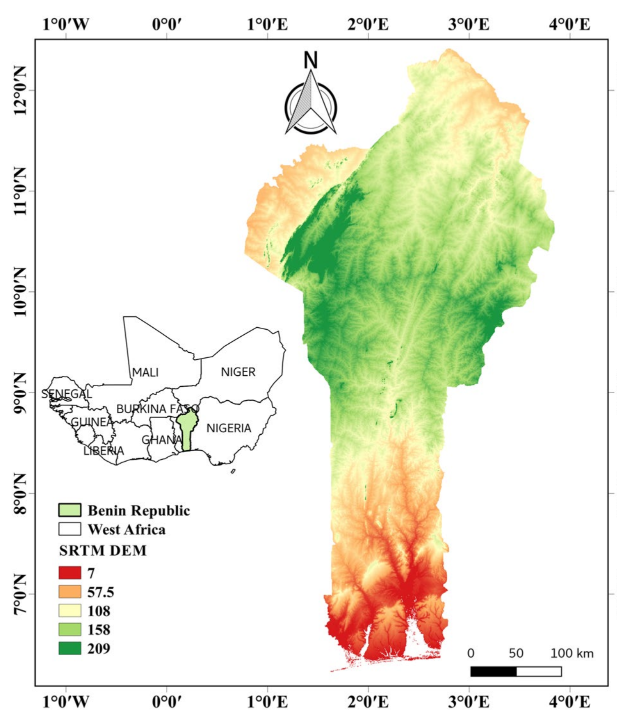

Fig. 1 Location of the study area as viewed on SRTM DEM

3 Materials and Methods

3.1 Data Used

The Climate Change Initiative Land Cover (CCI_LC) maps from the European Space Agency (ESA) were acquired for three different years: 2001, 2008 and 2013 (CCI-LC 2017). This project delivers a consistent global LC map at 300 m spatial resolution, annual images from 2001–2013 (ESA 2016). The coordinate reference system used for the global land cover database is a geographic coordinate system (GCS) based on the World Geodetic System (WGS 84). Table 1 summarises the CCI-LC products and shows an example of the land cover map of the world. The CCI-LC products are already classified maps. They proceed from a unique baseline LC map which brings forth times to the entire medium resolution imaging spectrometer (MERIS FR and RR) archive from 2003 to 2012. From this baseline, LC modification is observed at 1 km based on the advanced very high resolution radiometer (AVHRR) time series between 1992 and 1999, Satellite Pour l'Observation de la Terre of vegetation (SPOT-VGT) time series between 1999 and 2013 and Project for On-Board Autonomy, with the V standing for Vegetation (PROBA-V) data for years 2013, 2014 and 2015. When MERIS FR or PROBA-V time series are available, changes detected at 1 km are re-mapped at 300 m.

3.2 Data Processing

Data processing consisted of the reclassification of CCI-LC product in ARC Map and QGIS environment. Seven

Table 1 CCI land cover products

Data type	Spatial coverage	Temporal coverage	Spatial resolution	Temporal resolution	Sensor	Projection	Format
CCI-LC	Global	2001 2008 2013	300 m	1 year	MERIS; FR/RR SPOT-VGT; AVHRR; PROBA-V	WGS84	Geotiff

LULC classes were considered in the process: cropland, forest, Savannah, wetland, urban, bare land and water bodies. Change detection was carried out on the reclassified products.

3.3 LULC Change Prediction and Validation

Change detection was carried out using 2001, 2008 and 2013 satellite images. It helped to observe the evolution of forest and other land covers during the last two decades. In this study, multi-layer perceptron artificial neural network (MLP-ANN) based on great significance of LULC transitions that occurred on the geographical area was used to study LULC changes between 2001 and 2013. It allows generating a class statistics and a transition matrix of land use and land cover change. The class statistics describes changes that occurred in LULC between initial and final periods. The transition matrix depicts the number of pixels that change from one of LULC type to another. The outputs from this analysis were used to predict the future land use land cover using MOLUSCE (Modules for Land Use Change Evaluation). MOLUSCE is one of the QGIS Plugins. It is designed to analyse and simulate current and future land use and land cover. The prediction of LULC change includes different steps given as:

- Change detection: in this step, transition matrix and change maps were generated and subsequently used in the modelling process.
- Selection of variables: distances to major road were used as a variable to improve the accuracy of the model.
- Transition potential using the MLP-ANN method, generates a probability matrix that underpins the prediction model.
- Land use and land cover prediction: the MLP-ANN simulation tab was used to predict land use and land cover for 2025 and 2037.

The transition potential modelling was performed for the time period between 2001 and 2008 to predict the LULC map of 2013. Nevertheless, validation model is performed by comparing the predicted and observed map. Thus, the model was validated by comparing the predicted LULC map of CCI-LC of 2013 with the observed map of 2013 using kappa index statistics (Kamusoko et al. 2009; Wang et al. 2012; Asia Air Survey and Next GIS 2017). The components of kappa are: kappa overall (Kovr), kappa histogram (Khisto) and kappa location (Kloc) (Asia Air Survey and Next GIS 2017). Finally, the predictions for 2025 and 2037 were carried out using MLP-ANN and the plausible changes in LULC were determined.

4 Results and Discussion

4.1 Identification of Major Land Use and Land Cover Type for CCI-LC

The paramount LULC was Savannah, while the bare land occupied a small portion of the area. For example, in 2001, Savannah occupied 38,829.06 km^2 (35.0%), cropland 37,059.21 km^2 (33.4%), forest land 34,313.49 km^2 (30.9%), water bodies 408.51 km^2 (0.4%), urban 232.38 km^2 (0.2%), wetland 94.23 km^2 (0.1%), and bare land 4.8 km^2, respectively (Table 2, Fig. 3).

Similarly, in 2008, cropland covered the large portion spatially 38,087.1 km^2 (34.3%) in opposition to the other LULC types. Nevertheless, this land cover type increased. Thus, cropland increased in this period and covered 38,087.1 km^2 (34.3%), Savannah 36,832.86 km^2 (33.2%), forest land 35172.63 km^2 (31.7%), water bodies 380.79 km^2 (0.3%), urban 350.9 km^2 (0.3%), wetland 114.93 km^2 (0.1%), and bare land 2.4 km^2, respectively (Fig. 4). In addition, in 2013, Savannah decreased, but cropland reclaimed additional area from other land cover types (Fig. 5).

But, cropland remained the dominant land type. This last one covered about 39029.22 km^2 (35.2%), Savannah 35556.75 km^2 (32.0%), forest land 35406.99 km^2 (31.9%), urban 455.67 km^2 (0.4%), water bodies 375.21 km^2 (0.3%), wetland 115.65 km^2 (0.1%) and bare land 2.16 km^2,

Table 2 Proportion of land cover categories

LULC types	2001		2008		2013	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Cropland	37,059.2	33.4	38,087.1	34.3	39,029.2	35.2
Forest	34,313.5	30.9	35,172.6	31.7	35,407.0	31.9
Savannah	38,829.1	35.0	36,832.9	33.2	35,556.8	32.0
Wetland	94.2	0.1	114.9	0.1	115.7	0.1
Urban	232.4	0.2	350.9	0.3	455.7	0.4
Bare land	4.8	0.0	2.4	0.0	2.2	0.0
Water bodies	408.5	0.4	380.8	0.3	375.2	0.3
Total	110,941.7	100.0	110,941.7	100.0	110,941.7	100.0

respectively. Figure 2 shows the type of LULC-based slope gradient in percentage.

4.2 Dynamics of LULC Between 2001 and 2013

Most researches on LULC dynamics indicated agriculture as a predominant land use occupying the majority of the active population. Furthermore, it is depicted as the main factor of land degradation and deforestation that jeopardizes environmental sustainability and climate. The study area experienced drastic changes in LULC and was subject to study for all the three years. There are significant changes that occurred in all LULC classes particularly in agricultural land, forest land and urban areas over the years (2001–2013).

The dynamics of the distribution of major LULC was observed during the study period. These changes have some negative impact on climate through loss of carbon sinks (Gidey et al. 2017). On the other hand, as a negative impact, modification of land use would increase the intensity of runoff (Hurni et al. 2005; Gidey et al. 2017). Agricultural expansion significantly affects runoff intensity, loss of biodiversity, carbon cycling and people as well as their livelihood (Nourqolipour et al. 2014; Memarian et al. 2012; Sang et al. 2011). Thus, during the period 2001–2008, different LULC types were converted into other land cover types (Table 3) The analysis of land use conversion matrix showed that Savannah declined by 1996.2 km^2 with net loss of 1.8% which was converted to agricultural land and population growth. Population growth between 1992 and 2003 was, respectively, 5,371,226 inhabitants with 3.78% and 7,665,681 inhabitants with 3.38% rate growth (INSAE 2014).

The examination of land use and land cover change during the period 1992–2008 revealed a significant increase of cropland and forest, with a consequence of decrease in bare land and water bodies. Cropland increased to 1027.9 km^2 with the net change of 0.9% from its previous coverage. This increase was estimated to be 146.8 km^2 per annum in 2008.

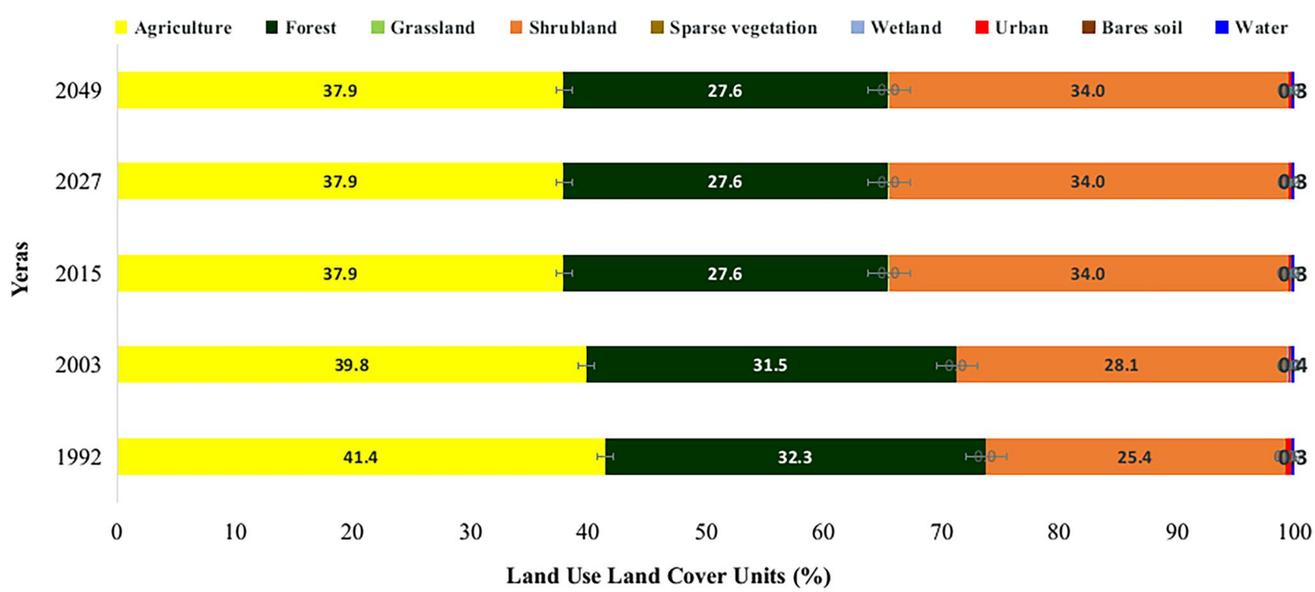

Fig. 2 LULC type based slope gradient of the study area in percent

Table 3 Changes in land use and land cover from 2001 to 2013

Years	2001–2008		2008–2013		2001–2013	
LULC units	Area (km^2)	Δ%	Area (km^2)	Δ%	Area (km^2)	Δ%
Cropland	1027.9	0.9	942.1	0.8	1970.0	1.8
Forest	859.1	0.8	234.4	0.2	1093.5	1.0
Savannah	− 1996.2	− 1.8	− 1276.1	− 1.2	− 3272.3	− 2.9
Wetland	20.7	0.0	0.7	0.0	21.4	0.0
Urban	118.5	0.1	104.8	0.1	223.3	0.2
Bare land	− 2.3	0.0	− 0.3	0.0	− 2.6	0.0
Water bodies	− 27.7	0.0	− 5.6	0.0	− 33.3	0.0

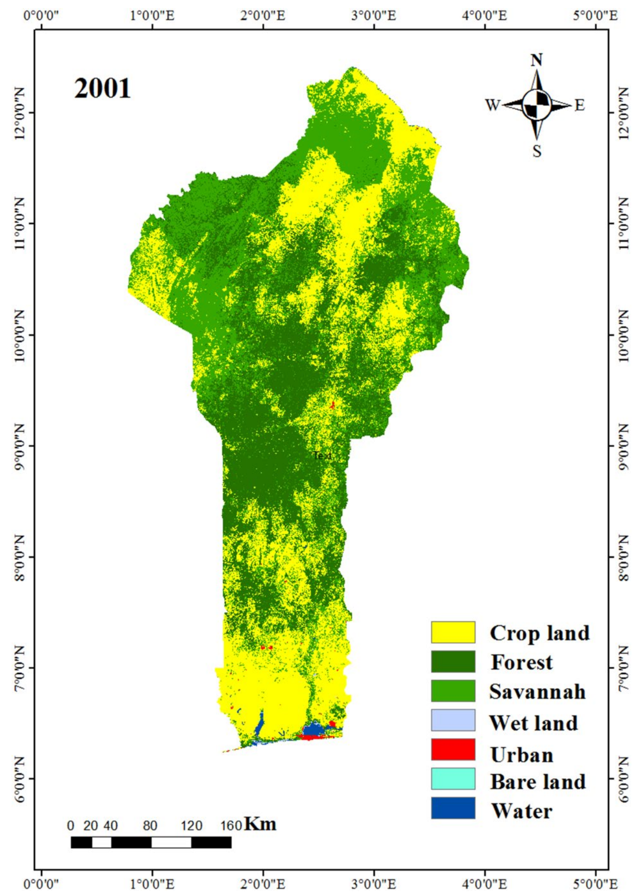

Fig. 3 LULC map of Benin for year 2001

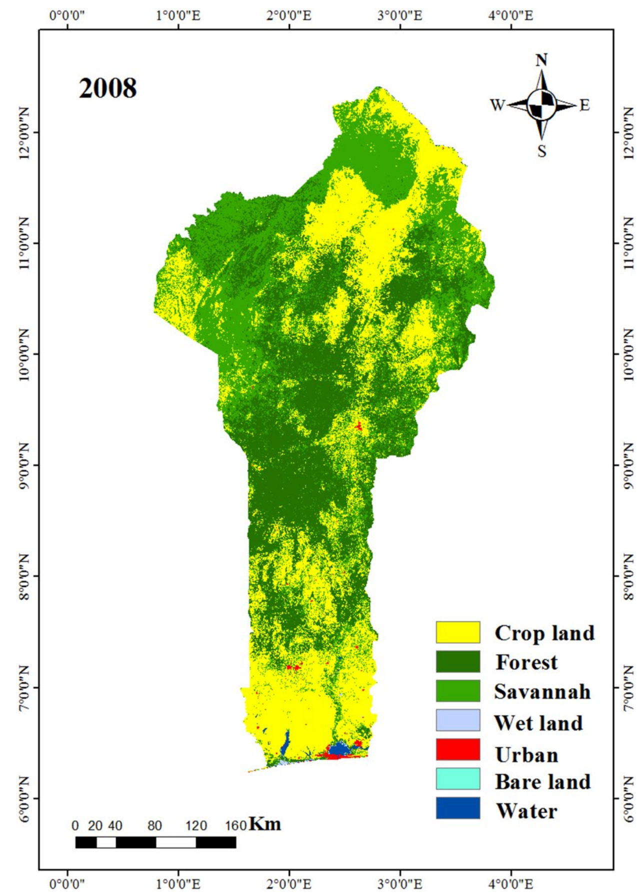

Fig. 4 LULC map of Benin for year 2008

Cropland expansion is the result of population growth which underpins the massive demand on crop production. Therefore, during the same period, forest land also decreased by 859.1 km^2 with an annual change rate of 107.4 km^2 (0.1%). Beside the major changes experienced by forest, urban and cropland, slight decrease was also recorded in bare land and water bodies and a minor increase in wetland. Thus, wetland increases by 20.7 km^2 and urban by 118.5 km^2 (0.1%). Bare land lost 2.3 km^2 of the allocated area and water bodies also lost 27.7 km^2 in the period 2001–2008.

Likewise, the periods 2001–2008, and 2008–2013 have experienced a decrease in Savannah, bare land and water bodies, but there was an increase in cropland, forest, wetland and urban. Thus, Savannah declined by 1276.1 km^2 (1.2%), bare land by 0.3 km^2 and water body by 5.6 km^2. Cropland increased by 942.1 km^2 (0.8%), forest land by 234.4 km^2 (0.2%), wetland by 0.7 km^2 and urban by 104.8 km^2 (0.1%). It was observed that the increase of cropland was considerable during the period 2001–2008 (0.9%) compared to that of in the period 2008–2013 (0.8%). Similarly, the decrease rate of Savannah was higher in 2001–2008 (1.8%) than that of in the period 2008–2013 (1.2%) (Table 3). This result indicates that the increase of urban areas mainly resulted from cropland and wetland during the period 2001–2013. The highest LULC types observed was the cropland and Savannah that occupied the largest area. This result is corroborated by the study of Houessou et al. (2013) in the northern part of Benin that reported agricultural land, tree, and the shrub Savannah as the most dominant land cover types.

Furthermore, during the period 2001–2013, the result showed the greatest increase in cropland, forest land, urban and wetland (Table 3). Cropland increased by 1970.0 km^2 (1.8%), forest land 1093.5 km^2 (1.0%), urban 223.3 km^2 (0.2%) and wetland 21.4 km^2, respectively. For each LULC type, the annual rate of growth was seen in cropland by 151.3 km^2, forest land by 84.12 km^2, urban by 17.2 km^2 and wetland 1.7 km^2. The USGS EROS (2016) between 1973 and 2013 reported that the important change in land cover is the large expansion of agricultural land in large area classes. It increased to 9.2–27.1% of the total country area or an increase of over 5% (about 600 km^2) per year between 1975 and 2013. According to the same author, the areas where the cropland showed the highest recorded change were in the south in the Pénéplaine Bénino-Togolaise Sud alongside the

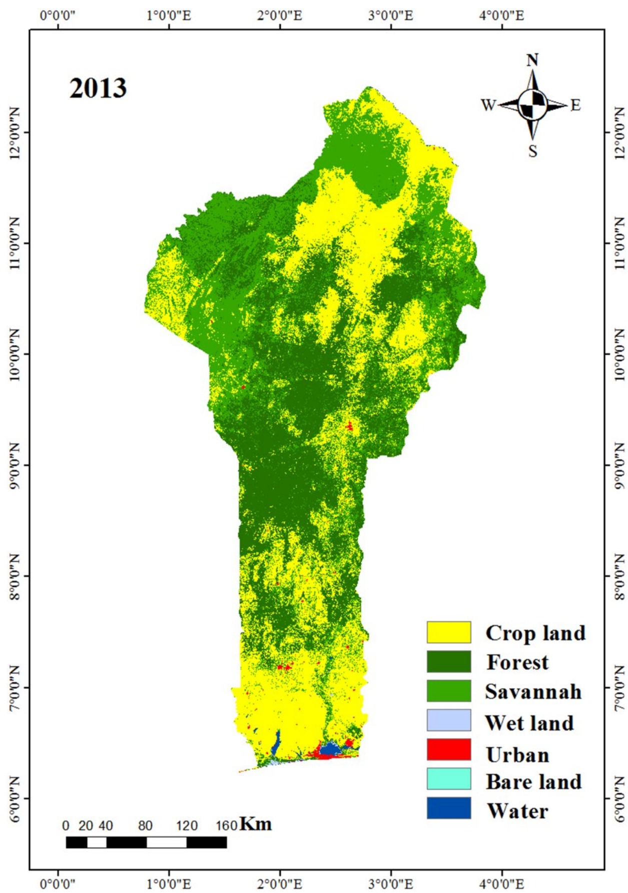

Fig. 5 LULC map of Benin for year 2013

Dassa-Savè axis. The agriculture in Benin is characterized by cropland mixed or associated with palm trees.

This study indicates a decrease of Savannah during the period 2001–2013. Despite this decrease, it remains the dominant land in the study area. Similarly, USGS EROS (2016) reported that despite the decrease in Savannah area by 23% since 1975, it remains the dominant land cover unit in Benin and still covers more than half of the territory. The decrease in Savannah could be due to population growth linked to the requirement of land and urban supplies.

In addition, forest land that was the second dominant LULC unit after cropland increased over the period 2001–2013. The gain in forest area might be due to the actions of afforestation projects. Such projects are implemented by Office National du Bois (ONAB). ONAB is an institution of Benin Republic in charge of protected areas. According to MEHU (2011) and Ministère de l'Environnement et de la Protection de la Nature (2009), ONAB is in charge of seven reforestation areas covering about 0.2% of the territory area. Unlike our study, USGS EROS (2016) indicated a continuous decrease in forest area in the period 1975–2013.

4.3 Analysis of Spatial Trend of Change

The spatial trend of change analysis is an effectual approach to visualize and provide the generalized patterns of changes using the observed map. The spatial trend of transition from the different LULC classes to cropland and urban areas during the years 2001, 2008 and 2013, respectively, is shown in the Fig. 3, 4 and 5.

Between the period 2001 and 2013, a further expansion in urban by 223.3 km^2 was observed which outpaced the growth rate of 2001–2008. This result was also found by USGS EROS (2016) which indicated that Benin's population tripled between 1975 and 2013, increasing from 3,263,000 to 10,600,000. Consequently, the surface area of villages, towns and cities has expanded by 24%. Urban development made it easy, as the land had negative impact on natural habitat and its biodiversity (Alphan 2003; Dewidar 2002). Forest and cropland areas have increased the detriment of Savannah and water bodies. Figure 6 showed the losses and gains of each LULC during the period 2001–2013.

4.4 LULC Prediction and Validation

To achieve a validation and prediction for future, LULC MLP-ANN method was used to predict LULC patterns in 2013 using map of the years 2001 and 2008. Using the transition potential modelling, the predicted LULC map for 2013 for validation was compared to the observed LULC map of 2013 using the kappa index statistic. The transition potential modelling statistics from MOLUSCE showed that the delta overall accuracy was ± 0.00196 which contains the difference between minimum reached error and the current error; the minimum validation overall error gave us 0.01062 which the minimum reached error on the validation set of samples and the current validation kappa gives us 0.90447.

The LULC change maps for future periods were made after successful prediction of the 2013 LULC map. 2013 LULC map was used as base map to transition potential modelling maps and the future LULC change maps were predicted for 2025 and 2037 as shown in Figs. 7, 8 and Table 4 contains the corresponding area statistics of various LULC classes. The ANN-MLP prediction for 2025 showed that cropland would decrease from 39,029.22 to 38,933.01 km^2 between 2013 and 2025, while for the other LULC types, forest land would also decrease from 35,406.99 to 35,406.45 km^2 between 2013 and 2025, Savannah would increase slightly from 35,556.75 to 35,664.12 km^2 between 2013 and 2025, urban (settlement) between 2013 and 2025 would decrease from 455.67 to 449.73 km^2, water bodies would decrease between 2013 and 2025 from 375.21 to 373.59 km^2, wetland from 115.65 to 112.68 km^2 and bare land would decrease from 2.2 to 2.1 km^2 between 2013 and 2025. For 2037 prediction, it

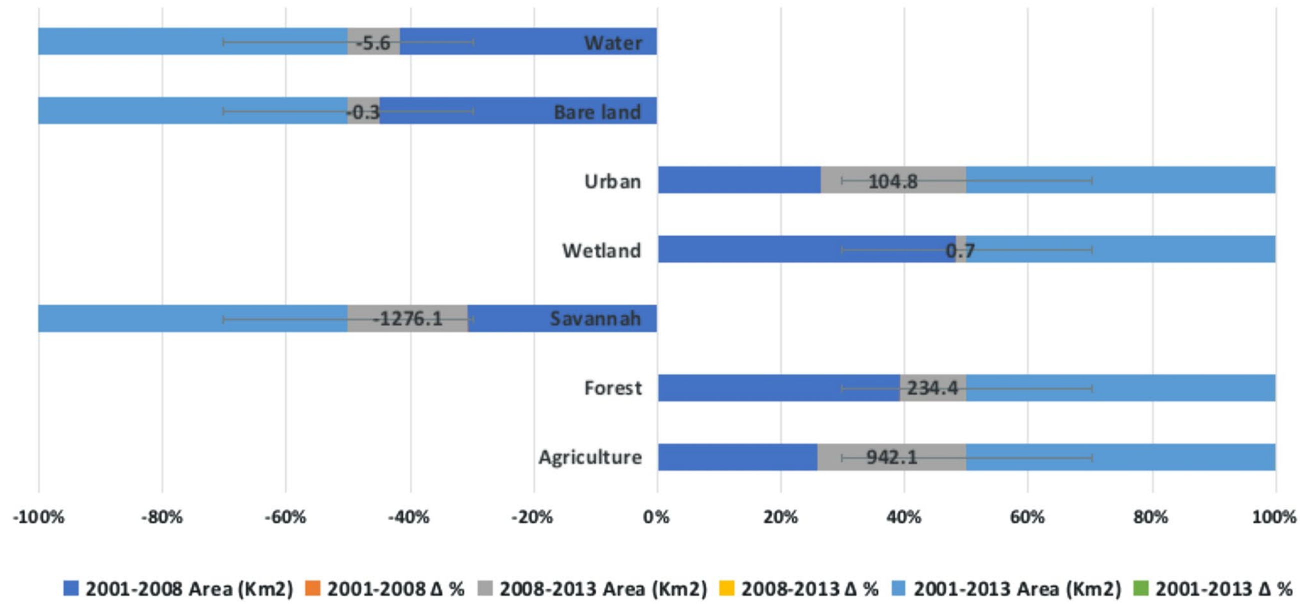

Fig. 6 Gains and losses in LULC (in%) and contributions to net change in built up area (in%) during 2001–2008, 2008–2013, and 2001–2013

was found that Savannah would increase drastically from 35,556.75 to 35,876.88 km^2 between 2013 and 2037, cropland would decrease drastically from 39,029.22 to 38,742.03 km^2, forest also would decrease from 35,406.99 to 35,405.64 km^2 between 2013 and 2037, urban (settlement) would also decrease from 455.67 to 437.58 km^2 between 2013 and 2037, water bodies from 375.21 to 371.79 km^2, wetland from 115.65 to 105.93 km^2, and bare land would also decrease from 2.2 to 1.8 km^2 between 2013 and 2037.

The change that occurred during the periods 2013–2025, 2013–2037 and 2001–2037 is shown in Table 5. The simulation based on the first period 2013–2025 showed that cropland and forest decline by 96.21 km^2 (0.09%) and 0.54 km^2, respectively, whereas Savannah increased by 107.37 km^2 in the same period. The other LULC types encounter some regression (e.g., wetland, urban, bare land, and water bodies). Likewise, during the period 2013–2037, cropland and forest still decline by 287.19 km^2 (0.26%) and 1.35 km^2, respectively, whereas Savannah still increases in area by 320.13 km^2 (0.29%). The other LULC type also experienced the reduction in their coverage area during this period (e.g., wetland, urban, bare land and water bodies). For the prediction during the period 2001–2037, the mean showed that cropland and forest increased by 1682.82 km^2 (1.52%) and 1092.15 km^2 (0.98%), respectively. Savannah met some regression during this period by 2952.18 km^2 (2.66%). Urban globally increased by 205.20 km^2 (0.18%), wetland by 11.70 km^2 and the other LULC types declined by 36.72 km^2 for water bodies and 2.97 km^2 for bare land.

The overall loss of LULC classes during 2001–2037 such as Savannah, bare land and water bodies occurred because of the rapid spreading of built-up area, increase of crop production and human activities. These results reflect for the future, a worrisome landscape of Benin Republic that will be the result of a totally degraded natural vegetation. In addition, it draws attention about sustainable management and development of the landscape. Meanwhile, 2037 demonstrated a vast decrease of cropland, urban, forest and water bodies.

In this study, using land use maps (2001, 2008 and 2013) and socio-economic data, MOLUSCE model was combined with GIS technology to successfully simulate the land use change in Benin Republic. The used model shows satisfiable results. Based on validation, MLP-ANN model is used to simulate the future change that will occur in 2025 and 2037. However, the accuracy of the prediction results is related to many factors. The accuracy of land use/cover maps and the prediction results is negative due to the resolution of the CCI-LC images. Then, to improve the results, image quality should be retrieved with high quality, and new predictions should be developed taking into account other variables (physical and socio-economic factors).

5 Conclusions

In this study, the spatio-temporal dynamic of LULC was examined using an integrated approach of remote sensing and geographic information system in Benin Republic. To achieve these objectives, CCI-LC map were reclassified.

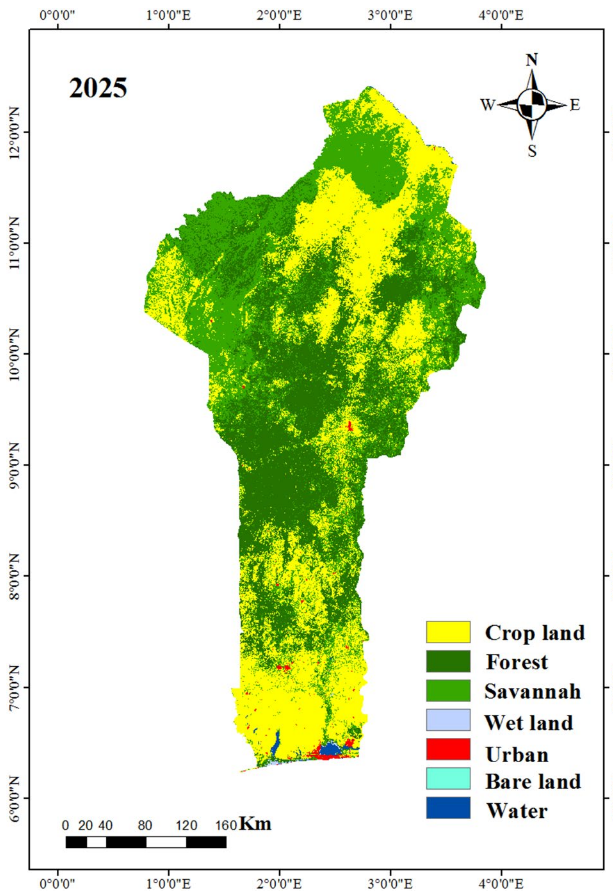

Fig. 7 Predicted LULC map for year 2025 using MLP-ANN

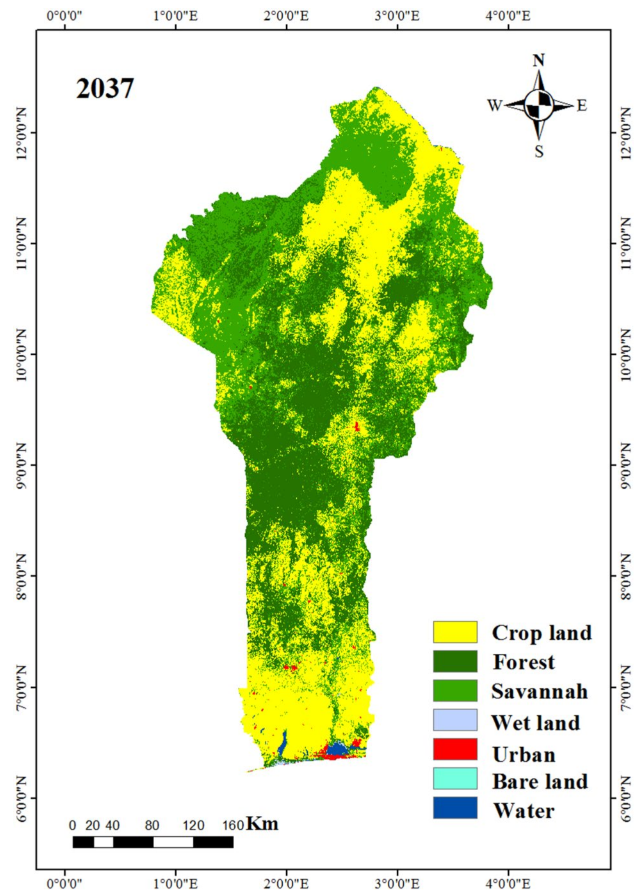

Fig. 8 Predicted LULC map for year 2037 using MLP-ANN

The multi-layer perceptron (MLP) artificial neural network (ANN) method was used to predict the future LULC change scenario effectively in Benin. In addition, kappa index statistic was used to assess the accuracy of predicted LULC map for 2013. Simulation for 2025 and 2037 was predicted using MLP-ANN method. The results from the simulation furnish comprehension about the quantity and location of probable changes.

Seven major LULC types that were considered are cropland (Cl), forest land (Fl), Savannah (Sh), wetland (Wl), urban (Ur), bare land (Bl) and water bodies (Wb). The results indicated that cropland was dominant, while bare land was the submissive LULC type present in the study area. The present study was conducted to reveal the changes in LULC during the period 2001–2013. The accuracy of the predicted LULC map of 2013 was assessed using the observed LULC map of 2013. The predicted LULC map shows the probable change in LULC spatially and quantitatively in future. The predicted results of the year 2025 shows an increase in cropland and Savannah which were estimated to be 38,933.01 km^2 and 35,664.12 km^2, respectively. Moreover, the predicted result of 2037 was estimated for the cropland as 38,742.03 km^2, whereas the Savannah was estimated as 35,876.88 km^2. This study shows the quality of remote sensing data and GIS combination for LULC change analysis and simulation for future LULC scenarios. Therefore, the reclassified map and the accuracy of the prediction of LULC result are greatly affected by the spatial resolution of the CCI-LC map. So, the quality of the image and the result are affected.

Table 4 Area statistics of predicted LULC of years 2025 and 2037

Years	2025		2037	
LULC units	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Cropland	38933.0	35.1	38742.0	34.9
Forest	35406.5	31.9	35405.6	31.9
Savannah	35664.1	32.1	35876.9	32.3
Wetland	112.7	0.1	105.9	0.1
Urban	449.7	0.4	437.6	0.4
Bare land	2.1	0.0	1.8	0.0
Water bodies	373.6	0.3	371.8	0.3
Total	110941.7	100.0	110941.7	100.0

Table 5 Area statistics of predicted LULC of the period 2013–2025, 2013–2037 and 2001–2037

Years	2013–2025		2013–2037		2001–2037	
LULC units	Area (km^2)	Δ%	Area (km^2)	Δ%	Area (km^2)	Δ%
Cropland	−96.21	−0.09	−287.19	−0.26	1682.82	1.52
Forest	−0.54	0.00	−1.35	0.00	1092.15	0.98
Savannah	107.37	0.10	320.13	0.29	−2952.18	−2.66
Wetland	−2.97	0.00	−9.72	−0.01	11.70	0.01
Urban	−5.94	−0.01	−18.09	−0.02	205.20	0.18
Bare land	−0.09	0.00	−0.36	0.00	−2.97	0.00
Water bodies	−1.62	0.00	−3.42	0.00	−36.72	−0.03

Compliance with Ethical Standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

Agustan KF, Pamitro YE, Abidin HZ (2012) Understanding the 2007–2008 eruption of Anak Krakatau Volcano by combining remote sensing technique and seismic data. Int J Appl Earth Obs Geoinf 14(1):73–82. https://doi.org/10.1016/j.jag.2011.08.011

Alphan H (2003) Land use change and urbanization in Adana, Turkey. Land Degrad Dev 14(6):575–586

Alves DS, Skole DL (1996) Characterizing land cover dynamics using multi-temporal imagery. Int J Remote Sens 17(4):835–839

Asia Air Survey and Next GIS (2017) MOLUSCE: modules for land use change evaluation. http://nextgis.com/blog/molusce/

Babalola O, Akinsanola A (2016) Change detection in land surface temperature and land use land cover over Lagos Metropolis, Nigeria. J Remote Sens GIS 5(3):1–7. https://doi.org/10.4172/2469-4134.1000171

Begue A, Vintrou E, Saad A, Hiernaux P (2014) Differences between cropland and rangeland MODIS phenology (start-of-season) in Mali. Int J Appl Earth Obs Geoinf. https://doi.org/10.1016/j.jag.2014.03.024

Byomkesh T, Nakagoshi N, Dewan AM (2012) Urbanization and green space dynamics in Greater Dhaka, Bangladesh. Landsc Ecol Eng 8:45–58

CCI-LC (2017) Land cover CCI, product user guide, Version 2.0. CCI-LC-PUGV2. http://maps.elie.ucl.ac.be/CCI/viewer/. Accessed 16 Oct 2017

Dewan AM, Yamaguchi Y, Rahman MZ (2012) Dynamics of land use/cover changes and the analysis of landscape fragmentation in Dhaka Metropolitan, Bangladesh. GeoJournal 77(3):315–330. https://doi.org/10.1007/s10708-010-9399-x

Dewidar KM (2002) Landfill detection in Hurghada, North Red Sea, Egypt using thematic mapper images. Int J Remote Sens 23(5):939–948

Foley JA, DeFries R, Asner GP, Barford C, Bonan G, Carpenter SR, Snyder PK (2005) Global consequences of land use. Science 309(5734):570–574. https://doi.org/10.1126/science.1111772

Garratt JR (1990) Boundary layer climates. Earth Sci Rev 27(3):265. https://doi.org/10.1016/0012-8252(90)90005-G

Gidey E, Dikinya O, Sebego R, Segosebe E, Zenebe A (2017) Modeling the spatio-temporal dynamics and evolution of land use and land cover (1984–2015) using remote sensing and GIS in Raya, Northern Ethiopia. Model Earth Syst Environ. https://doi.org/10.1007/s40808-017-0375-z

Grimm NB, Faeth SH, Golubiewski NE, Redman CL, Wu J, Bai X, Briggs JM (2008) Global change and the ecology of cities. Science 319(5864):756–760

Hibbard K, Janetos A, Van Vuuren DP, Pongratz J, Rose SK, Betts R, Feddema JJ (2010) Research priorities in land use and land-cover change for the Earth system and integrated assessment modelling. Int J Climatol 30(13):2118–2128. https://doi.org/10.1002/joc.2150

Houessou LG, Teka O, Toko I, Lykke AM, Sinsin B (2013) Land use and land-cover change at "W" biosphere reserve and its surroundings areas in Benin Republic (West Africa). Environ Nat Resour Res. https://doi.org/10.5539/enrr.v3n2p87

Hurni H, Tato K, Zeleke G (2005) The implications of changes in population, land use, and land management for surface runoff in the upper Nile basin area of Ethiopia. Mt Res Dev 25(2):147–154. https://doi.org/10.1659/0276-4741(2005)025%5b0147:TIOCIP%5d2.0.CO;2

INSAE (2014) Bénin—Troisieme Recensement General de la Population et de l' Habitation 2002. BENIN. http://nada.insae-bj.org/index.php. Accessed 30 Sep 2017

INSAE_Benin (2014) Densite de la population, pp 1–39. http://nada.insae-bj.org/index.php. Accessed 30 Sep 2017

Issiaka NT (2016) Cartographie De La Dynamique Spatio-Temporelle Des Parcours Naturels Des Troupeaux Transhumants Dans Les Communes De Banikoara Et De Karimama Au Bénin (Afrique De L' ouest) 12(32):251–268. https://doi.org/10.19044/esj.2016.v12n32p251

Kamusoko C, Aniya M, Adi B, Manjoro M (2009) Rural sustainability under threat in Zimbabwe simulation of future land use/cover changes in the Bindura district based on the Markov-cellular automata model. Appl Geogr 29:435–447

Kumar M, Shaikh VR (2013) Site suitability analysis for urban development using GIS based multicriteria evaluation technique. J Indian Soc Remote Sens 41(2):417–424. https://doi.org/10.1007/s12524-012-0221-8

Lambin EF, Meyfroidt P (2010) Land use transitions: socio-ecological feedback versus socio-economic change. Land Use Policy 27(2):108–118. https://doi.org/10.1016/j.landusepol.2009.09.003

Lambin EF, Meyfroidt P (2011) Global land use change, economic globalization, and the looming land scarcity. Proc Natl Acad Sci USA 108(9):3465–3472. https://doi.org/10.1073/pnas.1100480108

Lambin EF, Turner BL, Geist HJ, Agbola SB, Angelsen A, Bruce JW, Coomes O (2001) The causes of land-use and land-cover change: moving beyond the myths. Global environmental change-human and policy dimensions. Glob Environ Change 11(4):261–269. https://doi.org/10.1016/S0959-3780(01)00007-3

Lambin EF, Geist HJ, Lepers E (2003) Dynamics of land use and land cover change in tropical regions. Annu Rev Environ Resour 28:205–241. https://doi.org/10.1146/annurev.energy.28.050302.105459

Li X, Zhou W, Ouyang Z (2013) Forty years of urban expansion in Beijing: what is the relative importance of

physical, socioeconomic, and neighborhood factors? Appl Geogr 38(1):1–10. https://doi.org/10.1016/j.apgeog.2012.11.004
Lu X, Sasaki K (2008) Urbanization process and land use policy. Ann Reg Sci 42:769–786
Mayaux P, Richards T, Janodet E (1999) A vegetation map of Central Africa derived from satellite imagery. J Biogeogr 26(2):353–366. https://doi.org/10.1046/j.1365-2699.1999.00270.x
MEHU (2011) Deuxième Communication Nationale de la République du Bénin sur les Changements Climatique. Cotonou. http://www.agrhymet.ne/portailCC/images/pdf/nc2benin.pdf. Accessed 01 Oct 2017
Memarian H, Kumar Balasundram S, Bin Talib J, Teh Boon Sung C, Mohd Sood A, Abbaspour K (2012) Validation of CA-Markov for simulation of land use and cover change in the Langat basin, Malaysia. J Geogr Inf Syst 4(6):542–554. https://doi.org/10.4236/jgis.2012.46059
Meyfroidt P, Lambin EF, Erb KH, Hertel TW (2013) Globalization of land use: distant drivers of land change and geographic displacement of land use. Curr Opin Environ Sustain 14:78. https://doi.org/10.1016/j.cosust.2013.04.003
Ministère de l'Environnement et de la Protection de la Nature (2009) Quatrième rapport national du Bénin sur la convention des Nations Unies sur la diversité biologique. Cotonou
Mishra VN, Rai PK (2016) A remote sensing aided multi-layer perceptron-Markov chain analysis for land use and land cover change prediction in Patna district (Bihar), India. Arabian J Geosci 9(4):249. https://doi.org/10.1007/s12517-015-2138-3
Mishra VN, Rai PK, Prasad R, Punia M, Nistor MM (2018) Prediction of spatio-temporal land use/land cover dynamics in rapidly developing Varanasi district of Uttar Pradesh, India using Geospatial approach: a comparison of hybrid models. Appl Geomat 10(3):257–276. https://doi.org/10.1007/s12518-018-0223-5
Moghadam HS, Helbich M (2013) Spatiotemporal urbanization processes in the megacity of Mumbai, India: a Markov chains-cellular automata urban growth model. Appl Geogr 40:140–149. https://doi.org/10.1016/j.apgeog.2013.01.009
Muñoz-Robles C, Frazier P, Tighe M, Reid N, Briggs SV, Wilson B (2012) Assessing ground cover at patch and hillslope scale in semi-arid woody vegetation and pasture using fused Quickbird data. Int J Appl Earth Obs Geoinf 14(1):94–102. https://doi.org/10.1016/j.jag.2011.08.010
National Research Council (2014) Advancing land change modelling: opportunities and research requirements. The National Academies Press, Washington, DC. https://doi.org/10.17226/18385
Nourqolipour R, Mohamed Shariff ARB, Balasundram SK, Ahmad NB, Sood AM, Buyong T, Amiri F (2014) A GIS-based model to analyze the spatial and temporal development of oil palm land use in Kuala Langat district, Malaysia. Environ Earth Sci 73(4):1687–1700. https://doi.org/10.1007/s12665-014-3521-1
Oke TR (1987) Boundary layer climates, 2nd edn. Routledge, London
Ozdogan M (2010) The spatial distribution of crop types from MODIS data: temporal unmixing using independent component analysis. Remote Sens Environ 114(6):1190–1204. https://doi.org/10.1016/j.rse.2010.01.006
Rhett B (2007) Benin Environment profile. https://rainforests.mongabay.com/deforestation/archive/Benin.htm. Accessed 8 Feb 2018
Sang L, Zhang C, Yang J, Zhu D, Yun W (2011) Simulation of land use spatial pattern of towns and villages based on CA-Markov model. Math Comput Model 54(3–4):938–943. https://doi.org/10.1016/j.mcm.2010.11.019
Schaldach R (2006) The multi-scale land use change model landshift: a scenario analysis of land use change and environmental consequences in Africa. In: 3rd biennial meeting of the international environmental modelling and software society, pp 1–6
Schumann K, Wittig R, Thiombiano A, Becker U, Hahn K (2012) Uses, management, and population status of the baobab in eastern Burkina Faso. Agrofor Syst 85(2):263–278. https://doi.org/10.1007/s10457-012-9499-3
Thapa RB, Murayama Y (2009) Examining spatiotemporal urbanization patterns in Kathmandu valley, Nepal: remote sensing and spatial metrics approaches. Remote Sens 1:534–556
Thapa RB, Murayama Y (2010) Drivers of urban growth in the Kathmandu valley, Nepal: examining the efficacy of the analytic hierarchy process. Appl Geogr 30(1):70–83. https://doi.org/10.1016/J.APGEOG.2009.10.002
Thomson G (2007) Benin political geography. http://www.encyclopedia.com/places/africa/benin-political-geography/benin. Accessed 8 Feb 2018
Turner II, Billie L (2001) Land-use and land-cover change: advances in 1.5 decades of sustained international research. Am J Agr Econ 10(4):269–272
Turner II, Billie L (2002) Toward integrated land-change science advances in 1.5 decades of sustained international research. In: Challenges of a changing earth: proceedings of the global change open science conference, Amsterdam, NL, 10–13 July 2000, pp 269–272. https://doi.org/10.1007/978-3-642-19016-2_3
United Nations (2017) Benin population (2017-12-21). http://worldpopulationreview.com/countries/benin-population/. Accessed 05 Feb 2018
United Nations Framework Convention on Climate Change (2012) Report of the Conference of the Parties on its seventeenth session, held in Durban from 28 November to 11 December 2011, (March), 1–63
USGS EROS (2016) Land use, land cover, and trends in Benin|West Africa. https://eros.usgs.gov/westafrica/land-cover/land-use-land-cover-and-trends-benin. Accessed 13 Mar 2018
Van Asselen S, Verburg PH (2013) Land cover change or land-use intensification: simulating land system change with a global-scale land change model. Glob Change Biol 19(12):3648–3667. https://doi.org/10.1111/gcb.12331
Veldkamp A, Lambin EF (2001) Predicting land-use change. Agric Ecosyst Environ 85(1–3):1–6. https://doi.org/10.1016/S0167-8809(01)00199-2
Verburg PH, van de Steeg J, Veldkamp A, Willemen L (2009) From land cover change to land function dynamics: a major challenge to improve land characterization. J Environ Manag. https://doi.org/10.1016/j.jenvman.2008.08.005
Vintrou E, Desbrosse A, Bégué A, Traoré S, Baron C, Lo Seen D (2012) Crop area mapping in West Africa using landscape stratification of MODIS time series and comparison with existing global land products. Int J Appl Earth Obs Geoinf 14(1):83–93. https://doi.org/10.1016/J.JAG.2011.06.010
Wang SQ, Zang XB, Zheng XQ (2012) Accuracy assessments of land use change simulation based on Markov-cellular automata model. Procedia Environ Sci 13:1238–1245
White F, Hopkins B (1987) Vegetation map of Africa. The vegetation of Africa: a descriptive memoir to accompany the Unesco/AETFAT/UNSO vegetation map of Africa. J Ecol 75(4):1214. https://doi.org/10.2307/2260340
Yang F, Zeng G, Du C, Tang L, Zhou J, Li Z (2008) Spatial analyzing system for urban land-use management based on GIS and multi-criteria assessment modeling. Prog Nat Sci 18(10):1279–1284. https://doi.org/10.1016/j.pnsc.2008.05.007
Youssef AM, Pradhan B, Tarabees E (2010) Integrated evaluation of urban development suitability based on remote sensing and GIS techniques: contribution from the analytic hierarchy process. Arab J Geosci 4(3–4):463–473. https://doi.org/10.1007/s12517-009-0118-1
Zhang J, Feng L, Yao F (2014) Improved maize cultivated area estimation over a large scale combining MODIS-EVI time series data and crop phenological information. ISPRS J Photogramm Remote Sens 94:102–113. https://doi.org/10.1016/j.isprsjprs.2014.04.023