ORIGINAL ARTICLE

Analysis of land use/cover dynamics in Jimma city, Southwest Ethiopia: an application of satellite remote sensing

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ABSTRACT

Understanding changes in land use/cover provides essential information that can support informed decision making towards environmental sustainability. The objective of this study was to map and assess the dynamics of major land use/cover (LULC) types, and quantify magnitude and spatial patterns of the LULC changes that environments in and around Jimma city have undergone between the years 1984 and 2007. Satellite images of Landsat Thematic Mapper (TM) of year 1984 and SPOT image of year 2007 were used in this study. All images were processed using ERDAS IMAGINE v9.3 image processing software. Change analysis was undertaken by applying post-classification change detection procedures. Accuracy of the image classification was assessed using error matrix, overall accuracy and kappa coefficient. The overall accuracy of up to 84% was achieved. Maximum Producer's and User's accuracies were, respectively, 97% and 100%, and Kappa statistic ranged between 0.77 and 1.00. The change analysis result revealed that the LULC have shown both positive and negative significant changes. Built-up, settlement, plantation forest and cultivated land were the top LULC that experienced positive change; whereas natural vegetation, water body and wetlands have substantially declined. An important implication of the observed changes is that rapid urban expansion, compounded by poor urban planning is leading to enormous losses of key ecosystems such as wetlands and natural vegetation. The consequence of this rapid ecological degradation could potentially impact ecological functioning and environmental sustainability in and around Jimma city. Therefore, critical system thinking is required to address these complex problems in the study area and areas of rapid urbanization elsewhere in the country.

Key words: Land use/cover, GIS; image classification; remote sensing, ecosystem

INTRODUCTION

Land cover describes the physical material at the surface of the Earth such as water, vegetation, soil, and built-up surfaces (Lambin and Geist 2008); whereas land use is a description of how people utilize the land resources for various socio-economic activities, which include urban land, agricultural land, forest land, grazing land etc. Land use/cover (LULC) change is a continual process driven by humans and natural phenomena. Human development has substantially altered land resources through extraction and several processes/activities that alter land resources. The major socio-economic activities that have long history of causing LULC changes are agricultural activities, population growth, changes in consumption patterns, urbanization expansion, and technological advancements. Natural phenomena such as earthquake, fire, drought, flood, and volcanic eruption are also among the major factors causing LULC change.

The LULC change often leads to undesirable consequences that negatively impact functioning of natural ecosystems and human beings themselves. The impacts could be manifested across a wide spectrum of environmental systems including the atmospheric, hydrologic and ecological systems. Vegetation cover changes at local and global scales are some of the major sources of CO_2 emission, leads to accelerated soil erosion and biodiversity losses (Wu *et al.*, 2013). Urbanization is a normal process that follows economic development and human civilization. In developing countries such as Ethiopia, drivers of urbanization are not only economic development, but also rapid rural population growth, poor land productivity, which often leads to rural-urban migration and poorly planned urban expansion. Processes related to urbanization, development of transport infrastructures, industrial constructions, and other built-up areas are severely impacting the environment at both global and local levels (Grimm *et al.*, 2008).

LULC change is therefore, a critical environmental and socio-economic issue that requires research attention. Particularly, in the contemporary context of rapid human economic development and growing concerns of environmental challenges, up-to-date LULC change information is needed for policy and decision making processes at local and global scales. Information on land use/land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs, elfare and this information also assists in monitoring the dynamics of land use and help in making timely decisions and corrective measures when required.

Earth observatory satellites remote sensing technologies have been proven to provide detailed and accurate land resource data, which allows monitoring of LULC at various spatial and temporal scales. Since early 1970s, remote sensing and geospatial methods have been successfully applied for mapping land surface features, infrastructures, managing natural resources and studying environmental change (Lillesand, Kiefer, and Chipman 2014, Chen *et al.*, 2006). Along with widespread availability of remotely sensed data in public domain, recent development in change detection algorithms, has further enhanced suitability of remote sensing technologies for accurate mapping and quantification of the LULC dynamics at fine spatial resolution (Hansen and Loveland 2012; Sexton *et al.*, 2013). Over recent few decades, Jimma City has been experiencing rapid population and leading to enormous observable environmental changes, including loss of wetlands and other important ecosystems.

However, inadequate scientifically proven information is available regarding magnitude of changes, rate of change and specific information about urbanization-induced impacts in and around the city. Therefore, the objective of this study was to assess and analyze the urbanization-driven LULC changes in and around Jimma city and develop geospatial information regarding magnitude of changes and spatio-temporal dynamics LULC during time period of 1984 and 2007.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in Jimma city, Oromia National Regional State of Ethiopia. The city is located 346 km away from capital city (Addis Ababa) of Ethiopia. The center point of the city is approximately situated at geographic coordinate of 7°41'N latitude and 36 50 E longitudes (Fig 1).

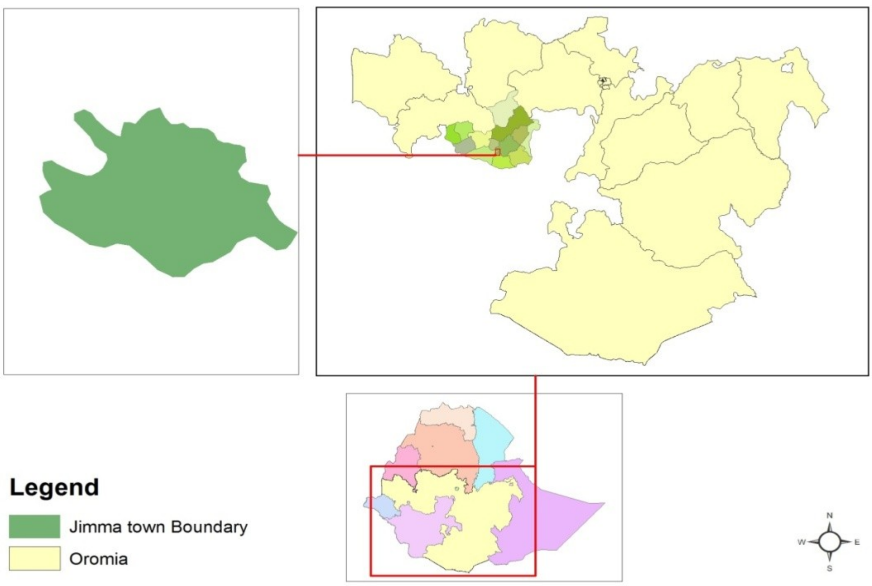

Figure 1. Map of the study area

The temperature data was collected from Jimma meteorological stations nearby to the Jimma city; the study area has an annual mean temperature ranges from about 12.1°C to 28°C (Figure 2A). The study area receives a mean annual rainfall about 1420 to 1800 mm (JMS, 2013) (Figure 2B). Jimma city lies on a low hill on the left side of the wide alluvial plain of the river Gibe and it is crossed by small streams. Topographically it exhibits features of the upper part of the Gibe-Omo River basin, made up of gentle slopping.

Based on the 2007 Ethiopian Population Census conducted by the Central Statistical Agency of Ethiopia, Jimma city has a total population of 120,960 of which 60,824 are men and 60,136 are women. The main economic activities are commerce, small scale manufacturing enterprises and industries and these activities account to 70%. Description of land use/cover types used in classification is indicated in Table 1.

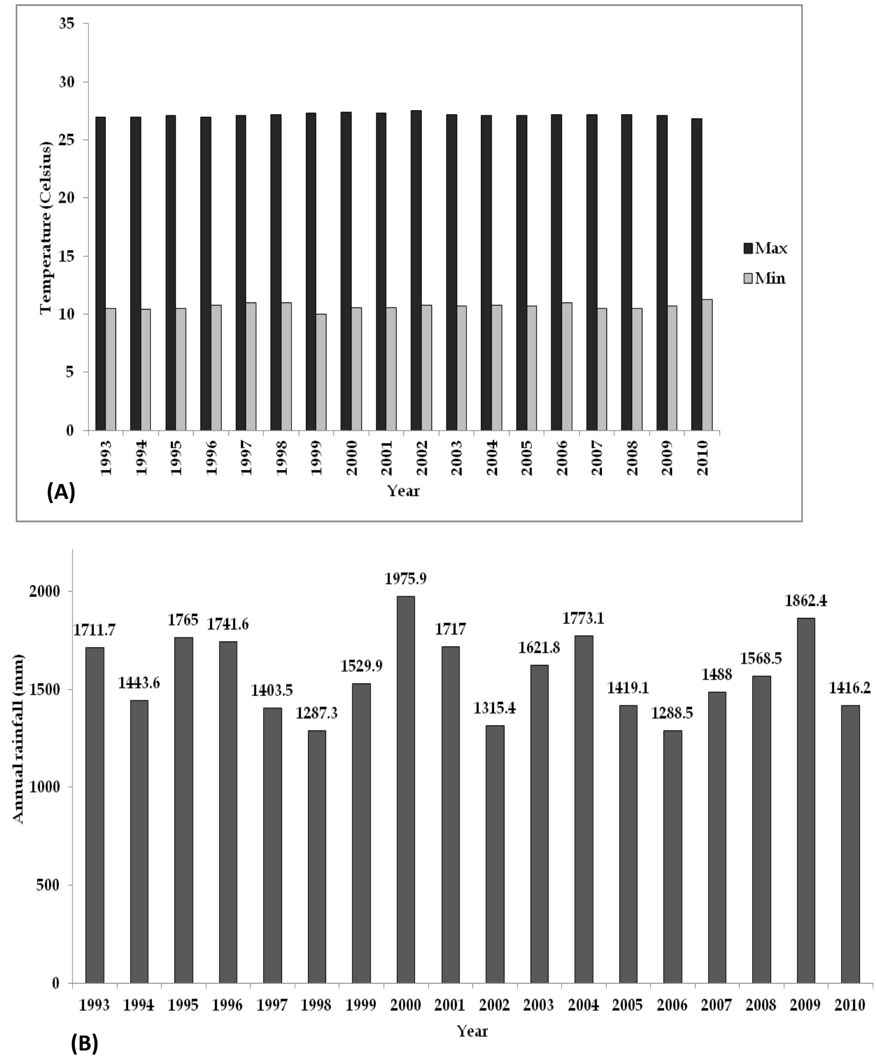

Figure 2: (A) Graphs showing maximum and minimum temperature, and (B) annual rainfall of the study area. (Data sources: Jimma Meteorological Station).

Data sources

A field survey was undertaken to collect ground truthing data, implementing systematic random sampling, where grid sampling techniques and the data was collected along transects. During the field survey, 206 sample points surveyed and at each point and 10 land use/land cover types were characterized (Table 2, Figure 3).

Table 1: Description of land use/cover types used in classification

LULC Classes	Descriptions
Built-up area*	Human-made built surfaces, which include residential and commercial buildings, other buildings for private and public services, concert and asphalt roads. These are predominant land cover in urbanized areas (cities)
Cultivated land	Areas for growing agricultural crops. The category includes areas currently under crop, and land under preparation.
Water bodies	Area covered by surface water bodies
Wetlands	Marshes, mudflats, swamps
Bare land	Areas with exposed soil, eroded lands such as gully and bad lands
Grass land	All areas covered with natural grass and small shrubs dominated by grass
Settlements	Land uses for human settlement, such as villages/small towns, rural market places, rural institution such as school, clinic, etc. Settlements include built-up areas in rural landscape, which have unique spatial patterns intermingled with natural land cover such as vegetation and soil.
Plantation forest	A rage of forest types which are establish on the sites by planting
Natural vegetation	Naturally occurring plant community dominated by trees
Bush land	Open shrub lands with scattered trees

*In the context of this paper, built-up is a land cover type, predominantly of urbanized areas, while settlements are rural land uses for human residence and public services such as rural market places.

Geographic location of each survey point was recorded using a global positioning system (GPS) instrument. The LULC characterization was based on the FAO, 2010 guide manual. Secondary data were also obtained by referring to historical records of LULC. Meteorological data were obtained from Jimma metrological station. High spatial resolution SPOT images were obtained from Ethiopian Mapping Agency.

Data analysis

LULC types were identified through supervised classification applying the widely used Maximum Likelihood Classifier (MLC) algorithm. Classification accuracy was assessed with error matrices, percentage of producers and user's accuracies, and Kappa statistics (Olofsson *et al.*, 2013). The ArcGIS version 10 and ERDAS imagine version 2011 tools were utilized to classify the satellite data to detect urban land cover changes. Post-classification change detection method was then used to explore LULC dynamics between years 1984 and 2007. The magnitude, spatial patterns and nature of changes were then mapped and analyzed using summary statistics. This spatial information enables a direct visual assessment of urban land cover and patterns of other land cover types within and around the city.

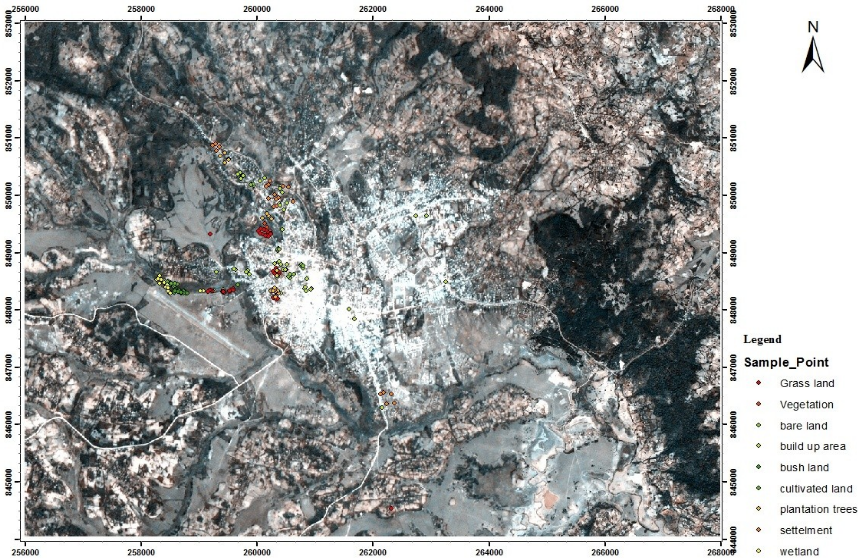

Figure 3: Sample points at Jimma town land use/cover map

RESULTS AND DISCUSSION

The result of the study indicated that there are spatial patterns of major LULC types in the study area (Figure 4). A total of ten LULC types were extracted in the study area over the two reference periods. Rapid urban expansion is clearly evident in Figure 4B and disappearance of water body is also another fundamental LULC change the study period 1984 and 2007.

Accuracy assessment

The overall accuracies for the Land cover map of the study area in the years 1984 and 2007 were (83.66%) and (84.16%) respectively. Producer's accuracy in 1984 land cover map ranged from the lowest value of 53.5% to the 100%, while in mapping LULC of year 2007 land cover map ranged from 76% to 100%. Producer's accuracy of individual classes ranged from (50%) to (90.57%) for classification of image in 1984, and (50%) to (96.67%) for year 2007. The least classification accuracy was observed for bush land; bare land and settlement (Table 2 and 3) indicate details of accuracy results.

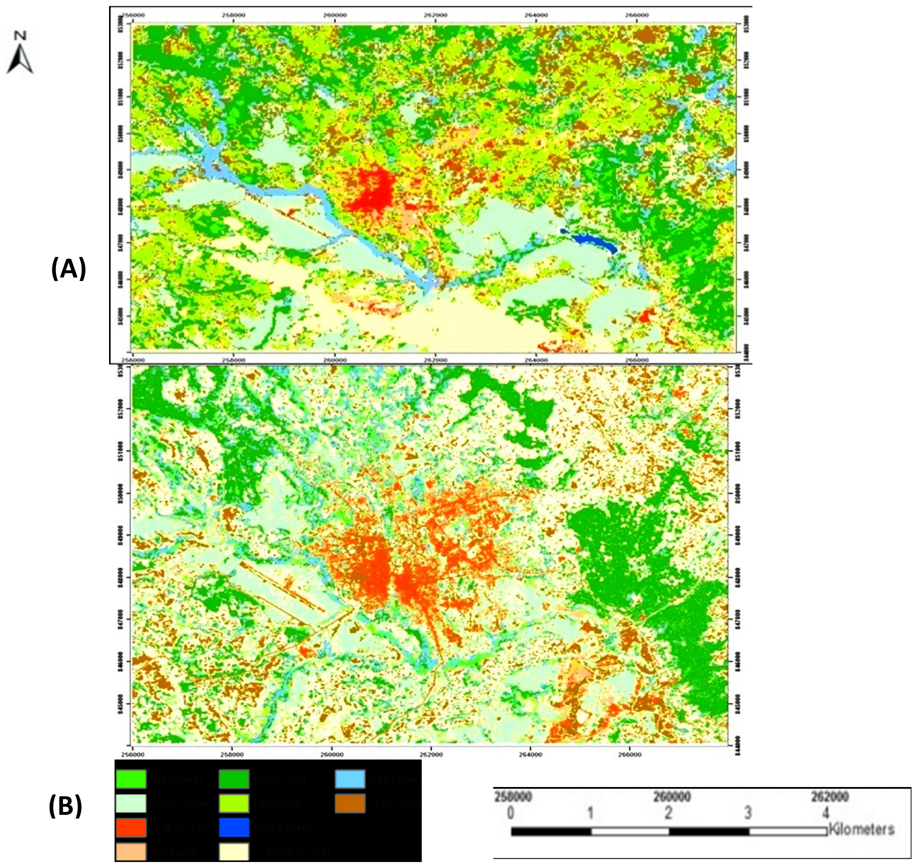

Figure 4: Land use/cover classes: (A) years 1984 and, (B) year 2007

Table 2: Overall accuracy assessment in 1984

	Land Cover Map of 1984						
Build up	13	12	11	84.62	91.67		0.9109
Cultivated land	7	6	4	57.14	66.67		0.6547
Grass land	8	7	4	50.00	57.14		0.5538
Settlement	18	20	16	88.89	80		0.7804
Plantation trees	29	26	24	82.76	92.31	83.66%	0.9102
Vegetation	14	14	12	85.71	85.71		0.8465
Bare land	48	57	44	91.67	77.19		0.7008
Bush land	12	12	6	50.00	85.71		0.8481
Water body	2	1	1	50.00	100.00		7804
Wetland	53	53	48	90.57	90.57		
Total	202	202	169				

Table 3: Overall accuracies in 2007

Land Cover Map of 2007							
Build up	30	31	29	96.67	93.55		0.9242
Cultivated land	25	28	23	92.00	82.14		0.7962
Grass land	23	19	17	73.91	89.47		0.8812
Settlement	2	1	1	50.00	100.00		1
Plantation trees	15	16	14	93.33	87.50	84.16%	0.865
Vegetation	18	18	17	85.00	94.44		0.9383
Bare land	34	38	33	97.06	86.84		0.8418
Bush land	14	22	12	85.71	54.55		0.5116
Wetland	38	29	24	63.16	82.76		0.7876
Total	202	202	170				

Land use/cover dynamics

Land use/cover change analysis results and magnitude of land LULC change over the period 1984 and 2007 indictated that at the initial state (1984), bush lands were the dominant land use land cover type, making up 22.64% of the study area. This was followed by grass lands (19.89%), cultivated land (18.91%), bare lands (13.22%), wetlands (8.74%), plantation forest (6.22%), settlement (3.68%), natural vegetation (3.19), buildup areas (3.04) and water body (21%). Between years 1984 and 2007, the LULC types have shown substantial positive and negative changes (Table 4). Build up, settlement, plantation forest were the top three LULC types, which have undergone large positive change of 116%, 69% and 66%, respectively. Whereas, the natural vegetation, bare land, bush land, water body and wetlands have critically declined during these periods (Table 4). The drastic consequences of ever increasing demand for residential and institutional building construction spaces, associated poor urban planning (evidenced by widespread informal settlements) are mainly attributable to the observed changes.

Table 4: Land use/cover change analysis results magnitude of change over the period 1984 and 2007

LULC	1984	Lul % area	2007	% area	*Change (ha)	change in % change
Build Up	292.68	3.04	633.18	5.29	+ 340.49	+116
Cultivated Land	1820.61	18.91	2477.76	20.72	+ 657.15	+36
Grass Land	1913.67	19.87	2543.63	21.27	+ 629.96	+32
Settlement	371.56	3.86	627.57	5.25	+256.01	+ 69
Plantation forest	599.32	6.22	1754.91	14.67	+ 155.59	+66
Other vegetation	307.49	3.19	252.09	2.12	- 55.395	-18
Bare Land	1272.87	13.22	992.19	8.3	- 80.69	-22
Bush land	2179.62	22.64	1894.2	15.84	- 285.5	- 13
Water Body	20.07	0.21	0	0	-20.07	-100
Wet land	841.75	8.74	783.2	6.55	-158.6	-17

+ and – signs, respectively, denote increase and decrease in LULC areas

A clear trend of replacement of natural forest by plantation forest shown in this study is another important ecological concern that needs sufficient attention from scientific communities, policy institutions and land administrators. Poorly planned urban sprawl is causing multidimensional socio-ecological impacts worldwide (Elmqvist *et al.*, 2013). Understandably, peri-urban areas have unique opportunities that favors easy access to market (Omiti *et al.*, 2009, Shiferaw, Hellin, and Muricho 2016), hence these factors often encourage land users to produce crops of high economic value such as coffee, fruit trees and Eucalyptus. However, proper land use needs to be identified to address both economic needs and sustainability of ecological functioning across landscapes. With anticipated rapid urban expansion and population growth, the observed trends of LULC change and associated undesirable environmental consequences such as habitat loss and degradation of key ecosystems are likely to amplify (Jantz *et al.* 2015, Seto, Güneralp, and Hutyra 2012, Pugh 2014). The environmental challenges associated with rapid urbanization (Grimm *et al.*, 2008) is of particularly concern in low income countries of Africa where urbanization is often poorly planned (Breuste, Qureshi, and Li 2013, Cohen 2006).

CONCLUSION

This study provided spatially explicit information about LULC dynamics that Jimma and its surrounding has undergone during the past three decades. The result of the study has revealed that, the rapid expansion of Jimma city coupled with fast demographic change and high demand for urban land has resulted in drastic changes in key ecosystems including natural forest, grasslands and wetlands. This imply that research and policy institutions need to give due attention to the dynamics and long-term socio-ecological impacts. This suggests that critical holistic scientific and development measures towards environmental sustainability in and around Jimma city need to be taken by both science and the policy environments. In sum, the results could contribute to informed decision making processes towards environmental sustainability in rapidly urbanizing areas of the country.

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