Environmental Management (2018) 61:132–146
DOI 10.1007/s00267-017-0953-x

Temporal Dynamics of the Driving Factors of Urban Landscape Change of Addis Ababa During the Past Three Decades

Meskerem Zewdie[1] · **Hailu Worku**[1] · **Amare Bantider**[2]

Received: 16 May 2017 / Accepted: 21 October 2017 / Published online: 2 November 2017

Abstract Mapping and quantifying urban landscape dynamics and the underlying driving factors are crucial for devising appropriate policies, especially in cities of developing countries where the change is rapid. This study analyzed three decades (1984–2014) of land use land cover change of Addis Ababa using Landsat imagery and examined the underlying factors and their temporal dynamics through expert interview using Analytic Hierarchy Process (AHP). Classification results revealed that urban area increased by 50%, while agricultural land and forest decreased by 34 and 16%, respectively. The driving factors operated differently during the pre and post-1991 period. The year 1991 was chosen because it marked government change in the country resulting in policy change. Policy had the highest influence during the pre-1991 period. Land use change in this period was associated with the housing sector as policies and institutional setups were permissive to this sector. Population growth and in-migration were also important factors. Economic factors played significant role in the post-1991 period. The fact that urban land has a market value, the growth of private investment, and the speculated property market were among the economic factors. Policy reforms since 2003 were also influential to the change. Others such as accessibility, demography, and neighborhood factors were a response to economic factors. All the above-mentioned factors had vital role in shaping the urban pattern of the city. These findings can help planners and policymakers to better understand the dynamic relationship of urban land use and the driving factors to better manage the city.

Keywords Addis Ababa · AHP · Driving factors · Temporal dynamics · Urban landscape change

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00267-017-0953-x) contains supplementary material, which is available to authorized users.

✉ Meskerem Zewdie
meskerem_zewdie@yahoo.com

[1] Ethiopian Institute of Architecture, Building Construction and City Development (EiABC), Addis Ababa University (AAU), Addis Ababa, Ethiopia

[2] Center for Food Security Studies, College of Development Studies, AAU, Addis Ababa, Ethiopia

Introduction

Landscapes around the world are changing and becoming more urban than before. Though this trend is expected to continue for years ahead, Asia and Africa's share of the increase in urban population will reach 90% by 2050 (UN 2014). This implies that rapid landscape change will occur in cities of developing countries than in any other part of the world. Recently, studying urban landscape change and its impact has gained attention because of different reasons. First, ecosystems in urban areas are strongly affected by urbanization-induced landscape change and these have been considered as the major causes to global change (Grimm et al. 2008; Kalnay and Cai 2003; Seto and Fragkias 2005; Vitousek 1994). Second, achieving sustainability in cities has been a global issue due to the rapid and worldwide urbanization (Andersson 2006; Hunziker et al. 2007; Wu 2010). Third, quantifying landscape change is important for planners and decision makers to understand the spatial extent, pattern, and impacts to better plan the future (Yang 2007; Yang et al. 2010; Zhou et al. 2008). One way of understanding landscape changes and their response is to address land use pattern dynamics (Maro 2011). Mapping such changes in urban areas, however, is challenging, as urban landscapes are highly heterogeneous (Alberti et al. 2004). Preferably, high spatial resolution imagery is best suited for urban change detection as it captures detail information which increases visibility and aids in classification. In line with this, research results have revealed that, with increased spatial resolutions, object-based image analysis has better accuracy as compared to the conventional pixel-based method as it combines spatial information with contextual information such as texture, shape, and the relationship with neighboring pixel during classification to extract meaningful features (Blaschke 2010; Myint et al. 2011; Zhou et al. 2008). However the fact that high-resolution imagery is unaffordable for large area poses a challenge for undertaking urban change detection studies especially in developing countries. As a result, free access medium-resolution imagery like Landsat and post classification method are commonly used to produce change maps by separately classifying images from two or more periods. Several researchers have examined the potential of medium-resolution satellite data for urban application to extract accurate geospatial information (Chen et al. 2010; Seto and Fragkias 2005; Yang 2002; Yuan et al. 2005). A detailed landscape change study, however, not only requires detecting the change in the landscape but also a sound understanding of the underlying processes and factors behind the change (Hersperger and Bürgi 2009; Peña et al. 2007). Studying the underlying driving forces behind landscape change is important because cities and their growth are the expressions of the interplay of the biophysical, economic, societal pressures, and political driving forces. Driving forces usually portray intricate relationships that are often difficult enough to comprehend as they manifest themselves diversely on several temporal and spatial levels (Lambin et al. 2001). For example, Brown et al. (2004) reviewed existing modeling approaches that aid in understanding the complex relationship between land use change and their explanatory factors. Pijanowski (2002) used a neural network model to explain how factors like roads, highways, rivers, coastline etc. influenced the urbanization pattern of Michigan's Grand Traverse Bay Watershed. Recent studies about drivers of urban landscape change even explored the spatiotemporal change of driving forces and their relative importance using different methods. For example, binary logistic regression was used to investigate the temporal variability of driving forces of land use change in various urban areas in China such as Guanyun, Kunshan, and Changshu counties, Beijing and port towns in Taicang City (Dong et al. 2015; Li et al. 2013; Shu et al. 2014). Other regression-based models were used to understand the spatiotemporal variability of urban growth drivers in Mumbai (Moghadam and Helbich 2015). However, the variables used in the above-stated studies mainly focus on physical factors (slope, elevation etc.) and distance-based factors (proximity to road, proximity to city center etc.) without representing other important factors like demography, spatial planning, policy and institutional factors that are difficult to find in consistent manner but have significant influence on urban land use change in rapidly growing cities of developing countries. In line with this, Thapa and Murayama (2010) managed to incorporate factors like physical, population growth, land market, economic opportunities, plans and policies, and political situation to quantitatively examine the drivers of urban expansion in Katmandu Valley, Nepal with the help of expert knowledge in Analytic Hierarchy Process (AHP) framework. Previous research also asserted that incorporating experts' knowledge is important to fill the data gap which could not be obtained through document analysis and relate the land use change with the social processes underneath (Hersperger and Bürgi 2007; Hersperger and Bürgi 2009).

Having the complexities of studying urban landscapes, studies on the urban dynamics of Addis Ababa and the underlying driving forces are very limited. For example, Tadesse et al. (2001) used Landsat Thematic Mapper images of 1987 and 1999 to analyze land use land cover changes of Addis Ababa without taking into account the boundary of the city and the accuracy assessment of classification results. Bekalo (2009) almost took similar years to study the extent and pattern of changes within the old urban boundaries of Addis Ababa that occurred between 1986 and 2000 using spatial metrics and remote sensing data. Fetene and Worku (2013) also used Landsat images of 1986, 2000, and 2011 to analyze the land use land cover change of the upper catchment of Addis Ababa for the purpose of mapping functional zones of urban forest in the area. Woldegerima et al. (2016) characterized the urban environment of Addis Ababa through urban morphology types. For a city like Addis Ababa that is undergoing a rapid change in recent past, there is a need for reliable and timely land use land cover information. In addition to this, all studies focused on the spatial aspect of change without understanding what the underlying driving factors behind these changes are, which are vital in understanding the dynamic human–environment link. Therefore, the objectives of this paper are to (i) quantify the land use land cover change of Addis Ababa between 1984 and 2014; (ii) examine the underlying driving forces and their temporal dynamics; and (iii) assess the pattern of growth of the city.

Study Area

The selected area of study is Addis Ababa (Fig. 1), the capital of Ethiopia, as well as the seat of the African Union.

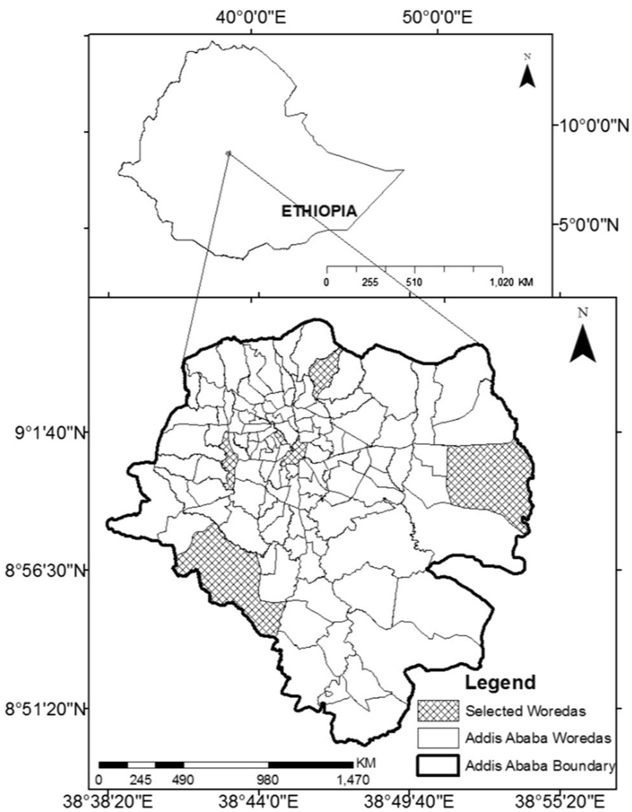

Fig. 1 Map of the study area, Addis Ababa

It is located in the horn of Africa at geographic coordinate 9° 2′ 0″ N latitude and 38° 42′ 0″ E longitude. At an altitude range of 2200–3100 m above sea level, the city is located in the central highland with Afro-Alpine temperate and warm climate. There are six rivers crossing the city from north to south. With an urban population growth rate of 4.18% between 2005 and 2010 (Population affairs directorate of MoFED 2011), Addis Ababa is currently among the fastest growing urban centers and the commercial, industrial and political center of the country. The service sector is the stronghold of the city's economy, contributing about 75.4% to the city's total GDP, while the industrial and agricultural sectors contributed, on average, for about 24.3 and 0.35% per annum, respectively, during 2005–2009 (AABoFED, 2010). The total population of Addis Ababa for the year 2014 was projected to be 3,201,662 which represented 19.8% of the country's urban population and 3% of the country's total population (CSA 2014). Since establishment in 1887, the city has gone through nine master plans. Addis Ababa is still a primate city (Addis Ababa is more than ten times as populous as the second largest city in the country) even though the primacy syndrome has declined in the recent past following the rapid growth of the regional capitals resulting in the decrease of Addis Ababa's share of the total urban population of Ethiopia. For administrative purpose, the city is subdivided into ten sub-cities and 116 "Woredas" (the lowest official administrative units) covering a total area of 540 km^2.

Method

Landsat Data

Four cloud free Landsat scenes were chosen to classify the study area: Landsat TM December 2, 1984, Landsat TM January 30, 1995, Landsat ETM+ January 12, 2003, and Landsat 8 December 20, 2014. Although image acquisition years highly corresponded with the availability of Landsat imagery (for classification) and aerial photographs (for accuracy assessment), the main reason for choosing these years was to link them to key events in history which might have influenced the land use land cover dynamics. For example, the period between 1984 and 1995 was characterized as a time of war and drought which could be the push factors to migration to Addis Ababa and represented the previous regime prior to government change in 1991. From 1995 to 2003, the country was mainly focusing on rural development strategy and the growth of regional towns resulting from the decentralized political system adopted since 1991. Contrary to this, the period between 2003 and 2014 was a time the government took strong initiative to promote urban development especially in Addis Ababa. All the above scenes were contained within path 168 and row 54 and geometrically corrected and freely downloaded from USGS web page. In order to better distinguish between crops (mainly in the outskirts of the city) and forest, all scenes were acquired during the dry season. Each scene was then pre-processed individually by combining separate image bands into a single multispectral image file. Finally, it was subsetted to the study area using ERDAS IMAGINE 2013 software.

Reference Data

Depending on data availability for the study years, various reference data sources were used to organize reference data for preparing representative samples for each land cover class. Known reference points were also required for undertaking accuracy assessment (to measure the agreement of classification results to what is actually on the ground). High-resolution panchromatic aerial photographs taken in 1971 (scale 1:50,000), 1984 (1:10,000 scale), and in 1994 (1:8000 scale) as well as digital color orthophotographs acquired in 2005 and Google Earth map of the study area for the year 2015 were used to delineate representative samples for each class by means of visual interpretation. Reference points for undertaking the accuracy assessment of the 1984 and 1995 classifications were taken from

Table 1 Land cover classification scheme used for Addis Ababa for years 1984–2014

Land cover class	Description
Urban/built-up	Residential, commercial, industry, transprtation, communication, and utilities
Agriculture	Cropland, pasture, and grassland
Forest	Natural and plantation forest, trees, and other woody species

panchromatic aerial photographs of 1984 and 1994, respectively. As it was not practical to have aerial photographs covering the whole study area in terms of cost and time, the study area composed of 116 "woredas" were first clustered into three broad groups (core, intermediate, and expansion/outskirt areas) based on the intervention map developed by Office of Revision of Addis Ababa Master Plan in 2002 in order to best represent the classes in the study periods. Using random sampling technique, two "Woredas" from each cluster were selected and the corresponding aerial photographs were then acquired from Ethiopian Mapping Agency. The aerial photographs were scanned using Epson Expression 10,000XL Scanner at 600 dpi and saved as tiff format. Then they were orthorectified to remove the geometric distortions using 3D geometric model in ERDAS IMAGINE 2013 software. For the year 1984, 12 aerial photographs were used and equalized random sampling was applied to select reference points. From a total of 3694 points taken, 159 reference points fall on the reference photographs. Fourteen aerial photographs were used to take reference points for performing the accuracy assessment of the 1995 classification. A total of 164 reference points were obtained from 3507 equalized random points taken. Digital color orthophotographs of Addis Ababa taken in 2005 were the only available reference data to undertake the accuracy assessment of the 2003 classification. A total of 170 photographs were mosaiced and 166 reference points were generated from 1026 equalized random points taken. Reference data for the 2014 accuracy assessment was obtained from Google earth map of 2015. It was first reprojected to UTM 84 zone 37N and from 258 equalized random points taken, 168 points fall within the study boundary.

Image Classification

Referring to the Landsat data of 30 m resolution used in this study, three generalized level I classes (Table 1) were developed based on the land use land cover classification system developed by Anderson (1976) and its modified version by Yang (2002). The satellite images were classified into three land use/land cover classes using supervised classification with maximum likelihood classifier. For each class between 12 and 15 representative sample training sites were extracted. After classification, they were recoded as per the classification scheme used. As suggested by Lillesand et al. (2014), a majority neighborhood filter was run after classification to reduce noise and avoid isolated pixels.

Classification Accuracy Assessment

Classification results from satellite images are subjected to accuracy assessment as they contain classification errors. Aerial photo having a higher resolution is often used to access the accuracy of maps produced from medium-resolution satellite imagery like Landsat. Accordingly, points taken using equalized random sampling from the aerial photographs of 1984 and 1994 as well as the 2005 orthophotographs and the 2015 Google earth map were used to measure the agreement between the classification results and the reference data. To meet the minimum sample of 50 per class suggested by Congalton and Green (2009), high number of reference points were taken as the historical photographs do not cover the entire study area. Details about the accuracy assessment are found in the Supplementary Material.

Change Detection

Examining the change over time or trend is among the important aspects of every landscape research (Ghosh et al. 2007). With its advantage of displaying "from-to" information on the classified images, post classification change detection has been used in change analysis of metropolitan areas (Yang 2002; Yuan et al. 2005). Change matrices were formulated (Table 2) to determine the specific changes and the gain and loss among the classes in four intervals, 1984–1995, 1995–2003, 2003–2014, and 1984–2014.

Driving Factors

Additional to literature review, interview with 15 experts in the field of urban economics, sociology, geography, ecology, policy, and urban planning and management were conducted to identify and broadly classify the underlying driving factors into six categories: (1) demographic factors that include natural population increase and in-migration, (2) economic factors such as employment and investment opportunities that promote urban development, (3) accessibility factors that include infrastructure expansion and proximity to road, centers, and services, (4) neighborhood factor that refers to prior development in an area that attract urban expansion, (5) policy factors that refer to national and planning policies which have restrained and promoted urban development, (6) physical factors such as topography, soil and natural features like rivers that have a positive or

Table 2 Matrix of land use/land cover change (000 ha) of Addis Ababa for years 1984–1995, 1995–2003, 2003–2014, and 1984–2014

	Forest	Urban	Agriculture	
1995	1984			1995 total
Forest	5.1	0.07	0.94	6.11
Urban	1.32	7.02	5.49	13.83
Agriculture	4.8	0.92	26.43	32.15
1984 total	11.22	8.01	32.86	52.1
2003	1995			2003 total
Forest	3.25	0.24	0.55	4.04
Urban	0.68	12.18	6.38	19.24
Agriculture	2.18	1.42	25.23	28.83
1995 total	6.11	13.84	32.16	52.1
2014	2003			2014 total
Forest	1.94	0.05	0.86	2.85
Urban	1.76	18	14.28	34.04
Agriculture	0.33	1.18	13.68	15.19
2003 total	4.03	19.23	28.82	52.1
2014	1984			2014 total
Forest	2.48	0.01	0.36	2.85
Urban	6.39	7.61	20.05	34.05
Agriculture	2.35	0.39	12.44	15.18
1984 total	11.22	8.01	32.85	52.1

negative impact on urban expansion. In order to understand the temporal variability of the driving forces, the factors were further categorized into two: pre-1991 and post-1991 driving factors. The pre-1991 period for this study represents the pro-socialist military government called the Derg regime (1974–1991) and corresponds with the 1984 classified map, while the post-1991 period represents the current government which is advocating market-oriented economic policy (1991-present) and match with the 1994, 2003, and 2014 classified maps in Fig. 2. Experts representing wide range of disciplines, with long-term experience and who can witness about the three decades of landscape change of Addis Ababa were interviewed. The level of education, area of expertise, and work experience of interviewed experts is summarized in Table 3. Semi-structured interviews were conducted and recorded. Each expert was then asked about the role that the driving factors in the two categories played in causing landscape change. For analysis, AHP was used. AHP is a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales in order to determine the importance of influence of one element over the other (Saaty 2008, p 83). The pairwise comparison involves in identifying which attribute has importance over the other and numerically expresses the level of importance ranging from 1 up to 9, where 1 denotes that both attributes have equal importance and 9 denotes that one has absolute importance over the other (Saaty 2008). Comparisons in AHP display reciprocal property, i.e., if attribute i has a value x when compared with attribute j, then j has a value of $1/x$ when compared with i. The process calculates the normalized value, criteria weight, and consistency ratio in order to finally rank which criteria or attribute has more weight over the others. A consistency ratio of less than or equal to 0.1 is accepted as measure of consistency of judgments. With its advantage of using both qualitative and quantitative attributes and its ability to solve complex problems with multiple criteria, recent applications of AHP include in land preservation (Duke and Aull-Hyde 2002), in regional forest planning (Ananda and Herath 2003), in wetland management (Herath 2004), and in identifying drivers of urban growth (Thapa and Murayama 2010). Each expert filled the pairwise comparison matrix/table twice: for pre-1991 and post-1991 and a total of 30 AHP matrices were filled and normalized values, criteria weights and consistency ratios were computed. In order to come up with the final ranking of the judgments, geometric mean of the final ranking given by all experts was used (Bhushan and Rai 2007). A consistency ratio ranging between 0.02 and 0.08 were achieved for all matrices which are within the allowable range. Later on, available secondary data on the driving factors were used to compliment primary perception data from experts in the “Results and discussions” section.

Results and Discussions

Classification Accuracy

In order to check the classification accuracy, confusion matrices were computed, and user, producer and overall accuracies were calculated. The overall accuracies for 1984, 1995, 2003, and 2014 are 89.94, 89.02, 85.54, and 85.39%, respectively (refer the Supplementary Material). Results comply with an acceptable overall accuracy of greater than 85% suggested by Campbell and Wynne (2012).

Classification Statistics and Change Maps

Figure 2 shows the land cover maps for the years 1984, 1995, 2003, and 2014 and Table 4 summarizes the change within classes interpreted in hectares and percentages. From 1984 to 2014, urban area increased by about 26100 ha (50%), while agriculture and forest decreased by 17700 ha (33.9%) and 8300 ha (16.1%), respectively. This signifies that from 1984 to 2014, urban area showed a relative increase of 325%, while agriculture and forest decreased by

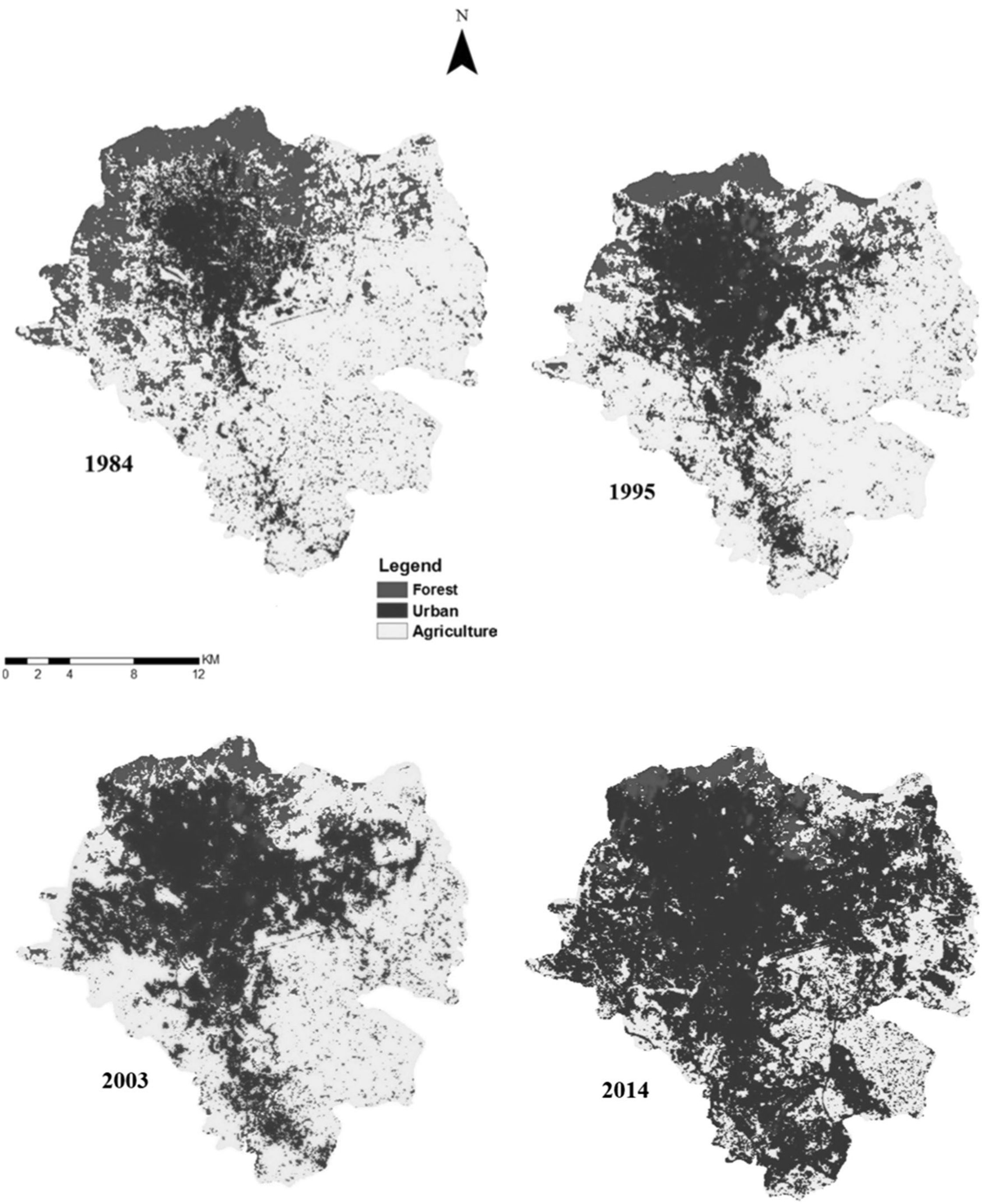

Fig. 2 Landsat land use land cover classification of Addis Ababa from 1984 to 2014

54 and 75%, respectively. Referring to Table 4, 77% (13700 ha) of the decrease in agriculture and 57% (14900 ha) of the increase in urban area was registered from 2003 to 2014. Meanwhile, 61% (5100 ha) of the decrease in forest was recorded from 1984 to 1995. Matrices of land cover change from 1984 to 1995, 1995 to 2003, 2003 to 2014, and 1984 to 2014 were calculated (Table 2) in order to understand the direction of change. Referring to Table 2, the period from 1984 to 1995 revealed that 4800 ha of forest was lost to agriculture and 1320 ha of forest was converted to urban. In the same period about 5490 ha of land was converted from agriculture to urban. From 1995 to 2003, the major change was from agriculture to urban which is about 6378 ha followed by 2179 ha from forest to agriculture (Table 2). The period between 2003 and 2014 recorded the highest change from agriculture to urban. 14281 ha of land was converted to urban while in the same period 861 ha of land was converted from agriculture to forest and 1764 ha of

Table 3 Level of education, area of expertise, and work experience of experts interviewed for analyzing the drivers of landscape change of Addis Ababa using AHP

No.	Level of education	Area of expertise	Work experience
Expert 1	Ph.D.	Geography, urban and regional planning, urban transport	Finance and Economic Develoment Bureau Head, Assistant Professor in urban transport planning
Expert 2	Ph.D.	Architect-planner, urban design	Assistant Professor in urban design
Expert 3	Ph.D.	Architect-planner, urban design, urban policy	City Manager of Addis Ababa city, Associate Professor in housing and urban design
Expert 4	Ph.D.	Urban sociologist	Associate Professor in urban sociology
Expert 5	M.Sc.	Architect-planner	Subcity Manager of Addis Ababa, Deputy Head of Master Plan Project Office of Addis Ababa
Expert 6	M.Sc.	Economist, urban management	Works and Urban Development Bureau Head of Addis Ababa
Expert 7	M.Sc.	Architect-planner	Urban Design Department Head at National Urban Planning Institute, Chief Planner at Master Plan Revision Office of Addis Ababa
Expert 8	M.Sc.	Economist, local and regional development planning	Lecturer and Chairholder in urban policy, Capacity Development Department Head at Addis Ababa Urban Managment Institute
Expert 9	M.Sc.	Urban economist, land management	Advisor to the Minster of Works and Urban Development of Addis Ababa, land management expert
Expert 10	M.Sc.	Geographer	Chief geographer at National Urban Planning Institute, expert at Master Plan Revision Office of Addis Ababa, Deputy Manager of urban planning consulting firm
Expert 11	M.Sc.	Architect-planner	Urban planner at National Urban Planning Institute, expert at Master Plan Revision Office of Addis Ababa, lecturer of urban planning
Expert 12	Ph.D.	Urban ecology	Associate Professor of urban ecology
Expert 13	Ph.D.	Urban policy	Professor in public managment and public policy
Expert 14	Ph.D.	Architect-planner, land policy	Regional Works and Urban Development Bureau Head, Assistant Professor of urban development
Expert 15	Ph.D.	Urban design	Subcity manager of Addis Ababa, Assistant Professor of urban development

Table 4 Summary of Landsat classification results of land use/land cover change of Addis Ababa for years 1984–2014 in terms of area and percentage

Land cover classes	1984		1995		2003		2014		Relative change
	Area (000 ha)	%	Area (000 ha)	%	Area (000 ha)	%	Area (000 ha)	%	1984–2015 (%)
Forest	11.2	21.5	6.1	11.7	4	7.8	2.9	5.4	−74.6
Urban	8	15.4	13.8	26.6	19.2	36.9	34.1	65.4	324.9
Agriculture	32.9	63.1	32.2	61.7	28.9	55.3	15.2	29.2	−53.8

forest was lost to urban (Table 2). This reveals that despite some reforestation efforts, there is no net increase to the total forest cover and it can be seen on the classified images that there are forest areas lost to other land uses and areas which were lost that have been regained. In the same period, 1177 ha of land was converted from urban to agriculture. This could be attributed to the vast urban areas cleared for urban renewal and left vacant and partially resulting from classification errors. As it has been summarized in Table 2, 77% (20,050 ha) of the total growth in urban land use between 1984 and 2014 was converted from agricultural land and the matrices revealed that urban expansion mainly took place in agricultural land than in forest.

Pattern

Figure 3 shows the urban growth map of Addis Ababa in time intervals 1984–1995, 1995–2003, and 2003–2014. Visual comparison has indicated that between 1984 and 1995, urban growth was mainly along the southern and eastern axes following the existing transport network. From 1995 to 2003, rapid expansion further pushed growth in eastern, western, and southern peripheries. This has further induced rapid and discontinuous patches of urban development in all direction but more intensified in eastern agricultural areas between 2003 and 2014. Growth in the north is inhibited as compared to other location though there is rapid growth along Gojam Road (Fig. 3). Referring to the results in Table 4, the built-up area in 1984 was 8000 ha which expanded to 34100 ha in 2014, while the population of Addis Ababa grew from 1,423,182 in 1984 to 3,201,662 in 2014 (CSA 1991; CSA 2014). Calculating the average population density, which is the ratio of urban population to the built-up area, revealed that the density in 1984 was 178 persons/ha which declined to 94 persons/ha in 2014. This signifies that the density is declining at 3% annually.

Driving Forces in Pre-1991 Period

Calculation of the percentage weights of each driving forces during the pre-1991 period revealed that policy and institutional factors with a weight of 41.6 had the highest impact in causing urban land use change. Demography was the second influencing factor with a weight of 22.1.

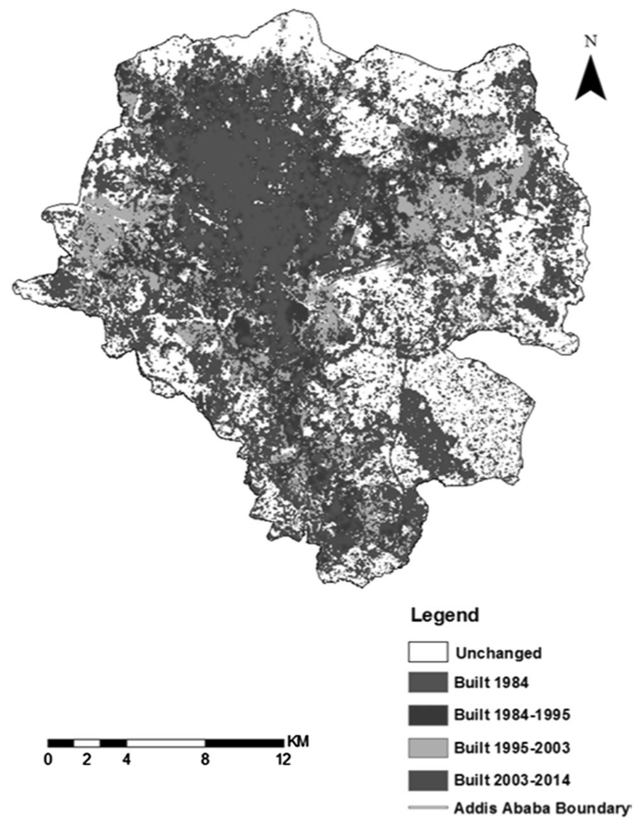

Fig. 3 Urban growth pattern of Addis Ababa from 1984 to 2014

Accessibility and economic factors had almost equal influence with weights 10.9 and 10.5, respectively. Physical factors (7.6) and neighborhood (7.3) were the least impacting factors to cause urban land use change.

Driving Forces in Post-1991 Period

The percentage weight of the driving factors during the post-1991 period showed that economic factors had the highest impact in causing urban land use change with a weight of 37.9. Policy and institutional factors had the second highest influence having a weight of 26.7. Demographic, accessibility, and neighborhood factors weighted 12.5, 11.2, and 7.2, respectively, impacting urban land use change. Physical factors were the least influencing factor with a weight of 4.6.

Discussion

Results from the classified maps showed the dynamics of urban land use in the past three decades in Addis Ababa. Change statistics revealed that a change from agriculture to built-up was the dominant form of land use change in all the study years, while the period from 2003 to 2014 took the largest share. Meanwhile a decline in forest was recorded between 1984 and 1995. Economic, demographic, accessibility, neighborhood, physical and policy and institutional factors have been the underlying factors and played a differentiated role in the pre and post-1991 periods.

Pre-1991 Driving Factors

When discussing the role of policy and institutional factors in causing urban land use change, Proclamation No. 47/1975, which nationalized urban land and extra houses, was a major policy shift from the previous system that changed the land tenure regime from private to state ownership. With this proclamation, a household was entitled a maximum of 500 m^2 and the property right of land was limited to use right, i.e., personal use which shall not include the right to transfer it by will, donation, mortgage or sale. As a result, all private investments were ceased and land delivery was administered through a redistributive system with nominal amount of land rent and housing tax as established by Proc. No. 80/1979 and its amendment Proc. 161/1979. This system encouraged housing cooperatives and individuals and from 1975 to 1985 21,301.2 ha of land were allotted for house builders (Ministry of Urban Development and Housing 1982). Institutions like The Housing and Savings Bank (HSB) established in 1975 and Construction Materials Supply Enterprise and Housing Construction Corporation established in 1987 facilitated mortgage and building material sales especially to those who were permanently employed civil servants. However, people whose need and demand could not be met by the formal system looked for informal options like buying land from farmers and peasant associations that led to conversion of farmland to settlement at peripheries especially in the eastern part of the city called Kotebe. This also led to the horizontal densification and overcrowding in existing urban core resulting in urban decay. The irregular pattern of growth in this period might also be attributed to the fact that 80% of the houses in Addis Ababa built between 1984 and 1995 were the result of unplanned and informal buildings extensions (PADCO 1997). This could also indicate that informal settlement was the prime cause to the decline in forest as shown in Table 2. The state being the sole actor in property development, the Agency for Administration of Rental Houses was also engaged in constructing apartment buildings, hostels, office buildings, and low-cost and self-help houses though not in a large scale. Later in 1984, allocation of urban land was barred due to shortage of building materials and the preparation of the new Addis Ababa Master Plan (Ethio-Italian Master Plan) with the intention to prepare a plan to guide urban land use of the city. However, its approval was only possible late in 1994, which led to further proliferation of informal settlements and was followed by Proclamation No. 292/1986, that reduced plot sizes from 500 to 108–250 m^2. For the first time cooperatives were also urged to build vertically, mainly a building with one storey that have shared common wall to save urban land and construction materials. After this policy was issued, 394.9 ha of urban land was allotted to cooperatives between 1986 and 1990 (Ministry of Urban Development and Housing 1982). The move toward mixed economy in 1990 relieved the limitations imposed on housing development with regard to plot size and allowed private sector involvement with the right to build, rent, sell, and lease. The capital limit of 250,000 Birr (Ethiopian currency exchanged at 1USD = 2.07 Birr during the pre-1991 period) was also relaxed to 500,000 Birr. Though this movement was cut short with the change in government in 1991, this was a time when construction of medium-storey buildings especially hotels started to reemerge in Addis Ababa.

Referring to demographic factors, the main data sources for discussion are published reports from Central Statistical Agency (CSA) of the 1984, 1994, and 2007 National Population and Housing Census of Ethiopia. Data on the inter-censal period 1984–1994 was considered to represent the pre-1991 period. In this period, Addis Ababa's population grew from 1,423,182 in 1984 to 2,084,588 in 1994 with annual growth rate of 3.6% (CSA 1991; CSA 1995). Though it is difficult to get reliable data on migration, apart from natural growth, it is implicit that migration has contributed to urban population growth in this period. On the one hand there was an attempt by government to control movement of people and even discourage rural–urban migration to the extent that if a famer abandons his land for some time, there is a possibility that he loses his land. But on the other hand, there were push factors such as environmental calamities and civil war that pushed people out to urban areas. Golini et al. (2001) also claimed that in-migration from affected areas to major towns has been the major contributor to the high growth rate registered during the inter-censal period 1984–1994. Therefore it is expected that in addition to natural population growth, rural–urban migration has been an important cause to urban land use change where others such as economic and neighborhood factors were less influential in the pre-1991 period.

Regarding accessibility factors, investment on infrastructure and service was so low during the pre-1991 period as the national economy was affected by the civil war and the city administration had little revenue to cover the huge cost. Infrastructure like road was considered as a service at that time and its importance in boosting other economic sectors was not realized. It was in fact similar to many developing countries that individuals and cooperatives develop their land first and infrastructure and services such as road and electricity come later. However, existing arterial roads had highly influenced urban land use change during the pre-1991 period. Planning experts interviewed confirmed that proximity to existing road and other infrastructures like water and electricity were priority factors considered when planning new settlements. Classification maps of the year 1984 and 1995 in Fig. 2 and earlier study conducted by Kassa (2014) also asserted that urban land use change of Addis Ababa was prominent along existing arterial roads which is a also a characteristic feature of other African cities (Braimoh and Onishi 2007; Vermeiren et al. 2012).

Under the centrally planned command economy of the socialist regime, the government was the main actor in all economic activities and urban development. The private sector involvement was almost non-existent and the investment policy limited investment capital not to exceed Ethiopian Birr 250,000 for domestic investors and 500,000 USD for foreigners. Therefore, the economy was not as such influencing land use change except in the housing sector and government-funded small-scale industries and administrative buildings. Low-density housing cooperatives were highly promoted that the HSB was offering a subsidized loan for cooperatives at 4.5% annual interest rate as opposed to 10% for individuals. The role of physical factor such as topography in transforming urban land use in the pre-1991 was minimal as land was monopolized by the government and people were not given a choice where to settle. Plot subdivision and allocation was made by different organs of the Ministry of Urban Development and Housing. It is likely that they have considered low slope areas during plot subdivision for the interest of development cost. Housing shortage was so severe that physical factor such as soil was not an issue that land was allocated for housing in area like Bole where the soil is less conducive for development. Generally seen, urban growth of Addis Ababa since establishment was southward due to high slope in the north direction. However, physical factors like topography and existing natural feature like river had impacted urban land use change contrary to the situation in developed countries. High slope areas were destinations for informal settlements as they are unreachable to government control and river banks in Addis are the most unkempt places of the city that they too are places for low income and informal settlement. Therefore, biophysical factors like topography and soil which can be modified through design had little impact to urban land use change in the pre-1991 period. When it comes to neighborhood factor, it was the least influencing factor in this period. The potential of a neighborhood to transform the land use in its surrounding was very low as the development process, land delivery, and scale of development were all government dictated. It was forbidden to tap economic gain using land as a commodity and there was almost no private property development which attracts individuals or businesses to an area. The land use change in this period was highly associated to the housing sector and there was a concern of equity that there was not much spatial and economic interaction that attracts further development. It is believed, however, that the cooperative houses might have influenced informal settlements to settle in close proximity with the expectation that the city expands and will reach their current location.

Post-1991 Driving Factors

From economic factors perspective, the first thing the government did when it took power in 1991 was to liberalize the economy by allowing the private sector in major economic sectors including real estate and banks (only for domestic investors). Being the capital city and due to the advantage of acquiring trained labor, infrastructure and access to financial services, investments want to locate their economic establishments in Addis or near Addis which increased the demand for land. The federal lease Proclamation No. 80/1993 (also amended in 2002 and 2011) and regulations 3/1994 were early economic and planning instruments the government used whereby the right to use urban land can have market value. It aimed at efficient utilization of urban land and generation of revenue that can be used to finance infrastructure and low-cost housing. Early years of the leasehold system resulted in low private involvement due to low level of awareness and capital shortage that only 200 ha of land were transferred through lease between 1994 and 2003 (Land Administration Authority of Addis Ababa City Administration 2003). Eventually, the city administration succeeded in collecting huge income from lease. According to Melaku (2016), the average share of lease income from non-tax income of the city reached 66% between 2008 and 2015 and the average contribution of lease income to the total revenue amounts to 8%. In spite of all this, it is also important to mention about the soaring prices of urban land in the city. This is attributed to the unmatched demand and supply that very few plots are out for lease tender and there are many applicants. In fact there is a very high speculation that investing on land property has high profit bubble than any other investment in Addis Ababa. Figures on Melaku (2016) are self-explanatory that the highest winning lease auction prices per 1 m^2 of land in 2014 was 355,555 Birr, while the lowest price offered for the same plot was 6689 Birr even though the minimum and maximum bench mark prices based on land grades were 126 and 2393 Birr/m^2. This implies that if the sector attracts more than what the real economy demands and continues to tie more land and capital to real estate, it might create imbalances that have negative consequences. It is evident that the lease system has some achievements with respect to changing the perception about urban land as an instrument for development and economization of land resource but it has encountered administrative and implementation failure. One notable undertakings of the post-1991 period is the involvement of the private sector in real estate. The housing backlog was so high which has created an incentive to invest in real estate. The share of housing from real estate, however, is small even though developers were granted subsidized land to build housed for mixed income groups. Result from EiABC (2011) revealed that 5000 housing units were built between 2003 and 2010 which accounted to only 3.8% of the housing provided in that period while consuming large area per family (500–1000 m^2) and building houses only for the high-income group. With reference to foreign direct investment (FDI) in the country, an increasing trend has been recorded since the issue of the investment proclamation in 1992. According to Wale (2015) FDI's share of the total investment projects licensed between 1992 and 2012 has reached 15.80%. China being the dominant actor, 86% of Chinese investments in Ethiopia between 1992 and 2005 were fully Chinese owned, while the remaining 12% were in joint ventures mostly located in Addis Ababa and Oromia Region (Desta 2009). Among Chinese-funded projects are railway, road construction, real estate, industry Park etc., where they created market for their capital, labor and goods while Ethiopia benefited from the inflow of investment and technology. However, there is a need for improved design, quality, and standard in order to ensure the sustainability of the projects.

Referring to policy and institutional factors in the post-1991 period, the government proclaiming ADLI (Agricultural Development Led Industrialization) as a national strategy in 1992 is to be noted. With a concept that development in agriculture will lead to industrialization, the focus remained in rural areas until 2003 when the government took serious reforms to address urban issues like housing shortage, unemployment, and poverty. This reform period also matched with the approval of the 2002 master plan which is the updated and revised version of the 1986 master plan. It is important to note that the period between 1986 and 2002 is hardly plan led because of the late approval of the 1986 master plan in 1994 and the need to revise it in 2002 to prepare a plan responsive to a market economic system. The 2002 master plan, with all its implementation gaps, was the most realized of all previous plans and has hugely changed the land use of the city. The five strategic areas include transport and road network, environment, housing, upgrading and renewal, and industry. The master plan also studied local development plans (LDP) for key areas and promoted vertical growth, established minimum building height requirement and indicated condominium approach to housing to curb urban expansion, provide low-cost housing, and renew the inner city. The condominium housing project launched in 2004 was one of the interventions in the post-1991 period that has changed the urban landscape. 61.1% (80,236 housing units) of the total houses provided between 2003 and 2010 was achieved through condominium housing consuming 794.5 ha of land (EiABC 2011). Even though the condominium housing has been successful in promoting vertical growth and increasing the housing stock, it could not be affordable to the low-income groups it was intended for. Moreover only few of them are built in renewal areas in order to reduce resettlement cost which has indirectly promoted expansion at peripheries even on ecologically sensitive areas. Due to the extensive scale, there are also situations where condominium houses are built on areas allocated for other uses like urban green which contradicts with the master plan. With reference to institutional factors, the decentralization of the city into 10 sub-cities and 116 Woredas and the subsequent arrangement of social services such as schools, health centers administrative buildings, micro and small enterprises into each subcity has also contributed to the land use change. The other key factor that has influenced urban land use change is the massive urban renewal process which is ongoing since 2008. It is aimed at removing the dilapidated urban settlement an insuring efficient use of urban land at inner city. This endeavor according to Office of the City Manager— Communication Affairs Office (2012) has cleared 155 ha of land at inner city and relocated 9777 households to periphery locations. Apart from allotting land for residential purpose, there is also strong government initiative in manufacturing and industry sector. As per the industrial LDP studies made, 1492.17 ha of land has been converted to industry parks, of which many of them are currently operational (EiABC Manufacturing Industries and Storage Facilities Team 2011).

Concerning demographic factors one cannot overlook the association of natural growth and migration to urban land use change. Based on data from 1994 and 2007 census, Addis Ababa's population grew from 2,084,588 in 1994 to 2,738,348 in 2007 at growth rate of 2.1% which showed a declining trend when compared to previous census period (CSA 1995; CSA 2007). However, it is realistic to say that that Addis Ababa has always been attracting migrants from all direction though the intensity varies across periods. In fact 46% of Addis Ababa population according to the 1994 census was migrant, of which 42% came from urban areas while the remaining were from rural origin (CSA 1995). Statistical Report on the 1999 National Labor Force Survey by CSA (1999) also reported that Addis has the highest percentage of migrants (46.9%) as compared to other regions. Recent data, however, are scant but experts interviewed perceived that the federal arrangement of the country, i.e., Woreda, Zone, Regional city and the growth of regional cities has made migration stepwise especially to those who aspire to formally reside in Addis. One the other hand, experts also expressed Addis Ababa as a non-ethnic melting pot that pulls migrants from all regions. It is believed that labor migration in the post-1991 period has increased as there are a number of attractions like construction boom, possibilities to engage in informal jobs, freedom of movement, the condominium housing projects (aspiring to get housing) etc. Hailemariam and Adugna (2011) also confirmed that labor migration is the recent trend of movement to urban areas by the landless, job transfers, environmental refugees, the internally displaced, and rural and urban poor. Migrants usually rent houses in group in low-income areas at the inner city where they engage into informal jobs and informally settle on inaccessible areas in Addis or in surrounding towns close to Addis where there is informal land market.

With reference to accessibility factors, tremendous progress has been made in expanding existing roads and constructing new ones even though there is no as such pro development approach in practice where infrastructure such as road precedes development. In spite of that the government has recognized the linkage between infrastructure development and economic growth and hugely investing on road infrastructure. According to UN-habitat (2007) the road coverage in Addis was only 6.1% in 2004. This figure has risen to more than 22% in 2016 (https://asokoinsight.com/news/addis-ababa-spends-big-on-roads-ethiopia viewed on 5 January 2017). Even though the trend of urban development in Addis Ababa is along the street network, one prominent characteristics of the post-1991 period is that the trend of expansion in road infrastructure (both asphalt and cobble stone) has led to area wise development where every piece of land in close proximity to road is a site for development. This has lead to land use dynamics like changing from residential to commercial and from single-storey to multi-storey with the introduction of access road. Neighborhood factor has relatively higher influence in the post-1991 period as there are a number of key projects like real estates, condominium housing projects, and industry parks which attract further development like magnet. The scale and intensity of these developments and the shift from low-rise development to medium and high-rise development have also transformed neighborhoods. Some of these moves in the housing sector not only have neighborhood effects but also transformed the social setting from mixed social structure to gated communities. Physical factors in the post-1991 period have the least impact in causing urban land use change as the development process consumes the remaining urban land. River banks still house informal settlements but high slope areas in some places are becoming destinations for the wealthy as opposed to the pre-1991 period.

In conclusion, it is worthwhile to highlight some of the key points that emerged from the discussion. First, the change from agriculture to built-up was the dominant form of land use change in the study years. Similar form of unplanned urban expansion on farmland and natural vegetation has also taken place in Nairobi, Kenya (Mundia and Aniya 2006). Second, urban landscape change in some areas have taken place on ecologically sensitive areas in violation of the master plan. Such forms of urban expansion have also happened in Kampala, Uganda (Vermeiren et al. 2012). Third, the driving factors have different roles during the pre and post-1991 period. Fourth, the decline in density shows that urban land is converting in a much faster rate than population growth and reveals that the city is experiencing a less compact growth pattern which is a great concern to sustainable development. The result is in agreement with the findings by Angel et al. (2011) that there is a decline in density especially in cities of developing countries (75 out of 88 sample cities). The same study revealed that the world urban land cover triples at 1% annual rate of density decline and it will increase fivefold at 2% decline.

Conclusion

The study analyzed three decades of urban landscape change in Addis Ababa and the temporal dynamics of the driving factors by: (i) quantifying the area of land belonging to each class, i.e., forest, urban, and agriculture for the study years and comparing the gain and loss in the respective class, (ii) indicating the nature of change by providing "from-to" statistics, (iii) assessing the accuracy of the classification results using historical data sets, (iv) assessing the pattern of growth, (v) examining the underlying driving factors and their temporal dynamics. Results of change analysis revealed that the highest percentage of change was recorded between 2003 and 2014 which is from agriculture to urban. The growth also changed to a less dense pattern which implies that unsustainable use of urban land is taking place. The interplay of the driving factors, namely, demographic, economic, accessibility, neighborhood, physical, and policy and institutional factors influenced the change differently during the pre and post-1991 period. Results of the driving factors analysis revealed that policy, demographic, and accessibility factors were highly influential during the pre-1991 period, while economic, policy, and demographic factors were very important during the post-1991 period. Linking remote sensing with social science data (expert knowledge) in this study was helpful in understanding the complex underlying processes behind the urban dynamics by uncovering important drivers like policy and economic factors that otherwise could not be seen spatially. However, further studies and investigation would lead to better understanding of the underlying factors.

In conclusion, the above-mentioned driving factors with their differentiated role during the pre and post-1991 period have caused landscape change in some areas that are (i) not compatible with the surrounding ecological system, through encroachment into fragile ecosystems, (ii) converted without considering the master plan and the suitability of that specific land for the intended development, (iii) located in areas that are vulnerable to natural hazards, such as flooding and landslides, (iv) developments that took place on agricultural land at peripheries than on renewal sites at inner city, (v) developments that do not fit with the local and regional ecological systems and affecting their sustainability over time. To resolve these problems, and make landscape changes sustainable, the city should consider systemic environmental planning within the landscape in which the city is embedding. This is a radical departure from the conventional practice of landscape change which involves planning urban development spaces first and inserting ecosystem/environmental functions into the leftover wastelands. To this end, it is important to perform landscape analysis and produce landscape plans which should differentiate areas of protection, excavation, deposition, ecosystem services, and scenic areas from areas of development/ buildable areas. In addition to this shift in planning approach, it is important to (i) perform regional environmental planning for better environmental resources allocation, (ii) encourage plan-led system of land conversion and strict implementation of the master plan to keep development away from ecologically sensitive areas, (iii) plan new developments on renewal sites at urban core than on agricultural land at peripheries to reduce environmental and social costs, (iv) strategically increase urban density to save urban land and green spaces, and (v) encourage better coordination of federal, regional, and local government programs and policies to curb sprawl and unsustainable land conversion.

Acknowledgements We gratefully acknowledge the financial support from Addis Ababa University Office of the Director of Research under the thematic research title "Resource efficiency, environmental quality and sustainability of urban areas in Ethiopia", Grant number TR/11/2013. The authors would also like to thank USGS for the provision of Landsat data sets and all experts who participated in the interview.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no competing interests.

References

AABoFED (2010) Addis Ababa city government urban development indicators. Finance and Economic Development Bureau. Addis Ababa. Unpublished technical report, Addis Ababa, Ethiopia

Alberti M, Weeks R, Coe S (2004) Urban land-cover change analysis in Central Puget Sound. Photogramm Eng Remote Sens 70:1043–1052

Ananda J, Herath G (2003) The use of analytic hierarchy process to incorporate stakeholder preferences into regional forest planning. For Policy Econ 5:13–26

Anderson JR (1976) A land use and land cover classification system for use with remote sensor data. US Government Printing Office, Washington, DC

Andersson E (2006) Urban landscapes and sustainable cities. Ecol Soc 11:34

Angel S, Parent J, Civco DL, Blei A, Potere D (2011) The dimensions of global urban expansion: estimates and projections for all countries, 2000–2050. Prog Plan 75:53–107

Bekalo MT (2009) Spatial metrics and Landsat data for urban landuse change detection: case of Addis Ababa, Ethiopia. Dissertation, Jaume I University, Spain

Bhushan N, Rai, K (2007) Strategic decision making: applying the analytic hierarchy process. Springer Science & Business Media, London

Blaschke T (2010) Object based image analysis for remote sensing. ISPRS J Photogramm Remote Sens 65:2–16

Braimoh AK, Onishi T (2007) Spatial determinants of urban land use change in Lagos, Nigeria. Land Use Policy 24:502–515

Brown DG, Walker R, Manson S, Seto K (2004) Modeling land use and land cover change. In: Gutman et al. (eds) Land change science: obs monit underst traject chang Earth's surf. Springer, The Netherlands, p 395–409

Campbell JB, Wynne RH (2012) Introduction to remote sensing. Guildford publications, New York

Chen D, Liu W, Tian J, Luciani P (2010) Evaluating the ecological and environmental impact of urbanization in the greater toronto area through multi-temporal remotely sensed data and landscape ecological measures. In: Jiang B, Yao X (eds) Geospatial analysis and modelling of urban structure and dynamics, Springer, The Netherlands, p 251–264

Congalton RG, Green K (2009) Assessing the accuracy of remotely sensed data: princples and practices, 2nd edn. CRC press/ Taylor & Francis Group

Central Statistical Authority (CSA) (1991) The 1984 Population and Housing Census of Ethiopia: Analytical Report at National Level, Vol. II. Central Statistical Authority, Addis Ababa

Central Statistical Authority (CSA) (1995) The 1994 Population and Housing Census of Ethiopia: Results for Addis Ababa Volume 1. Statistical Report

Central Statistical Authority (CSA) (2007) The 2007 Population and Housing Census of Ethiopia: Statistical Report for Addis Ababa City Administration

Central Statistical Authority (CSA) (1999) Statistical Report on the 1999 National Labour Force Survey, March 1999, Statistical Bulletin 225. Central Statistical Agency, Addis Ababa

Central Statistical Authority (CSA) (2014) Statistical Report on the 2014 Urban Employment Unemployment Survey: Statistical Bulletin. Central Statistical Agency

Desta A (2009) Chinese investment in Ethiopia: devlopmental opportunity or deepening China's new mercantilism? Int J Bus Strategy 9(2). http://works.bepress.com/asayehgn_desta/24/

Dong G, Xu E, Zhang H (2015) Spatiotemporal variation of driving forces for settlement expansion in different types of counties. Sustainability 8:39

Duke JM, Aull-Hyde R (2002) Identifying public preferences for land preservation using the analytic hierarchy process. Ecol Econ 42:131–145

EiABC Manufacturing Industries and Storage Facilities Team (2011) Evaluation of the 2003–2010 development plan of Addis Ababa. Unpublished Technical report, Addis Ababa, Ethiopia

EiABC (2011) performance evaluation Development Plan of Addis Ababa 2003–2010: Housing component. Unpublished technical report, Addis Ababa, Ethiopia

Fetene A, Worku H (2013) Planning for the conservation and sustainable use of urban forestry in Addis Ababa, Ethiopia. Urban forestry & urban greening 12:367–379

Ghosh S, Beran J, Heiler S, Percival D, Tinner W (2007) Memory, non-stationarity and trend: analysis of environmental time series. In: Kienast F, Wildi O, Ghosh S (eds) A changing world: challenges for landscape research, Springer Science+Business Media B.V, The Netherlands, p 223–247

Golini A, Said M, Casacchia O, Reynaud C, Basso S (2001) Migration and urbanization in Ethiopia, with special reference to Addis Ababa. In-depth analysis of the 1994 Population and Housing Census of Ethiopia. Central Statistical Authority (CSA) Addis Ababa Ethiopia, Institute for Population Research – National Research Council (Irp-Cnr), Roma, Italy

Grimm NB, Faeth SH, Golubiewski NE, Redman CL, Wu J, Bai X, Briggs JM (2008) Global change and the ecology of cities. Science 319:756–760. https://doi.org/10.1126/science.1150195

Habitat, UN (2007) Situation analysis of informal settlements in Addis Ababa. Cities without slums: Sub-regional program for Eastern and Southern Africa

Hailemariam A, Adugna A (2011) Migration and urbanization in Ethiopia: addressing the spatial imbalance. In: Teller C, Hailemariam A (eds) The demographic transition and development in Africa. Springer, The Netherlands, p 145–165

Herath G (2004) Incorporating community objectives in improved wetland management: the use of the analytic hierarchy process. J Environ Manag 70:263–273

Hersperger AM, Bürgi M (2007) Driving forces of landscape change in the urbanizing Limmat valley, Switzerland. In: Eric Koomen E, Stillwell J, Bakema A, Scholten HJ (eds) Modelling land-use change: progress and applications. Springer, The Netherlands, p 45–60

Hersperger AM, Bürgi M (2009) Going beyond landscape change description: quantifying the importance of driving forces of landscape change in a Central Europe case study. Land Use Policy 26:640–648

Hunziker M, Buchecker M, Hartig T (2007) Space and place–two aspects of the human-landscape relationship. In: Kienast F, Wildi O, Ghosh S (eds) A changing world: challenges for landscape research. Springer Science+Business Media B.V, The Netherlands, p 47–62

Kalnay E, Cai M (2003) Impact of urbanization and land-use change on climate. Nature 423:528–531. http://www.nature.com/nature/journal/v423/n6939/suppinfo/nature01675_S1.html

Kassa F (2014) The rates and effects of urban sprawl in developing countries: the case of Addis Ababa, Ethiopia. Reg Stud 9:135–151

Lambin EF, Turner BL, Geist HJ, Agbola SB, Angelsen A, Bruce JW, Coomes OT, Dirzo R, Fischer G, Folke C, George P (2001) The causes of land-use and land-cover change: moving beyond the myths. Glob Environ Change 11:261–269

Land Administration Authority of Addis Ababa City Adminstration (2003) Report on the general survey of the implementation of lease policy and land market situation in Addis. Unpublished report, Addis Ababa, Ethiopia

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 38:1–10

Lillesand T, Kiefer RW, Chipman J (2014) Remote sensing and image interpretation. John Wiley & Sons, New York

Maro P (2011). Environmental change in Lesotho: an analysis of the causes and consequences of land-use change in the Lowland region. Springer Science+Business Media B.V, The Netherlands

Melaku IC (2016) A study on the impact of the current land lease law on business and investment expansion. Addis Ababa Chamber of Commerce and Sectoral Associations, Addis Ababa

Ministry of Urban Development Housing (1982) ye ketema bota atekakem. Unpublished report in Amharic, Addis Ababa, Ethiopia

Mundia CN, Aniya M (2006) Dynamics of landuse/cover changes and degradation of Nairobi City, Kenya. Land Degrad Dev 17:97–108

Myint SW, Gober P, Brazel A, Grossman CS, Weng Q (2011) Per-pixel vs. object-based classification of urban land cover extraction using high spatial resolution imagery. Remote Sens Environ 115:1145–1161

PADCO (1997) Ethiopian Housing Sector study: a study prepared for Urban Development Support Services, Ministry of Works and Urban Development Government of Ethiopia. PADCO, Inc, Addis Ababa, Ethiopia

Peña J, Bonet A, Bellot J, Sánchez J, Eisenhuth D, Hallett S, Aledo A (2007) Driving forces of land-use change in a cultural landscape of Spain. In: Eric Koomen E, Stillwell J, Bakema A, Scholten HJ (eds) Modelling land-use change: progress and applications, Springer, The Netherlands, p 97–116

Pijanowski BC, Brown DG, Shellito BA, Manik GA (2002) Using neural networks and GIS to forecast land use changes: a land transformation model. Comput Environ Urban Syst 26:553–575

Saaty TL (2008) Decision making with the analytic hierarchy process. Int J Serv Sci 1:83–98

Seto KC, Fragkias M (2005) Quantifying spatiotemporal patterns of urban land-use change in four cities of China with time series landscape metrics. Landsc Ecol 20:871–888

Shafizadeh MH, Helbich M (2015) Spatiotemporal variability of urban growth factors: a global and local perspective on the megacity of Mumbai. Int J Appl Earth Obs Geoinf 35:187–198

Shu B, Zhang H, Li Y, Qu Y, Chen L (2014) Spatiotemporal variation analysis of driving forces of urban land spatial expansion using logistic regression: a case study of port towns in Taicang City, China. Habitat Int 43:181–190

Tadesse W, Tsegaye T, Coleman T (2001) Land use/cover change detection of the city of Addis Ababa, Ethiopia using remote sensing and geographic information system technology. Paper presented at the Geoscience and Remote Sensing Symposium

Thapa RB, Murayama Y (2010) Drivers of urban growth in the Kathmandu valley, Nepal: examining the efficacy of the analytic hierarchy process. Appl Geogr 30:70–83

Vitousek PM (1994) Beyond global warming: ecology and global change. Ecology 75:1861–1876

Vermeiren K, Van Rompaey A, Loopmans M, Serwajja E, Mukwaya P (2012) Urban growth of Kampala, Uganda: pattern analysis and scenario development. Landsc Urban Plan 106:199–206

UN (2014) World urbanization prospects:The 2014 revision, highlights. United Nations, Department of Economic and Social Affairs, Population Division

Wale Y (2015) Determinants of private investment in Ethiopia: time series analysis. Proceedings of the 9th annual nationtional student research forum, Research and knowledge management office of Saint Mary's University, Addis Ababa

Woldegerima T, Yeshitela K, Lindley S (2016) Characterizing the urban environment through urban morphology types (UMTs) mapping and land surface cover analysis: the case of Addis Ababa, Ethiopia. Urban Ecosyst 20:245–263

Wu J (2010) Urban sustainability: an inevitable goal of landscape research. Landsc Ecol 25:1–4. https://doi.org/10.1007/s10980-009-9444-7

Yang X (2002) Satellite monitoring of urban spatial growth in the Atlanta metropolitan area. Photogramm Eng Remote Sens 68:725–734

Yang X (2007) Integrating remote sensing, GIS and spatial modelling for sustainable urban growth management. In: Mesev V (ed) Integration of GIS and remote sensing. John Wiley & Sons, New York, NY, p 173–193

Yang Y, Zhou Q, Gong J, Wang Y (2010) Gradient analysis of landscape spatial and temporal pattern changes in Beijing metropolitan area. Sci China Technol Sci 53:91–98

Yuan F, Sawaya KE, Loeffelholz BC, Bauer ME (2005) Land cover classification and change analysis of the Twin Cities (Minnesota) metropolitan area by multitemporal Landsat remote sensing. Remote Sens Environ 98:317–328

Zhou W, Troy A, Grove M (2008) Object-based land cover classification and change analysis in the Baltimore metropolitan area using multitemporal high resolution remote sensing data. Sensors 8:1613–1636