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THE CITY OF ADDIS ABABA FROM 'FOREST CITY' TO 'URBAN HEAT ISLAND': ASSESSMENT OF URBAN GREEN SPACE DYNAMICS

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Abstract: The unprecedented rate of urban growth in developing countries causes various problems such as deficiency in public infrastructure services, lack of green spaces and inadequate service provisions. This study applies GIS tools and remote sensing techniques to assess the effects of urban development on urban green space in Ethiopia's capital. Spatial and non-spatial datasets were collected from different organizations and processed using GIS tools and remote sensing techniques for land use/ land cover classification and analysis. The analysis demonstrated shrinking of urban green spaces- plantations, forestland, grassland and cultivated land (at annual rates of 5.9%, 3.3%, 5.4% and 3.7 % respectively) by 82.1%, 62.1%, 78.8 and 65.8 % respectively during the past three decades (1986-2015) whereas built-up and transport areas increased at annual rate of 5.7% and 1.3% and consumed 419% and 47% of the city's total area respectively.

Keywords: Urban green space; land use / land cover; remote sensing; geographic information systems; Addis Ababa

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INTRODUCTION

The world has recently become more urbanized as many developing countries revealed major changes in the distribution of their population and as a consequence of changes in the structure and spatial relations of capitalism from monopoly capitalism to transnational corporate capitalism, and the global extent of patterns of production, trade and service provision (Clark, 1995).
It is expected that the urban population to increase by 84 percent by 2050, from 3.4 billion in 2009 to 6.3 billion in 2050 (Brunn *et al.*, 2012). Nearly 90 percent of the expected growth will take place in the developing countries. The rate of urbanization is so great that the population living in urban areas now exceeds that living in rural areas, and the disparity is increasing steadily. The pace of change brings its own problems, since developments in some fields are inevitably faster than in others, particularly in urban areas, where the infrastructure services have often failed to keep pace with the rapid growth (Iles, 2005).

It has been observed that nowadays cities, towns and their people in the developing countries are facing problems of inadequate financial resources, increased poverty and a widening gap between rich and poor, unsustainable use of land, uncoordinated development and insecure land tenure (Obeng-Odoom, 2013). Added to these prime problems, cities and towns in the Third World are challenged by lack of jobs, spreading homelessness and expanding squatter settlements, growing insecurity and rising crime, inadequate and deteriorating building stock, services and infrastructure, lack of health and educational services, rising traffic congestion and more pollution, lack of green spaces and inadequate water supply and sanitation (Malayeri, 2010; Obeng-Odoom, 2013; Kiamba, 2012).

Urbanization has negative impacts on the natural environment by exerting pressure on and shrinking green spaces in many cities in Europe, North America, South America, Asia and Africa with the situation in Africa being critical (Mensah, 2014). According to the same source, in many cities of Africa urban green spaces constitute less than 10% of the land area.

Ethiopia is among the least urbanized countries in sub-Saharan Africa with only 16−17% of its population living in urban areas. Nonetheless, with an annual growth rate of more than 5%, Ethiopia has been grouped among countries with the fastest urbanization processes in the world (CSA, 2011). Addis Ababa hosting nearly 30 percent of the urban population of the Ethiopia reveals a typical primate city characteristics having overwhelming dominance in the economic, social and political affairs of the country. This unprecedented growth of the city of Addis Ababa has shrunken green areas to the extent that there is evidence of rising temperatures and hot conditions in many neighborhoods including the study area: Bole Sub-City. The city of Addis Ababa was once said “forest city”.

The problem is expected to worsen in the coming years due to the massive construction of houses, buildings and roads and the less attention given to green spaces. Besides, the city does not have up-to-date information that can give an impression about the physical changes in general and the amount of green space in particular. These highlight the need for analyzing urban land use/land cover change particularly urban green space using remote sensing and GIS technologies. This study aims to assess the extent, pace and pattern of urbanization and its effects on green areas by taking Ethiopia’s capital: Addis Ababa as case study.

METHODS AND MATERIALS

Description of the study area

The City Administration of Addis Ababa extends over 540 km² sub-divided into 10 sub-cities. The Bole sub-city, the focus of this study, is one of the largest sub-cities located in the eastern part of Addis Ababa. The sub city has 14 woredas (districts) and covers an area of 122.8 km² (**Fig. 1**).

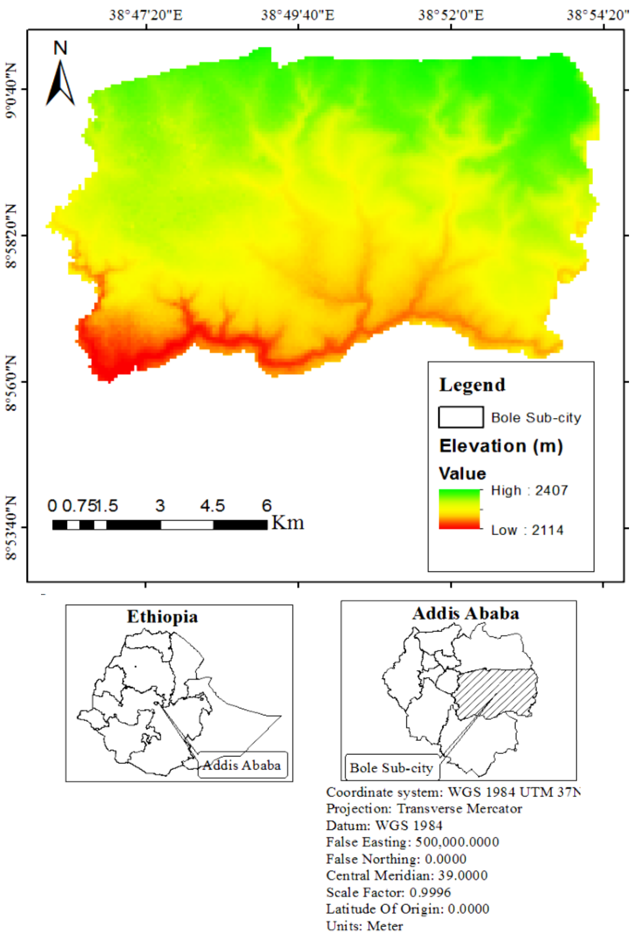


Fig. 1 Study area map.

Table 1. Data sources

Dataset	Source	Resolution	Purpose	Type	Year
Landsat TM	GLCF	28.5 × 28.5 (m)	Classification	Raster	21/01/1986
Landsat ETM+	GLCF	28.5 × 28.5 (m)	Classification	Raster	05/12/2000
Landsat ETM+	http://libra.developmentseed.org	15 × 15 (m)	Classification	Raster	14/12/2015
Land use plan	Integrated land Information center	-	Reference		2012
GPS field survey	Survey	-	Point data for proximity analysis	Vector	2015/2016
Bole boundary	CSA		For delineated	vector	2007
Topographic maps: sheet no.0838 B2,0838B1and 0938 D4	EMA	1:50000	Reference	vector	1973 /1982
City map of Addis Ababa	EMA	1:15000 & 1: 25000	Reference	Raster	1986 & 2000

Sources of data

Various spatial and non-spatial datasets were obtained from different organizations and processed using multiple GIS tools for mapping and analysis purposes (**Table 1**).

Sampling techniques

There are ten sub-cities in Addis Ababa. The study employed purposive sampling techniques to select Bole sub-city because, Bole sub-city is one of the largest sub-cities in terms of area hosting many business centers and shopping malls, organizations, recreational sites and the Bole International Airport, but urban forest area coverage is relatively smaller than other sub-cities (Yeka, Gullele, Kolfe Keranyo, Nifas Silk-Lafto and Akaki Kality) (Mokenen, 2012).

Sample ground reference data

Ground truth data for the year 2015 Land Use Land Cover (LULC) training site identification and accuracy assessment were done during field work and their positions were precisely recorded using GPS. There is no common standardized consent for reference sample size determination. Some researchers like Gao (2009) argued that the minimum sample size for each LULC class for 85% and 90 % accuracy interpretation is to be set to 20 and 30 respectively. Conversely, Lillesand *et al.* (2008) argued that a minimum of 50 samples for each map class should be collected for maps of < 4000 km² and fewer than 12 classes. Therefore, by considering the size of Bole sub-city (122.8 km²) and seven LULC classes (built-up, transport area, plantation, forestland, grassland, cultivated land and bareland) a minimum of 50 samples per LULC category were used.

Data pre-processing

Before LULC classification, remotely sensed data pre-processing techniques were employed. Various false color composite raster band combinations in Red-Green-Blue order, contrast enhancement, histogram equalization and principal component analysis image enhancement techniques were employed. Image enhancement is predominantly concerned with the modification of images to optimize their appearance of the visual system.

Image classification

Using the basic photogrammetric elements (color, tone, texture, size, shape, structure, association, shadow) and the prior knowledge of the area, visual interpretation was applied on every satellite imageries (**Fig. 2**).

LULC map for 1986, 2000, and 2015 were produced by supervised classification using the maximum likelihood classifier. In supervised classification, three activities were done such as collecting spectral signature, evaluating signature and classified images using maximum likelihood classification. The images were interpreted or classified into seven LULC classes, namely built-up, transport area, plantation, forestland, grassland, cultivated land and bareland (**Table 2**). Post classification comparison and Normalized Difference Vegetation Index (NDVI) were used in this study.

The NDVI equation is expressed as:

$$NDVI= (NIR-RED)/(NIR+RED) \quad (1)$$

where, NIR and RED are reflectance in the near infrared and the red bands, respectively. The NDVI value is ranging from -1 to +1 whereas vegetation surfaces have NDVI values ranging from 0.1 to 1.0.

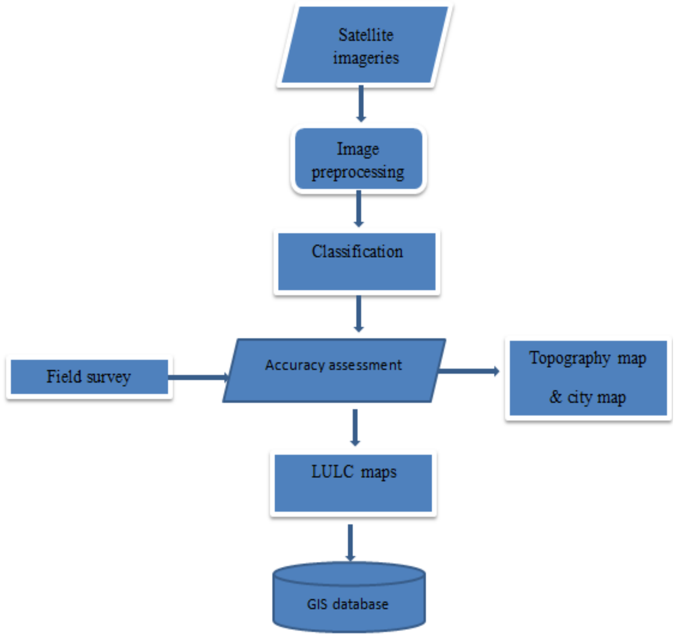


Fig. 2 Image classification process.

Table 2. Description of LULC classification scheme

LULC types	Description
Plantation	Forests Areas covered by man-made trees.
Forestland	Areas dominated by natural high forests, which are coniferous or deciduous.
Grasslands	All areas covered with natural grass and small shrubs dominated by grass.
Cultivated land	Areas of land prepared for growing agricultural crops. This category includes areas currently under crop and land under preparation.
Bare lands	Are parts of the land surface which is mainly covered by bare soil.
Built-up	Areas allotted for residential, commercial and government and private institution.
Transport area	Area occupied by airport, road network and transport stations.

Accuracy assessment

Accuracy assessment was employed for determining whether the output map meets or does not meet level of acceptance. Error matrices, common methods of expressing classification accuracy (Lillesand *et al.*, 2008), were created to compare category by category basis, the reference data (ground truth) and the corresponding results of classification The study assessed the accuracy of the classification results for 50 randomly sampled reference points for each classified image.

After creating the error matrix for each classification, user accuracy, producer accuracy, overall accuracy and Kappa coefficient were computed. According to Lillesand *et al.* (2008) user's accuracies are computed by dividing the number of correctly classified pixels in each category by the total number of pixels that were classified in that category (the row total). Producer's accuracies result from dividing the number of correctly classified pixels in each category (on the major diagonal) by the number of training set pixels used for that category (the column total). The Kappa coefficient of agreement was used for multivariate statistical measure that can be used to test LULC classification accuracy. Computing Khat is the ability to use this value as a basis for determining the statistical significance of any given matrix or the differences among matrices.

Methods of data analysis

After the data were collected from various sources, they were analyzed by using Arc GIS 10.3 and ERDAS Imagine 2013. The cross tabulation in the spatial analyst module of the ArcGIS was employed to drive the change matrix. The changes from 1986 to 2000, from 2000 to 2015 and for the whole entire period from 1986 to 2015 were tabulated in matrix (**Tables 3 a–c**).

$$\hat{K} = \left(n\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} (x_i \cdot x_{+i})\right) / \left(N^2 - \sum_{i=1}^{r} (x_i \cdot x_{+i})\right) \quad (1)$$

where r = number of rows in the error matrix; xii = number of observations in row i and column i (on the major diagonal); xi+ = total of observations in row i (shown as marginal total to right of the matrix); x+i = total of observations in column i (shown as marginal total at bottom of the matrix) and N = total number of observations included in matrix.

The matrix shows the amount of changes in hectare and percentage of which LULC class changed to other classes. The persistence values were the diagonal values which mean unchanged amount. The gain values computed by subtracting the persistence value from the total area of final year and the loss value also computed by negative of subtracting the persistence value from the total area of the initial year. The values were presented in terms of hectares and percentages. The percentage LULC changes were calculated using the following equation: Percentage LULC change = (Area final year- Area initial year)/(Area initial year) ×100. Where, area is the extent of each LULC type. Positive values suggest an increase whereas negative values imply a decrease in extent.

The LULC change rate was computed using the formula suggested by Puyravaud (2003):

$$r = (1/\Delta t)\ln(A2/A1)*100 \quad (2)$$

Table 3. Land use/Land cover change matrix in Bole Sub-city during the period 1986 – 2000

		Land use/Land cover types 1986															
	LULC	PL		TA		FL		GL		BL		CL		BA		Total	
		Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%
LULC type 2000 (a)	PL	78.7	10.4	111.2	8.2	102.3	9.5	429.0	11.6	18.7	4.3	1003.0	19.7	37.4	1.7	1780.3	17.6
	TA	96.0	12.7	352.1	26.1	86.5	8.0	1935.6	52.4	58.0	13.2	492.9	9.7	159.4	7.1	1438.4	14.2
	FL	65.1	8.6	196.2	14.5	283.9	26.3	128.4	3.5	60.1	13.7	439.3	8.6	173.8	7.7	1346.7	13.3
	GL	34.7	4.6	166.3	12.3	235.2	21.8	634.7	17.2	63.7	14.5	636.3	12.5	48.7	2.2	1819.7	18.0
	BL	1.3	0.2	12.1	0.9	18.1	1.7	13.1	0.4	23.2	5.3	23.1	0.5	6.6	0.3	97.6	1.0
	CL	410.5	54.3	344.6	25.6	212.3	19.6	340.4	9.2	72.3	16.5	2151.7	42.3	952.8	42.2	3627.1	35.9
	BA	69.4	9.2	165.8	12.3	142.4	13.2	212.9	5.8	142.1	32.4	338.3	6.7	880.0	39.0	0.2	0.0
	Total	755.7	100.0	1348.3	100.0	1080.8	100.0	3694.1	100.0	438.1	100.0	5084.6	100.0	2258.6	100.0	12038	100.0

		Land use/Land cover types 2000															
	LULC	PL		TA		FL		GL		BL		CL		BA		Total	
		Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%
LULC type 2015 (b)	PL	6.1	0.3	7.6	0.5	24.3	0.8	10.1	0.6	0.5	0.5	81.5	2.2	5.3	0.3	135.3	1.1
	TA	291.7	16.4	456.1	31.8	194.8	6.5	312.0	17.2	17.2	17.7	534.1	14.7	173.3	8.9	1979.0	16.4
	FL	31.8	1.8	38.8	2.7	147.0	4.9	75.5	4.2	7.7	7.9	63.9	1.8	43.6	2.2	408.4	3.4
	GL	107.7	6.1	37.4	2.6	24.4	0.8	113.1	6.2	2.6	2.7	119.6	3.3	9.3	0.5	414.2	3.4
	BL	25.6	1.4	13.0	0.9	9.8	0.3	32.6	1.8	1.9	2.0	30.8	0.8	8.4	0.4	122.2	1.0
	CL	255.7	14.4	134.0	9.3	1833.2	61.3	191.2	10.5	5.8	6.0	919.0	25.4	47.8	2.5	1736.8	14.4
	BA	1060.1	59.6	749.3	52.2	758.7	25.4	1082.9	59.6	61.7	63.3	1872.9	51.7	1656.5	85.2	7242.2	60.2
	Total	1778.7	100.0	1436.3	100.0	2992.2	100.0	1817.4	100.0	97.6	100.0	3621.7	100.0	1944.2	100.0	12038	100.0

		Land use/Land cover types 1986															
	LULC	PL		TA		FL		GL		BL		CL		BA		Total	
		Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%
LULC type 2015 (c)	PL	13.8	1.8	10.7	0.8	6.5	0.6	7.4	0.4	1.3	0.3	91.5	1.8	4.1	0.3	135.3	1.1
	TA	133.1	17.6	396.4	29.4	143.4	13.3	284.2	14.6	68.6	15.7	817.8	16.1	135.6	9.7	1979.0	16.4
	FL	6.8	0.9	32.2	2.4	106.7	9.9	56.5	2.9	43.5	9.9	107.3	2.1	55.5	4.0	408.4	3.4
	GL	15.0	2.0	42.4	3.1	53.7	5.0	142.1	7.3	9.9	2.3	141.3	2.8	9.8	0.7	414.2	3.4
	BL	1.9	0.2	11.4	0.8	10.4	1.0	33.7	1.7	7.4	1.7	48.0	0.9	9.4	0.7	122.2	1.0
	CL	172.8	22.9	190.2	14.1	63.2	5.9	174.4	8.9	13.0	3.0	1082.0	21.3	41.2	3.0	1736.8	14.4
	BA	411.1	54.5	663.4	49.3	693.1	64.4	1252.8	64.2	293.2	67.1	2788.6	54.9	1140.0	81.7	7242.2	60.2
	Total	754.6	100.0	1346.6	100.0	1077.0	100.0	1951.0	100.0	436.9	100.0	5076.6	100.0	1395.5	100.0	12038	100

Note: PL=Plantation, TA=Transport Area, FL=Forest land, BL= Bareland, CL= Cultivated land, and BA= Built-up

where, r is the annual rate of change in %; Δt is the time interval in years during the LULC change being assessed; ln is the base of the natural logarithm function; and A1 and A2 are initial and final LULC areas respectively.

RESULTS AND DISCUSSION

LULC classification and dynamics

In this study, three LULC classification maps were produced (**Figures 3a–c**) and spatio-temporal LULC dynamic process was analyzed (**Table 4**). Based on the LULC classification, the major part of the area was covered by cultivated land in 1986 later shifted to built-up area. In 1986, cultivated land, grassland, forestland and plantation were covered 42.2%, 16.2%, 8.9% and 6.3% of the total area respectively. The remaining parts of the area were covered with built-up (11.6%), transport area (11.2%) and bareland (3.6%), respectively.

In 2000, cultivated land, grassland, forestland and plantation covered 30.1%, 15.1%, 11.2% and 14.8% of the total area respectively. The rest of the areas were covered with built-up (16.2%), transport area (11.9%) and bareland (0.8%) respectively. Large area was occupied by built-up areas (60.2%) and the remaining 39.8% were covered by other LULC classes in 2015 (**Table 4** and **Figure 3**). To some extent in the classification, the planation LULC type was generalized to other classes, but as evident in the field observation, plantation is highly diminished due to urbanization. The vegetation cover has been declining since the year 1986 in the order of 73.6% for 1986, 71.1% for 2000 and 22.4% for 2015.

The vegetated land cover types were highly transformed categories throughout the study period (**Table 5**). From 1986−2015, plantations, forestland, grassland and cultivated land shrunk at annual rates of 5.9%, 3.3%, 5.4% and 3.7% with a corresponding loss of 82.1%, 62.1%, 78.8 and 65.8% respectively. In contrary, built-up and transport areas highly expanded at an annual rate of 5.7 % and 1.3% respectively with 419% and 47% change in the total area respectively.

The NDVI analysis was employed in order to show the vegetation cover transition. In 1986, the NDVI value was ranging from -0.33 to 0.83 witnessing a high vegetation cover whereas in 2000 and 2015 the value declined from -0.10–0.54 and -0.37–0.27 respectively (**Table 5**). Therefore, vegetation covers have been transformed to other LULC unit such as built-up, transport area and bareland. In general, a total of 6165 ha of green spaces have been changed in to other LULC types since 1986.

Table 4. LULC transformation processes between 1986, 2000 and 2016

LULC	1986		2000		2015		Change 1986-2000			Change 2000-2015			Change 1986 -2015		
	Ha.	%	Ha.	%	Ha.	%	Ha.	(%)	Rate (%)	Ha.	%	Rate (%)	Ha.	%	Rate (%)
PL	754.6	6.3	1780.3	14.8	135.3	1.1	1 025.7	135.9	6.13	-1645.0	-92.4	-16.84	-619.3	-82.1	-5.9
TA	13466	11.2	1438.4	11.9	1979.0	16.4	91.	6.8	0.48	540.6	37.6	2.15	632.4	47.0	1.3
FL	1077	8.9	1346.7	11.2	408.4	3.4	269.7	25.0	1.59	-93	-69.7	-8.03	-668.6	-62.1	-3.3
GL	1951	16.2	1819.7	15.1	414.2	3.4	-131.3	-6.7	-0.52	-1 405.4	-77.2	-8.45	-1 536.8	-78.8	-5.4
BL	436.9	3.6	97.6	0.8	122.2	1.0	-339.4	-77.7	-10.82	24.6	25.2	1.49	-314.7	-72.0	-4.4
CL	5 076.6	42.2	3 627.1	30.1	1 736.8	14.4	-1 449.5	-28.6	-2.45	-1 890.3	-52.1	-4.90	-3 339.8	-65.8	-3.7
BA	1 395.5	11.6	1 950.9	16.2	7 242.1	60.2	555.4	39.8	2.30	5 291.2	271.2	8.74	5 846.6	419.0	5.7
Total	1 2038	100.0	1 2038	100.0	1 2038	100.0									

Note: PL=Plantation, TA=Transport Area, FL=Forest land, BL= Bareland, CL= Cultivated land, and BA= Built-up

Table 5. NDVI value

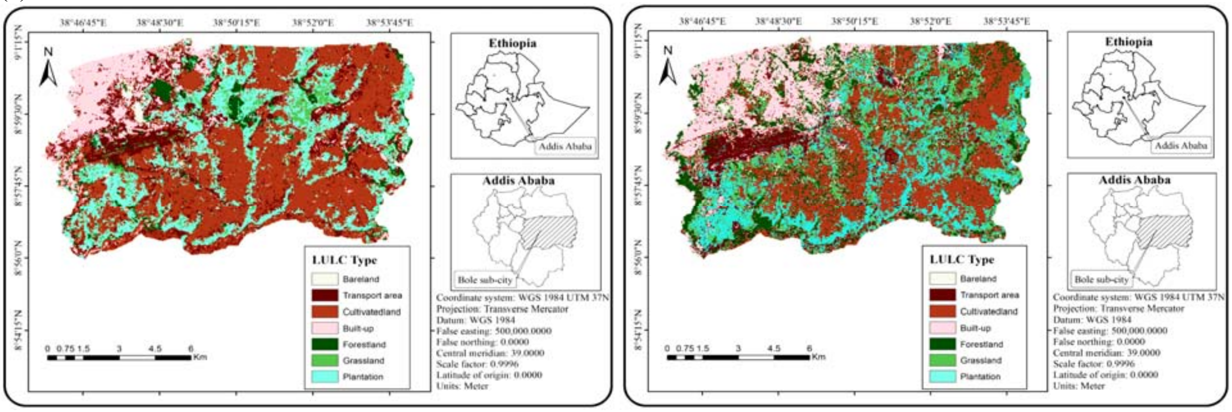
Images year	NDVI value range
1986	-0.33-0.83
2000	-0.10-0.54
2015	-0.37-0.27

As can be observed from **Table 6**, in the period 1986 to 2000, green spaces such as plantation, forestland, grassland and cultivated land had gained 1701.6, 1062.8,1185 and 1475.4 hectares of land respectively, and lost 677, 796.9, 3059.4 and 2932.9 hectares of land in the same order. However, 78.7, 283.9, 634.7 and 2154.7 hectares of plantation, forestland, grassland and cultivated land remained without area change respectively. The cultivated land and grassland highly changed to other LULC class. Plantation had shown a remarkable increase with a net change of 15.6%. Estimates of vegetation cover for 2000 as obtained from the WBISPP (Woody Biomass Inventory and Strategic Planning) (2004) report were around 7900 ha, which is a high figure as it includes other vegetated area like forestland.

In the period 2000–2015, green spaces such as plantation, forestland, grassland and cultivated land have shrunken with net change value of 15.6%, 24.4%, 13% and 16.7% of the total area respectively. However, plantation (0.3%), forestland (4.9%), grassland (6.2%) and cultivated land (25.4%) area persisted without area change. During the same period, the built-up and transport area highly gained (63.9% and 17.4% respectively); whereas 2.8% and 9.4% were converted into another LULC class respectively (**Table 7**).

In the period 1986 to 2015, cultivated land was highly changed as compared to other vegetated land with additional gains of 654.8 hectares (7.2%) and with loses of 3994.6 hectares (43.7%) to another LULC type.

(b)



(c)

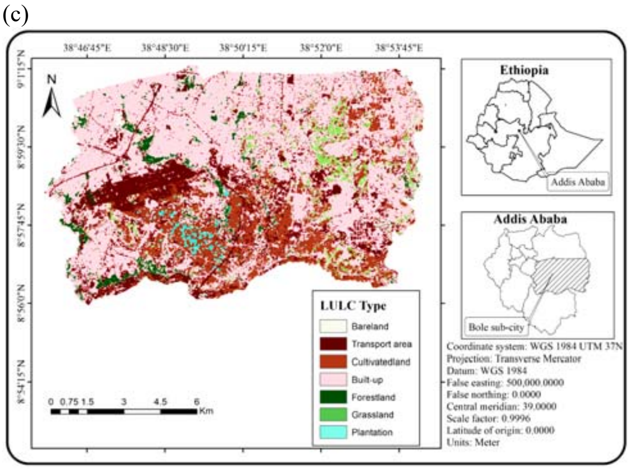


Fig. 3 LULC classification of (a) 1986, (b) 2000 and (c) 2015.

Table 6. Land use/Land cover change during 1986−2000

LULC Type	Persistence		Gains		Losses		Net Change	
	Ha	%	Ha	%	Ha	%	Ha	%
PL	78.7	10.4	1701.6	21.2	-675.9	-8.4	1025.7	12.8
TA	352.1	26.1	1086.3	13.5	-994.5	-12.4	91.8	1.1
FL	283.9	26.3	1062.8	13.2	-793.1	-9.9	269.7	3.4
GL	234.7	12.0	1585.0	19.7	-1716.3	-21.4	-131.3	-1.6
BL	23.2	5.3	74.4	0.9	-413.7	-5.1	-339.3	-4.2
CL	2151.7	42.3	1475.4	18.4	-2924.9	-36.4	-1449.5	-18.0
BA	880.0	39.0	1070.9	13.3	-515.5	-6.4	555.4	6.9
Total	4004.3	33.26	8033.9	100	-8033.9	-100.0	0.0	0.0

Table 7. Land use/Land cover change during 2000−2015

LULC Type	Persistence		Gains		Losses		Net Change	
	Ha	%	Ha	%	Ha	%	Ha	%
PL	6.1	0.3	129.2	1.5	-1774.2	-20.3	-1 645.0	-18.8
TA	456.1	31.8	1 522.9	17.4	-982.3	-11.2	540.6	6.2
FL	147.0	10.9	261.4	3.0	-1 199.7	-13.7	-938.3	-10.7
GL	113.1	6.2	301.1	3.4	-1 706.6	-19.5	-1 405.5	-16.1
BL	1.9	2.0	120.3	1.4	-95.7	-1.1	24.6	0.3
CL	919.0	25.4	817.8	9.4	-2708.1	-31.0	-1 890.3	-21.6
BA	1 656.5	85.2	5585.7	63.9	-294.4	-3.4	5 291.3	60.6
Total	3 299.7	27.4	8738.4	100.0	-8738.4	-100.0	0.0	0.0

However, 1083 hectare (21.3%) remained without area change. On the other hand, other green spaces, namely, plantation, forestland and grassland lost large areas (740.8, 970.2 and 1809 hectares respectively) and gained (121.5, 301.7 and 272.2 hectares respectively). The remaining LULC type- built-up and transport area had gained 6102.2 and 1582.7 hectares and lost 255.5 and 950.3 hectares respectively (**Table 8**).

Accuracy assessment of the classification

Classified LULC maps from remotely sensed imageries may contain some errors. Therefore, accuracy assessment was employed to find out those errors so as to ensure reliability of the produced LULC maps. The classified maps have to be assessed and compared with a referenced data and ground truth using an error matrix. The overall accuracies for the three reference years 1986, 2000 and 2015 are 87%, 86% and 89% with the Kappa statistics of 81%, 80% and 83%, respectively (**Table 9**).

Table 8. Land use/Land cover change during 1986−2015

LULC Type	Persistence		Gains		Losses		Net Change	
	Ha	%	Ha	%	Ha	%	Ha	%
PL	13.8	1.8	121.5	1.3	-740.8	-8.1	-619.3	-6.8
TA	396.4	29.4	1582.6	17.3	-950.2	-10.4	632.4	6.9
FL	106.7	9.9	301.7	3.3	-970.3	-10.6	-668.6	-7.3
GL	142.1	7.3	272.1	3.0	-1808.9	-19.8	-1536.8	-16.8
BL	7.4	1.7	114.8	1.3	-429.5	-4.7	-314.7	-3.4
CL	1082.0	21.3	654.8	7.2	-3994.6	-43.7	-3339.8	-36.5
BA	1140.0	81.7	6102.2	66.7	-255.5	-2.8	5846.7	63.9
Total	2888.4	23.99	9149.7	100	-9149.7	-100.0	0.0	0.0

Table 9. Error matrix of classification for (a) 1986, (b) 2000 and (c) 2015

(a)

Classified samples	PL	TA	FL	GL	BL	CL	BA	Row total	UA (100%)
PL	46	0	2	2	1	6	0	57	81
TA	3	49	0	0	0	0	3	55	89
FL	5	0	48	2	1	4	0	60	80
GL	3	4	1	56	4	1	0	69	81
BL	0	3	0	0	45	0	0	48	94
CA	0	0	5	1	0	64	0	70	91
BA	0	2	0	0	0	0	54	56	96
Column total	57	58	56	61	51	75	57	415	
PA(100%)	81	84	86	92	88	85	95		

Overall accuracy = 87% – K^= 81%

(b)

Classified samples	PL	TA	FL	GL	BL	CL	BA	Row total	UA (100%)
PL	50	0	4	2	1	4	0	61	82
TA	3	47	1	1	4	0	0	56	84
FL	4	0	45	3	1	3	0	56	80
GL	3	0	4	54	1	1	1	64	84
BL	0	3	0	0	42	1	0	46	91
CA	2	0	2	4	1	62	0	71	87
BA	0	3	0	0	0	0	58	61	95
Column total	62	53	56	64	50	71	59	415	
PA(100%)	81	89	80	84	84	87	98		

Overall accuracy = 86% – K^= 80%

(c)

Classified samples	PL	TA	FL	GL	BL	CL	BA	Row total	UA (100%)
PL	48	0	2	2	0	1	0	53	91
TA	4	58	1	0	1	0	1	65	89
FL	2	1	52	2	2	2	0	61	85
GL	1	0	3	52	1	3	1	61	85
BL	0	2	0	1	46	1	0	50	92
CA	1	0	4	3	1	54	0	63	86
BA	0	0	0	0	2	0	65	67	97
Column total	56	61	62	60	53	61	67	420	
PA(100%)	86	95	84	87	87	89	97		

Overall accuracy = 89% – K^= 83%

Note: PL=Plantation, TA=Transport Area, FL=Forest land, BL= Bareland, CL= Cultivated land, BA= Built-up Area, UA=User Accuracy and PA=Producer Accuracy

Results of user's accuracy in this study showed that in 1986 built-up area had the maximum class accuracy of 96%, and the minimum was for forestland (80%). For the year 2000, user's accuracy ranged from lowest accuracy 80% (forestland) to relatively correctly classified 95% (built-up); whereas the corresponding range in 2015 was from 85% (grassland and forestland) to 97% (built-up). On the other hand, results of producer's accuracy showed that built-up area relatively correctly classified with accuracy levels of 95%, 98% and 97% in 1986, 2000 and 2015, respectively. The lowest accuracy recorded for built-up areas was 81%, 80% and 84% in 1986, 2000 and 2015, respectively.

CONCLUSION

The study demonstrated a rapid and unplanned expansion and commercial development, along with population pressure, has exerted tremendous negative impacts on green space in the City of Addis Ababa in general and the study area in particular. At present the green spaces of Addis Ababa are almost transformed to urban habitats. Now, the 'forest city' definition, explaining Addis Ababa of the past, is no more acceptable.

The city is heating as a result of heat island effects in many neighborhoods. Unsustainable use of land, uncoordinated urban development and insecure land tenure system might be the source of these prime problems. Added to these, lack of public awareness, low level of community participation, poor implementation of government policies, lack of budget, lack of skilled manpower, shortage of land, illegal settlement, problem of regular follow-up, problem of pollution from different sources and lack of cooperation among different stakeholders have contributed to the shrinking of green spaces in the city.

The study also witnessed the power of remote sensing and GIS technologies in capturing and analyzing land use/ land cover changes and dynamics of urban green spaces vis- a-vis urbanization.

REFERENCES

Brunn, S.D., Hays-Mitchell, M., Zeigler, D.J. (2012) *Cities of the World*. Fifth Edition, Rowman & Littlefield Publishers, Inc.

Clark, J.G. (1995) Economic development vs. sustainable societies: reflections on the players in a crucial contest. *Ann. Rev. Ecol. System.* **26**, 225–248.

CSA – Central Statistical Agency (2011) *Ethiopia Demographic and Health Survey*. Central Statistical Authority of Ethiopia. Addis Ababa, Ethiopia.

CSA – Central Statistical Agency (2007) *Ethiopian Census of Population and Housing*. Central Statistical Authority of Ethiopia. Addis Ababa, Ethiopia.

Gao, J. (2009) *Digital Analysis of Remotely Sensed Imagery*. Neywork: McGraw-Hill Companies Inc.

Iles, R. (2005) *Public transport in developing countries*. Elsevier.

Kiamba, A. (2012) The Sustainability of Urban Development in Developing Economies. *Consilience*: *The J. Sustain. Develop.* **8**(1), 20–25.

Lillesand, T.M., Kiefer, R.R.W., Chipman, J.W. (2008) *Remote Sensing and Image Interpretation*. 6th ed. New York: Wiley.

Malayeri, F.D. (2010) *Good Urban Planning and Management: New Aspects and Methodologies. Int. J. Social, Behav., Educat., Economic, Business Indust. Enging.* **4**(8), 1904–1909.

Mekonnen, B. (2012) *An Overview of Status of the Green Areas, Floristic Composition and Conservation Efforts in Addis Ababa*. Ethiopia.

Mensah, C.D. (2014) Destruction of urban green spaces: A problem beyond urbanization in Kumasi city (Ghana). *Amer. J. Environm. Protec.* **3**(1), 1–9. Doi: 10.11648/j.ajep.20140301.11

Obeng-Odoom. F. UN-HABITAT (20102013) The State of African Cities 2010: Governance, Inequality and Urban Land Markets. *Cities,* **31**, 425–429. Doi: 10.1016/j.cities.2012.07.007

Puyravaud, J.P. (2003) Standardizing the Classification of Annual Rate of Deforestation. *Forest Ecology Ecol. and Managemement.*. **177**(1–3), 593–596 Doi: 10.1016/S0378-1127(02)00335-3

WBISPP (2004) *Forest Resource of Ethiopia*. Addis Ababa, Ethiopia.