Monitoring Urban Growth and Land Use/ Cover Changes using Remote Sensing and Geospatial Techniques in Adama, Ethiopia

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***Abstract*—Urbanization has a pivotal role to play on land use land cover changes and ecological degradation, in return with some socioeconomic benefits. Hence, it is important to have frequent update on urban information to secure urban land use sustainability in order to minimize its impacts on urban ecology. The aim of this study is to use geospatial techniques for assessment of land use land cover change detection of Adama city, Ethiopia. Four datasets of landsat 5 and 7 thematic mapper (TM) were used to identify LULC from 1984 to 2014 over a period of 30 years using maximum likelihood technique and subsequently analysed within a GIS environment. The study area has been categorized into five different LULC classes, namely, urban, agriculture, shrub and bushes, barren area and hilly area. Results shows that during the last thirty years, urban area has increased by 31.73% (i.e., 42.66 km^2), while agriculture area have decreased by 24.53% (i.e., 32.98 km^2). Further, it is observed that during this period, population in the area has increasing at an average rate of 5%. Correlating population and urban growth, it is found that by the year 2030 the whole area would be fully converted into urban area.**

***Key words*—Land use land cover (LULC), Geospatial techniques, Change detection, Urban and population growth.**

I. INTRODUCTION

Land use land cover change has become a central and important component in current strategies for managing natural resources and monitoring environmental changes [9]. Land use is intended employment of land management strategy placed on land cover by human agents or land managers to exploit land cover and reflects human activities such as industrial zones, residential zones, agricultural fields, grazing, logging and mining among many others. The LULC pattern of a region is an outcome of natural and socio–economic factors and their utilization by man in time and space. Due to rise in human population, land is becoming a scarce resource due to immense pressure of agricultural and urban activities [10].

Local-level dynamics is important in determining the status of land and ecosystem health. Therefore, information on LULC and possibilities for their optimal use is essential for selection, planning, and implementation of land use schemes to meet increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use changes resulting out of changing demands of increasing population. Studies related to rate of change, extents, patterns, causes, and implications of LULC dynamics at local level can help to design appropriate land management practices, strategies and policies [2].

Gathering information about LULC changes is fundamental for a better understanding of the relationships and interactions between humans and natural environment. Remote sensing (RS) data have been one of the most important data sources for studies of LULC related to spatial and temporal changes. Multi-temporal RS datasets, opportunely processed and elaborated, allow us to map and identify landscape changes, thus giving an effective effort to sustainable landscape planning and management [4]. In particular, by means of integration RS and GIS techniques, it is possible to analyze and to classify a changing pattern of LULC during a long time period and, as a result, to understand the changes within the area of interest [6]. The availability of time-series dataset is essential to understand and monitor the change process, to characterize and locate the evolution trends at a detailed level. Thus, the application of geospatial techniques to study LULC change and spatio-temporal expansion process of Adama city is the right and timely decision to avert the negative consequences of uncontrolled urbanization and associated problems.

II. STUDY AREA

The study area, Adama city "Fig. 1," is a central city in Oromiya regional state and one of the major city of Ethiopia. Its approximate location is 8°33'35"N - 8°36'46"N latitude and 39°11'57"E - 39°21'15"E longitude. The city has an average altitude of 1,712m (5,617ft) above mean sea level.

III. DATA AND METHODOLOGY

A. Input data sets

In the present study, a set of temporal satellite images for Adama at 10 years interval each have been obtained for the years 1984, 1994, 2004 and 2014 "Fig 2,". Table I lists detail for the year 1984 upto 1994. The images are from landsat 5 MSS having seven spectral bands (30m resolution), while the images for the year 2004 and 2014 are from landsat 7 having eight spectral bands (30m resolution). All the images are geometrically rectified and registered to same projection of UTM WGS 84 zone 37 North. In this study, five LULC classes have been identified, namely, urban, agriculture, shrub and bushes, barren area and hilly area, using ERDAS Imagine 2014 software. Once the classification is performed, the image is subset using ArcGIS 10.3 to focus on the study area with a boundary of 134.46km^2. The agriculture class is defined to include all other types of land use classes other than the 4 classes.

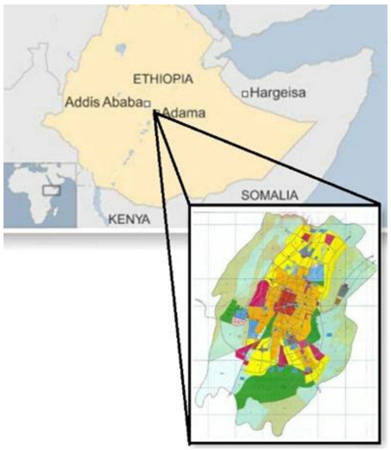
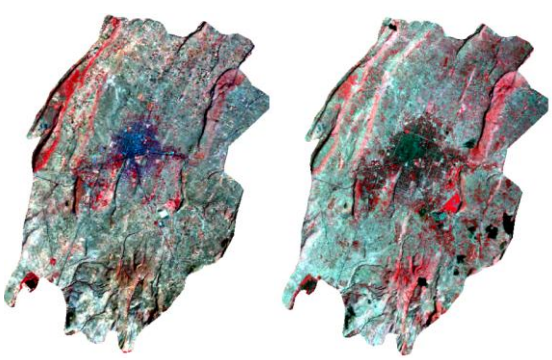


Fig. 1. Location map of the study area [5].

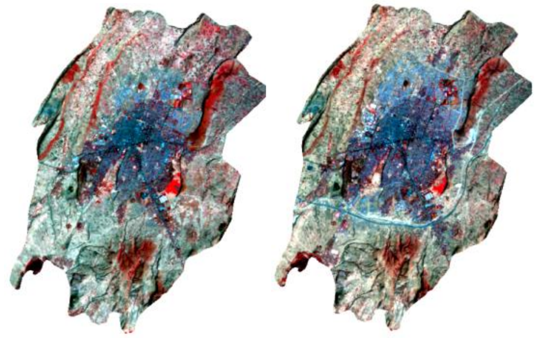
TABLE I
DATA SET USED FOR THE STUDY

S/n	Spacecraft Id	Data acquired	Resolution and sensor Id	Origin
1	Landsat image 5	1984-12-17	30m TM	USGS
2	Landsat image 5	1994-11-27	30m TM	USGS
3	Landsat image 7	2004-12-16	30m ETM+	USGS
4	Landsat image 7	2014-12-28	30m ETM+	USGS

TM- Thematic mapper, ETM+-Enhanced mapper unit



(a) 1984 (b) 1994



(c) 2004 (d) 2014

Fig 2. Satellite imagery of different years (1984, 1994, 2004 and 2014)

B. *LULC methodology*

In order to perform LULC detection, comparison of supervised classified maps have been carried out to identify change in LULC. In order to illuminate occurrence of single pixel of any class, Majority filter as post classifier has been used. Change detection matrix page7produced with the help of ArcGIS 10.3. software. Detailed methodology adopted shown in Fig. 3.

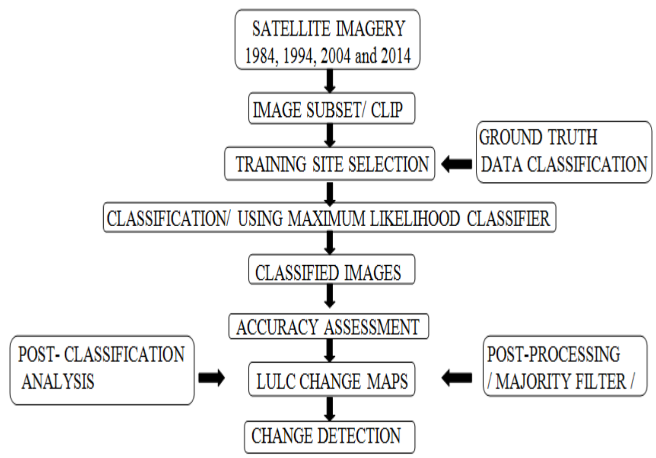


Fig. 3. LULC and change detection methodology flow chart.

IV. RESULTS AND DISCUSSION

A. *Land use/ cover Change Detection (1984-2014)*

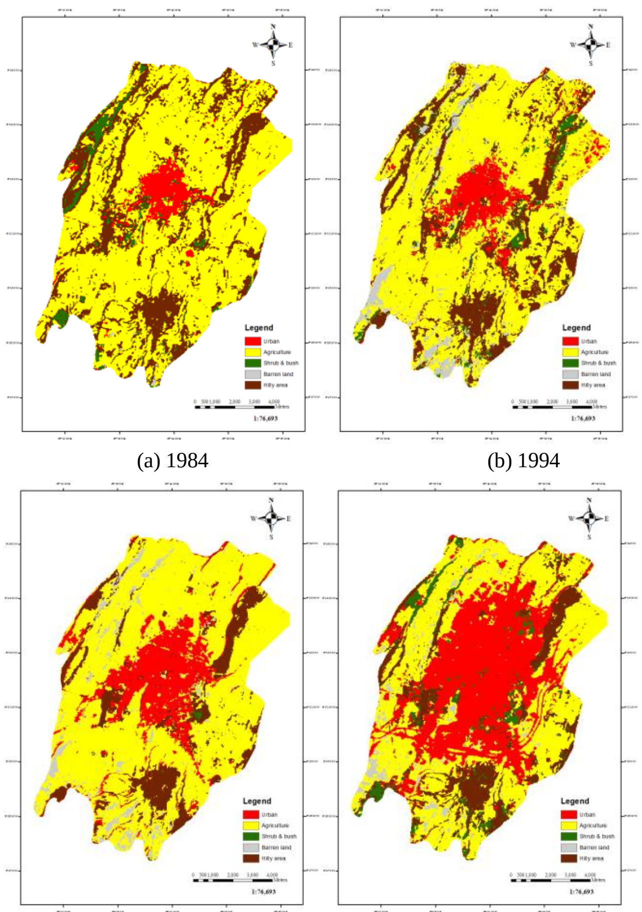
LULC change studies allow planners to understand the role of different factors including rapid population and urban growth, frequency of migration, rural to urban changes. Due to involvement of multiple data sets, latest technologies like remote sensing and GIS used to create LULC map "Fig. 4,", LULC change graph "Fig. 5," and quantify LULC change map "Fig. 6, and 7" LULC on the basis of interpretation of remote sensing imagery.

Table II shows that the distribution of LULC in terms of area and percentage for four years of assessment, while Table III shows the amount of change occurring during each decadal period between 1984 - 2014.

TABLE II
AREA OF DIFFERENT LULC CATEGORIES

Class name	Area, km^2			
	1984	***%***	***1994***	***%***
Urban	5.45	4.05%	11.39	8.47%

Agriculture	91.04	67.71%	84.41	62.78%
Shrub and bushes	5.82	4.33%	4.86	3.61%
Barren area	0	0.00%	6.37	4.74%
Hilly area	32.15	23.91%	27.43	20.40%
Total	134.46	100	134.46	100
Overall Accuracy (%)	90.0		91.43	
Kappa Coefficient	0.83		0.87	
Class name	**Area, km^2**			
	2004	***%***	***2014***	***%***
Urban	22.17	16.49%	48.11	35.78%
Agriculture	88.73	65.99%	58.06	43.18%
Shrub and bushes	0.00	0.00%	6.64	4.94%
Barren area	6.38	4.74%	4.05	3.01%
Hilly area	17.18	12.78%	17.60	13.09%
Total	134.46	100	134.46	100
Overall Accuracy (%)	93.33		90.0	
Kappa Coefficient	0.90		0.82	



(a) 1984 (b) 1994

(c) 2004 (d) 2014

Fig. 4. Land use/ cover of different years (1984, 1994, 2004 and 2014).

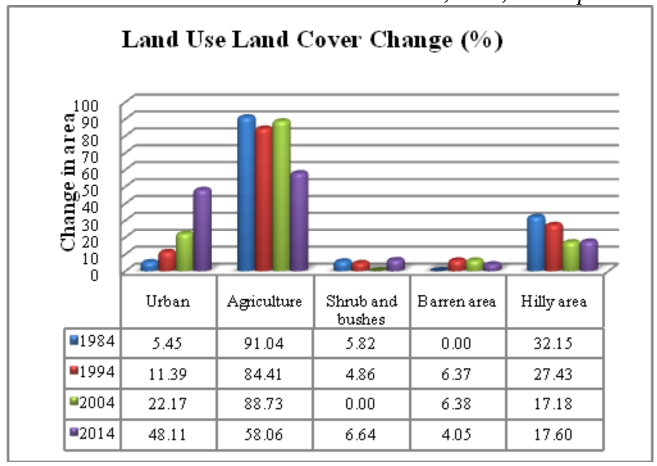


Fig. 5. LULC change in different years.

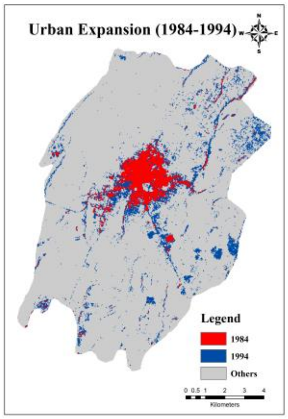
B. Land use Land cover Change Detection Matrix

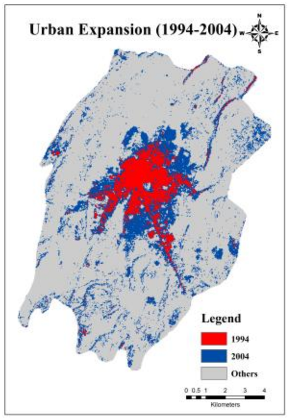
The change detection matrix records the correlation of each land cover category to the each category. To understand urban change and LULC change for different land categories within 30 years (1984–2014), a change detection matrix Table IV, was prepared which reveals that:

1. Nearly 36.58% (33.30 km^2) area of agriculture cover has been converted into urban area.
2. Nearly 24.98% (8.03 km^2) area of hilly area cover has been converted into urban area.

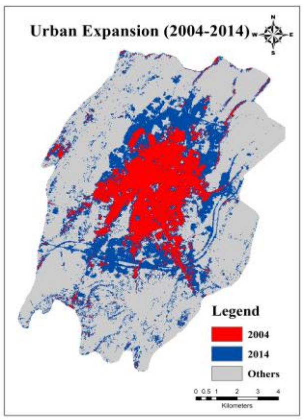
TABLE III
AMOUNT OF CHANGE DETECTED IN DIFFERENT LULC CATEGORIES

Class name	**Change**			
	1984-1994		***1994-2004***	
	Area (km^2)	***%***	***Area (km^2)***	***%***
Urban	5.94	4.42%	10.78	8.02%
Agriculture	-6.63	-4.93%	4.32	3.21%
Shrub and bushes	-0.96	-0.71%	-4.86	-3.61%
Barren area	6.37	4.74%	0.01	0.01%
Hilly area	-4.72	-3.51%	-10.25	-7.62%
Class name	**Change**			
	2004-2014		***1984-2014***	
	Area (km^2)	***%***	***Area km^2)***	***%***
Urban	25.94	19.29%	42.66	31.73%
Agriculture	-30.67	-22.81%	-32.98	-24.53%
Shrub and bushes	6.64	4.94%	0.82	0.61%
Barren area	-2.33	-1.73%	4.05	3.01%
Hilly area	0.42	0.31%	-14.55	-10.82%



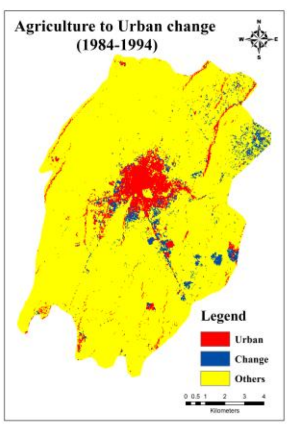


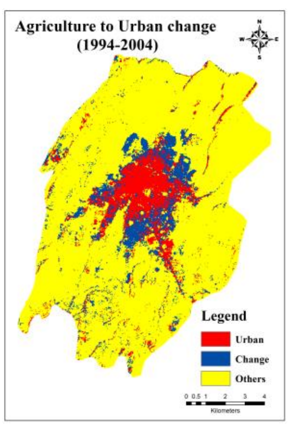
(a) 1984-1994 (b) 1994-2004



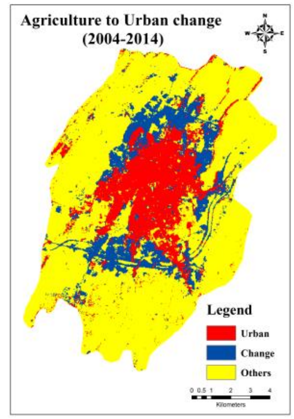
(c) 2004-2014

Fig. 6. Urban expansion in different 10 years interval.





(a) 1984-1994 (b) 1994-2004



(c) 2004-2014

Fig. 7. Agriculture to Urban change in different 10 years interval.

Thus, it can be inferred that apart from urban expansion, there is a marked change in hilly area where earlier agricultural activities have been given way to urban areas and that there is further conversion of hill area into agriculture. This is a strong indication with time, the hill landscape may undergo change further, leading to major environmental concerns. In order to understand environmental concerns phenomenon, population projection and urban area required has been studied.

TABLE IV
LULC CLASS CHANGE DETECTION MATRIX BETWEEN 1984 AND 2014 IN KM^2

	Class name	2014				
		Urban	***Agri-culture***	***Shrub and bushes***	***Barren area***	***Hilly area***
1984	***Urban***	5.45	0.00	0.00	0.00	0.00
	Agriculture	33.30	47.17	2.51	3.05	5.01
	Shrub and bushes	1.33	1.52	1.64	0.00	1.33
	Barren area	0.00	0.00	0.00	0.00	0.00
	Hilly area	8.03	9.37	2.49	1.00	11.26

C. Population and spatio-temporal expansion of Adama

The population of Adama has been increasing drastically from years to years, this plays an important role of urbanization. Migration plays a main role; various studies point that Adama has been one of the areas both in the region and the country that receives heavy influx of migrants each year [3]. For instance, the 1984 Census indicates that 53.7 percent of the city's populations were migrants. Similarly, after a decade, in 1994 the second census showed that the extent of migrants were 53.6 percent [1].

In order to assess spatial expansion of the city, Table V, classified multi temporal datasets were extracted to show consecutive annual growth rate observed in urban landscape. In reference to urban expansion history of Adama city in past 30 years, the city was significantly experienced spatial expansion to different parts. To this effect, further expansion in the coming future is thought to be inevitable.

According to [7] [8], arithmetic urban growth can be calculated by using exponential formula as shown in (1).

Hence, the built-up expansion of the city after 2014 has been computed.

$$A_f = A_b * (1 + \%/_{100})^{(f-b)} \quad (1)$$

where, A is area, f is future year, b is base year and % is the growth rate per year.

The estimation conducted by applying average growth rate per year and thus the aforementioned projection will take place if there is no implementation of rules and regulations both at national or local level to monitor unplanned and irregular urban expansion. Moreover, the projection has been conducted assuming that the horizontal built-up area expansion will continuing to increase at an average expansion rate of the past 30 years with other factors remaining constant.

TABLE V
ANNUAL GROWTH RATE OF URBAN AND POPULATION GROWTH OF ADAMA (1984-2030)

Years	**Urban (Km^2)**	**Population**	**Annual Growth Rate (%)**		
1984	6.5	76284	***Interval***	***Urban***	***Population***
1994	11.39	127842	1984-1994	5.8	5.3
2004	21.11	187000	1994-2004	6.4	3.9
2014	45.83	324000	2004-2014	8	5.7
Estimated urban and population growth with average annual growth rate					
2020	67.83	434160	2014-2020	6.7	5
2030	129.55	707680	2020-2030	6.7	5

V. CONCLUSION

The study conducted in Adama, Oromia regional state, Ethiopia advocates that multi-temporal satellite data and geospatial techniques are helpful in LULC change detection. The study shows that now a day's major land use increscent in Adama area is urban area, during the last 30 years, area under urban land has been increased by 31.73% (42.66 km^2) due to construction and infrastructure development, while area under agricultural land is decreased by 24.53% (32.98 km^2) due to expansion of urban construction. The driving factors for urban expansion of the Adama were highly related to the socio-economic importance of the city. One of the main cause associated to spatial expansion process is thought to be related with the migration of population growth which increased demands of land for the investment and residential housing. The correlation of population and urban growth, it is found that by the year 2030 the whole area would be fully converted into urban areas. Therefore, the output information should implement for future development in the region. In conclusion, this study illustrates that geospatial techniques are important technologies for identifying growth of the urban region and conversion of land type with much more accuracy temporal analysis and quantification of spatial phenomena.

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REFERENCE

[1] Adama city administration. [online]. Available: http://www.adamacity.gov.et/demograph.htm/.
[2] Bireda A., "Gis and remote sensing based land use/land cover change detection and prediction in fagita lekoma woreda, awi zone, north western Ethiopia," PhD diss., AAU, 2015.
[3] CSA., The 1994 Population and Housing Census of Ethiopia: Results for Oromia Region, Statistical Report on Population Size and Characteristics, Volume I: Part I, Addis Ababa, 2013.
[4] Dewan A.M., Yamaguchi Y., "Using remote sensing and GIS to detect and monitor land use and land cover change in Dhaka Metropolitan of Bangladesh during 1960–2005," Environmental monitoring and assessment 150, no. 1 (2009): 237-249.
[5] EMA., Topographic Map of Adama city, Addis Ababa, Ethiopia, 2013.
[6] Fichera, Carmelo R., Giuseppe M., and Maurizio P., "Land Cover classification and change-detection analysis using multi-temporal remote sensed imagery and landscape metrics," European Journal of Remote Sensing 45, no. 1 (2012): 1-18.
[7] Gezahegn W., Anteneh D., "Assessing Land-Use/Land-Cover Changes and Spatio-Temporal Expansion Process of Assela Town, Arsi Zone, Ethiopia," International Journal of Science and Research (IJSR), ISSN [Online]: 2319-7064, 2013.
[8] Hofstee, P., and M. Brussel, "Analysis of suitability for urban expansion in Villavicencio, Colombia," 1995.
[9] Rawat, J. S., Vivekanand Biswas, and Manish Kumar, "Changes in land use/cover using geospatial techniques: A case study of Ramnagar town area, district Nainital, Uttarakhand, India," The Egyptian Journal of Remote Sensing and Space Science 16, no. 1 (2013): 111-117.
[10] Zubair, A. O., "Change detection In land use and land cover using remote sensing data and GIS," A case study of Ilorin and its environs in Kwara, State, 2006.