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Monitoring Urban Growth and Land Use Land Cover Dynamics Using GIS and Remote Sensing: Case study of Assela Town, East Arsi Zone, Ethiopia

HAILEMARIAM ZEWDIE[1]
Arsi University
SHIMELIS SISAH[2]
Arsi University
KIMIYA AMAN[3]
Adama Science and Technology University

Abstract

In the last decades, Assela town has experienced drastic changes in its vast geographical expansion, and also by internal transformations. Subsequently, understanding and evaluating the spatiotemporal dynamics of urban growth and land use and land cover (LULC) shifts, and it is important to bring forth the right strategies and processes to track urban development in decision-making. The goal of this analysis was therefore to examine LULC changes that have taken place bewtween 1995 to 2021, forecast the long-term urban development in Assela town using geospatial techniques. For this study a three time series data Landsat 5 for 1995, Landsat 7 for 2008, and Landsat 8 for 2021 satellite images were used to extract LULC types. Four LULC classes were extracted using a Support Vector Machine (SVM) supervised classification approach for image classification. Agricultural land, paved surfaces, vegetation, and water bodies were the LULC classes. Maximum likelihood supervised classification of satellite imageries was applied for Image classification. The area in terms of LULC can be divided into following four classes: Paved surface, agriculture land, and vegetation and water bodies.

[1] **Hailemariam Zewdie** has held his B.A degree in geography and environmental management from Debub University in 2006, and M.A degree in population and socio-economic development planning from Adama Science and Technology University. He has served as a lecturer in Arsi university and published the following articles: "Opportunities and Challenges of African Growth Opportunity Act (AGOA) on Ethiopia Foreign Trade Development: The Case of Textile & Apparel Sub-Sector" European Academic Research Vol. V, Issue 10/ January 2018; "Socio-Economic Impacts of Migration and Remittances: Examinations of Households in Gohatsion Town" Journal of Sustainable Development in Africa Vol, 17 No.8, 2015. Email: hzwossen@yahoo.com

[2] **Shimelis Sishah** has held his BSc degree in Geographic Information Science from Hawassa University in 2016, and MSc degree in Geographic Information Science and Remote Sensing from University of Gondar in 2021. He has served as a lecturer in Arsi university and published a journal article: "Rainfall Runoff Estimation Using GIS and SCS-CN Method for Awash River Basin, Ethiopia" Journal of Earth Science and Climate Change Volume 12, Issue 4, 2021. Email: shimelisgis2015@gmail.com

[3] **Kimiya Aman** has hold BA degree in History from Addis Ababa University in 2010 and MA degree in Population and Socio- economic Development planning from Adama Science and Technology University currently she is served as lecturer in Rift-valley University.

The outcome over the past 25 years demonstrated a high reduction in vegetation cover , agricultural land and water body with a reduction percentage of 37.94 % (9.3 sq.km), 16.1 % (3.94 sq.km) and 0.06 % (0.014 sq.km) respectively, On the other hand, paved surface has increased by 54.09 % between the year 1995 and 2021 study periods. This study informs the need to tackle the expansion of the town and land use land cover dynamics through careful spatial planning and design future appropriate land management options.

Keywords: Ethiopia, GIS, Land use/Land Cover; Landsat, Remote sensing

1. INTRODUCTION

In recent decades, urbanization, the most extreme anthropogenic land cover/use transformation has been a universal and important socioeconomic phenomenon and is being confronted by both developed and developing countries. It all began during the post war prosperity of the 1950's and 60's, when housing developments popped up across the landscape like mushrooms after a rain (Barros, 2004). A half century later, it is understood that many environmental problems accompanied the outward spread of cities: fragmenting and destroying wildlife habitat, for example, and discharging polluted runoff water into streams and lakes. In developing countries, sprawl is largely the result of mobility of people to the city in search of better employment and opportunity. This leads to an increase in size well beyond the limits of the city and has become one of the leading causes of the disorganized expansion of settlements and activities which facilitated uneconomical use of land. In contrast, sprawl in developed countries is the results of higher incomes, which in turn result in people preferring (and affording) to live in the outskirts of the city, with open spaces at reasonable distances from cities. However, with the expansion of urban land day by day, engulfing the neighboring land, there is a major threat to sustainability and quality of life (Menon, N, 2004).

Africa is urbanizing fast. Its rate of urbanization soared from 15 % in 1940 to 40 % in 2010, and is projected to reach 60 percent in 2050 (UN HABITAT, 2010). Africa's urban growth is in line with trends observed in most emerging and developed countries.

Nonetheless, the level of urbanization is still below 20% in poorest countries of the region including Burundi, Ethiopia, Malawi, Burkina Faso, and Uganda. But, in the rapidly industrializing economy of South Africa, approximately 60% of the population now lives in urban areas (UN HABITAT, 2010).

Ethiopia is one of the most populous countries in Sub Saharan Africa (SSA) and urban population growth is estimated at about 4.8 per cent, a higher figure compared to other Sub Sahara African countries. Thus, mapping and quantifying urban expansion by interpreting multi-temporal datasets of the past has a paramount importance to analyze urban expansion trend of the past. It also plays a great role in monitoring further expansion so as to introduce some possible remedial intervention to avert or minimize the socio-economic and environmental impacts of unstructured urban expansion process (Barredo *et al.*, 2003). Therefore, as in many other towns of Ethiopia rapid urban population growth and spatio-temporal expansion conditions over the last three decades have created considerable economic, social and environmental problems in Assela town. Consequently, the municipal authorities and other decision makers faced challenges in course of managing urban expansion of the town with timely update information supported by GIS and RS techniques. Thus, the application of GIS and RS to study Land-use/Land-cover change and spatio-temporal expansion process of Assela town is the right and timely decision to avert the negative consequences of uncontrolled urbanization and associated problems.

2. REVIEW LITERATURE

2.1 Conceptualization of Urbanization, Land use and Land cover

Urbanization is defined as the demographic process whereby an increasing share of the national population lives within urban settlements. Settlements are also defined as urban only if most of their residents derive the majority of their livelihoods from non-farm occupations. Throughout history, urbanization has been a key force in human and economic development. This increasing of population in urban area causes urban expansion if they are unplanned and unchecked (Arouri, M et al, 2014).

Urbanization also deals with the increase in the proportion of people living in towns and cities. Urbanization occurs because people move from rural areas to urban areas. This usually occurs when a country is still developing. Rural to urban migration is happening on a massive scale due to population pressure and lack of resources in rural areas. People living in rural areas are pulled to the city.

Land use means, use of land for different purposes like built-up recreation, commercial, forest etc. Moreover, it is related to the human activities or economic function rated with a specific piece of land In other words the land use denotes the multifaceted use of land, which includes both use and misuse of the land. Land cover relates to the type of feature present on the surface of the earth (Arouri, M et al, 2014). Besides, it can be described as ground blanket of natural and culture landscape. It consists of vegetation, soils, snow, rocks, settlements etc. Generally, land cover means the area covered by various physical features like vegetation, hills, water bodies etc.

2.2. Land use and Land cover Changes

The definition of land use and land cover has been used interchangeably in the land use research community because of the availability of many existing information systems. However, these two terms explain two different issues and meanings. Land cover refers to the observed biophysical cover on the earth's surface including vegetation, bare soil, hard surfaces and water bodies. Whereas land use is the utilization of land cover type by human activities for the purpose of agriculture, forestry, settlement and pasture by altering land surface processes including biogeochemistry, hydrology and biodiversity (Di Gregorio and Jansen, 2000).

Land use and land cover changes became prominent as a research topic on the global environmental change several decades ago with the idea of processes in the earth's surface influence climate. In early 1980's the significance impact of land use and land cover change on the global climate via carbon cycle was understood where terrestrial ecosystems acted as a source and sinks due to the changes. Following this, the forthcoming volume of the 1991 Global Change Institute of the Office of Interdisciplinary Earth Studies (OIES) dedicated to land use and land cover changes at global level by explaining the major recent trends of changes, their consequences in environment, human causes on it as well as data and modeling of changes (Meyer and Turner, 1992). Latter, under the support of land use and land cover change project of the International Geosphere and Biosphere Programme (IGBP) and International Human Dimensions Programme on Global Environmental Change (IHDP), the research community has identified three basic issues. These were understanding the causes of land use and land cover changes, how to quantify it and how to apply models of predicting the changes (Lambin et al, 2003).

2.3 Application of GIS and Remote Sensing in Analysis of Urban Sprawl

Now a day the field of Remote Sensing and GIS has become exciting and glamorous with rapidly expanding opportunities. They are very useful in the formulation and implementation of the spatial and temporal changes, which are essential components of regional planning to ensure the sustainable development. The different stages in the formulation and implementation of a regional development strategy can be generalized as determination of objectives, resource inventory, analysis of the existing situation, modeling and projection, development of planning options, selection of planning options, plan implementation, and plan evaluation, monitoring and feedback (Yeh, A.G.O. and Xia Li ,2001).

GIS and remote sensing techniques are quite developed and operational to implement such a proposed strategy. The spatial patterns of urban sprawl on temporal scale are studied and analyzed using the satellite imageries. The image processing techniques are also quite effective in identifying the urban growth pattern from the spatial and temporal data captured by the remote sensing techniques. These help in delineating the growth patterns of urban sprawl such as, the linear growth and radial growth patterns (Yeh, A.G.O. and Xia Li ,2001).

Therefore, integrated use of GIS and remote sensing technology plays key role in land use /land cover mapping as well as detection of extent and patterns sprawl of urban landscape.

2.4 Study area

The study was conducted in Assela town, East Arsi Zone, Ethiopia. The town situated at about 161 kilometers away from Addis Ababa capital City. Astronomically situated 7^0 54'55"N – 8^0 00'05"N latitude and 39^0 06'10"E - $39^0$10'00'E longitudes.

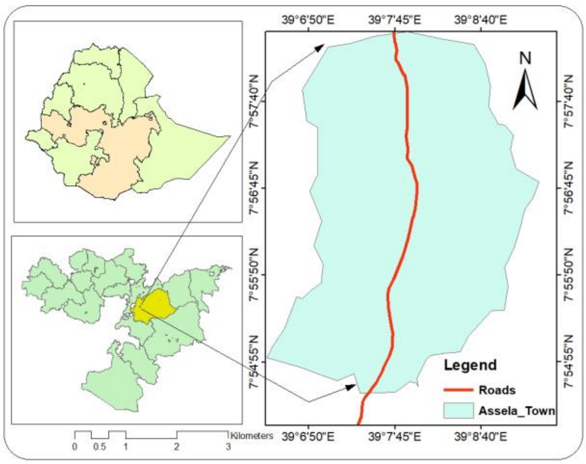

Figure 1: Location Map of the study area

3. MATERIAL AND METHODS

3.1 Software *and Instruments*

ArcGIS 10.3 version software was used for the analysis and mapping land use/land cover maps and sprawl map of the study area. ERDAS Imagine software was also used for image processing and detection of the land use/land cover and sprawling developments of the buildup area of the town. For ground trothing and field verification purpose Garmin GPS 60 instrument was utilized.

3.2 Image preprocessing

Landsat 5, 7, and 8 images were geometrically and radiometrically corrected to improve quality and yield better results. Before using the image for analysis, it was preprocessed with layer stacking, image sub setting, atmospheric correction, and image resampling. The nearest neighbor algorithm was used to resample Landsat thermal bands to a spatial resolution of 30 m by 30 m pixel.

Table 1: Datasets used in the study

Satellite	Sensors	Resolution (PAN/MS/TIRS)	Acquisition date	Source
Landsat	TM	15/30/120m	1 December 1995	USGS
	ETM+	15/30/60m	17 December 2008	
	OLI/TIRS	15/30/100m	27 December 2021	

3.3 LULC class extraction

Landsat 5 for 1995, Landsat 7 for 2008, and Landsat 8 for 2021 satellite images were used to extract LULC types. Four LULC classes were extracted using a Support Vector Machine (SVM) supervised classification approach for image classification. Agricultural land, paved surfaces, vegetation, and water bodies were the LULC classes. To assess the accuracy of classified LULC classes, a total of 400 reference samples were digitized from Google Earth and used to check their validity. On the basis of these reference data, an error matrix was created. Overall accuracy and Kappa statistics were calculated using the error matrix.

Table 2: Description of LULC classes of Asella town and its surrounding (1995-2021)

Main LULC classes	Descriptions of sub-classes included in the main LULC classes
Agricultural land	Cropland, fallow land, Pastureland, and bare land
Paved Surface	Built-up, asphalt and concrete roads, parking lots and industrial zones
Vegetation	Forest, wetland vegetation, Grassland, Shrubland, and woodland
Waterbody	Rivers, ponds, and wetland water

Source: - (Abel. B and Tesfaye. K, 2020)

4. RESULT AND DISCUSSIONS

4.1 Spatial-temporal pattern of LULC dynamics

The spatial extent of LULC maps of Assela town (1995–2021) is shown in Fig. 1. Agricultural land was the dominant LULC class in the town during these study periods, and it could be found in the town's south western and south eastern areas. Vegetation cover can be found along waterbodies and wetland areas, as well as in the town's settlement, recreational, and institutional areas. Waterbodies were found in the town's southern section, while paved surfaces covered the town's east and west sides, as well as the majority of the town's central area.

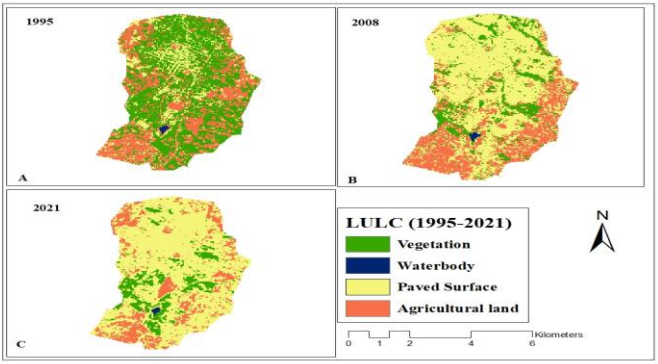

Figure 1: LULC map of the year 1995(a), 2008(b), and 2021 (c)

In 1995, agricultural land covered 8.137 km2, and by 2008 and 2021, it had shrunk to 6.5862 km2 and 4.1895 km2, respectively (Table 3). These graphs show how the spatial extent of agricultural land has shrunk between 1995 and 2021. Between 1995 and 2008, 1.5516 hectares of agricultural land were converted to other LULC types. However, between 2008 and 2021, 2.396 km2 of agricultural land was converted to other LULC categories. 3.948 km2 of agricultural land was converted to other LULC types during the study period (1987–2017). From 4.14 km2 in 1995 to 14.43 km2 in 2008 and 17.11 km2 in 2021, the paved surface has increased. Other LULC types were converted to paved surfaces in the amounts of 4.393 km2, 7.05 km2, and 0.0054 km2 between 1995 and 2008, 2008–2021, and 1995–2021, respectively. As a result, paved surfaces such as settlements, industrial areas, asphalt and concert roads, and parking lots have seen significant growth at the expense of vegetation, agricultural land, and water bodies. Another LULC type in the tow is vegetation cover, which was 12.17 km2 in 1995 and fell to 3.4 km2 in 2008. Meanwhile, due to the expansion of tree plantations, green spaces, and recreation areas, vegetation cover decreased slightly to 2.87 km2 in 2021.

As a result, between 1995 and 2008, 7.05 km2 of wetland, shrubland, forest, and woodlandvegetation cover was converted to other LULC types, primarily paved surfaces. Water body increased slightly from 0.069 km2 in 1995 to 0.072 km2 in 2008 and 0.054 km2 in 2021. (Table 3). 0.14 km2 of water body changed to other LULC types during the study period (Table 4). Between 1995 and 2021, there was a rapid urban expansion, as evidenced by the decrease in agricultural land, vegetation, and water bodies, as well as an increase in paved surfaces (Figs. 2, and 3).

Table 3:- Statistical summary of LULC in Assela town and its surrounding (1995–2021).

LULC Types	1995		2008		2021	
	KM²	%	KM²	%	KM²	%
Vegetation	12.177	49.64	3.4335	14.00	2.871	11.70
Waterbody	0.0693	0.28	0.0720	0.29	0.0549	0.22
Paved Surface	4.1454	16.90	14.437	58.86	17.4141	70.99
Agricultural land	8.1378	33.18	6.5862	26.85	4.1895	17.08

Table 4:- Statistical summary of LULC change in Assela town and its surrounding.

LULC Types	1995-2008		2008-2021		1995-2021	
	KM²	%	KM²	%	KM²	%
Vegetation	-8.7435	-35.64	-0.5625	-2.29	-9.306	-37.94
Waterbody	0.0027	0.01	-0.0171	-0.07	-0.0144	-0.06
Paved Surface	10.292	41.96	2.976	12.13	13.268	54.09
Agricultural land	-1.5516	-6.33	-2.396	-9.77	-3.948	-16.10

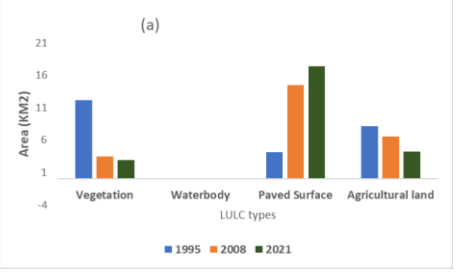

Figure 2:- Statistical descriptions of LULC in Assela town and its surrounding from 1995 to 2021

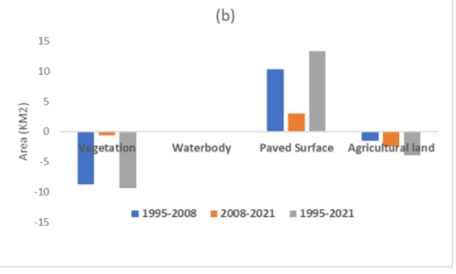

Figure 3:- Descriptions of LULC change in different time periods in Assela town and its surrounding from 1995 to 2021

6. CONCLUSIONS AND RECOMMENDATIONS

The study is concerned with analyzing the spatio-temporal land use/cover change, extent and pattern of urban expansion of Assela town between 1995 and 2021. The analysis was carried out based on satellite imageries of 25 years (three periods). The result of the analysis reveals that paved surface has been progressively increasing from the beginning to the end of the study period with a net gain of 54.09 % against the other land uses/land covers. The impact of sprawl on vegetation cover is higher than other land uses; it decreased by 37.94 % through study period. Besides, agricultural land and water bodies have also decreased by 16.1 % and 0.06 %, respectively from 1995 to 2021. The increase in the paved surface has been resulted from intensified land use transformation due to urban land use encroachment to rural lands particularly new residential development in the town. The developments in paved surface are scattered and uncoordinated and thus it intensifies uneconomical use of land and created sprawling impact.

It was concluded that the paved surface showed great horizontal expansion and uncoordinated growth pattern resulting in putting burden on the town administration to provide the necessary infrastructure. Hence, an increase in urban expansion and sprawl led to higher loss of vegetation cover and agricultural land which negatively affected the pattern of land use.

The study also demonstrated the role of integrated application of GIS and remote sensing in quantifying and mapping the extent and pattern of urban sprawl through different time periods. Based on the findings, the study recommends that as urban areas are rapidly growing and putting pressure on efficient use of land, it requires periodic monitoring and regulation of urban growth using the geospatial technologies for proper, productive and sustainable development of urban areas including Assela town. However, the remote sensing approach provides information only on the dynamics of the different land use land cover types over time but does not show information about the driving forces behind the conversion of these resources. Further investigation is, therefore, needed to find the different driving forces of change that help to design and look for alternative solutions for future development plans and strategies.

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REFERENCES

1. Arouri, M., Youssef, A, Nguyen-Viet, C. & Soucat, A. Effects of urbanization on economic growth and human capital formation in Africa. Working paper. Harvard University. 2014.

2. Balew and T. Korme, Monitoring land surface temperature in Bahir Dar city and its surrounding using Landsat images, The Egyptian Journal of Remote Sensing and Space Sciences, https://doi.org/10.1016/j.ejrs.2020.02.001

3. Barredo, J., Kasanko, M., McCormick and Lavalle, C, .2003, *Modeling dynamic spatial process':* Simulation of urban future scenarios through cellular automata. Landscape and Urban Planning, 64, 145-160.

4. Barros, J. X. (2004). Urban growth in Latin American cities: exploring urban dynamics through agent-based simulation (Doctoral), University of London.

5. Di Gregorio, A and Jansen, L. J. (2000). Land cover classification system: LCCS: classification concepts and user manual. Food and Agriculture Organization of the United Nations Rome

6. Lambin, E. F., Geist, H. J and Lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions. Annual Review of Environment and Resources, 28(1), 205–241.

7. Menon, N. “Urban Sprawl: A developing country approach.” Journal of The World Student Community for Sustainable Development, 2004.

8. Meyer, W. B and Turner, B. L. (1992). Human population growth and global land-use/cover change. Annual Review of Ecology and Systematics, 23, 39–61.

9. United Nations Human Settlements Programme (UN HABITAT). State of the World Cities 2010/2011: Bridging the Urban Divide. United Nations Human Settlements Program, Nairobi, Kenya, 2007.

10. Yeh, A.G.O. and Xia Li (2001). “Measurement and monitoring of Urban sprawl in rapidly growing region using entropy.” Photogrammetric Engineering and Remote Sensing, Vol. 67 (1): 83, 2001.