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**Spatio-Temporal Analysis of Land Use/Land Cover  
Change and Urban Sprawl Using GIS and Remote Sensing  
Technologies: The Case of Laga Tafo-Laga Dadi Town,  
Special Zone of Oromia, Central Ethiopia**

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**Abstract**

This study analyzed spatiotemporal land use/land cover change and urban sprawl of Laga Tafo Laga Dadi town in the Special Zone of Oromia, surrounding Addis Ababa city using Geographic Information System and Remote Sensing. For this study a two decades time series data (Landsat TM 1996, SPOT-5 image of 2006, and Landsat ETM<sup>+</sup> 2016) was used and analyzed quantitatively using GIS and remote sensing data processing softwares. Maximum likelihood supervised classification of satellite imageries was applied for Image classification. The finding of the study shows that urban/built up area of the town has significantly expanded by 48.3 per cent against agricultural land loss of 42.95 per cent over the study period. This indicates that there was a major land use/land cover change of the town with the agricultural land lost to built-up area being the dominant one. An increase in the number of residents, expansion of new developments and land use/land cover change has caused rapid sprawling development of the town. The sprawling of various developments has negatively affected the economical and balanced development of land use in the town. The town is currently becoming the destination of housing estates and new industries and it became the residence place of quite large number of people commuting to- and- from Addis Ababa city in the vicinity.

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Therefore, it is recommended that because the town shares boundary with the sprawling city of Addis Ababa, it is undoubtedly clear that there is a pressure on the land use plan of the town and thus Laga Tafo Laga Dadi town administration should work on ways of monitoring sprawling development and guide proper growth of the town.

**Key words:** Ethiopia; GIS; LagaTafo Laga Dadi; Land use/Land Cover; Remote sensing; Urban sprawl.

## **1. Introduction**

Urban sprawl has become a global or universal problem, and is being confronted by both developed and developing countries [10]. 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. 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 [12].

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 [20]. 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 [20].

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. The country is one of the least urbanized in the third world and its economy almost entirely depends on smallholder agriculture. Like most developing countries, Ethiopia experiences high rural to urban migration in search of better employment and different opportunities. The need for housing is not integrated with the need to prevent horizontal expansion and hence saving land. Formal and informal settlements are stretching out horizontally from the central capital in all directions. Land is ineffectively used, and new developments are planned on virgin land usually leapfrogging from cores. [15] has put the lists of problems linked to sprawl such as the loss of open space, urban decay, unsightly strip mall developments, the loss of a sense of community, patchwork housing developments in the midst of agricultural land, increasing reliance on the automobile, the separation of residential and work locations, and the spreading of urbanized developments across the landscape. Generally, urban sprawl in Ethiopia is a result of population pressure both from natural increase and migration [11].

Laga Tafo Laga Dadi town is one of the emerging towns of Ethiopia located in the outskirts of Addis Ababa is

rapidly growing since 2008 when the administrative restructuring of the Special Zone of Oromia took place. The town is under the influence of population spillover from the Addis Ababa city which caused fast land use/land cover dynamics within the past few years. Hence, due to competition over the land for various developments, the town is sprawling to the surrounding rural areas where in many circumstances the land use is not efficiently utilized. Therefore, such spontaneous developments require identification of the extent and patterns of sprawling of the town for guiding and monitoring its urban development. Given such rapid development characteristics and land use/land cover dynamics of the town, there is little/no study conducted on analyzing the extent and pattern of urban sprawl of Legetafo Legedadhi town. A study conducted by [16] on urban sprawl mapping and land use detection of the city of Addis Ababa and its surroundings assessed the wider sprawling characteristics of Addis Ababa city than particularly addressing the situation in Laga Tafo and Laga Dadi town. Other similar studies done on towns of similar or greater sizes gave much attention to describing the impact of urban sprawl than quantifying the extent of urban sprawl and its patterns of development.

The current study, however, attempted to analyze and map land use/land cover change, extent and patterns of urban sprawl of Laga Tafo Laga Dadi town using geospatial technologies (GIS and remote sensing).

## **2. Review Literature**

### ***2.1 Conceptualization of Urban Sprawl, Urbanization, Land use and Land cover***

The concept of sprawl was developed by Earle Draper in 1937 in the United States of America. This concept has been used by city planners to refer to a wasteful type of urban growth. Urban sprawl is defined in different way by different scholars in the field. Most of the researchers argue that urban sprawl is an expansion and spread of development across the urban landscape to agricultural land due to increasing of population growth and rural urban migration. On the other hand, urban sprawl is not to be considered as increase of urban lands in a given area rather it is an extent of urbanization mainly caused by population growth and large-scale migration which is mainly unplanned and unchecked [18]. It is also described as scattered development on the outer part of compact urban and village centers along highways and in rural countryside [14]. [9] defined it as a cause of an externality, such as high dependence on the automobile, isolation of the poor in the inner city, the spatial mismatch between jobs and housing, or loss of environmental qualities. He also explained it as the consequence or effect of some independent variables such as fragmented local government, poor planning, or exclusionary zoning.

Urban sprawl is a pattern of uncontrolled development around the periphery of a city, and is an increasingly common feature of the built environment both in the industrialized and developing nations. The phenomenon reduces the orderly physical development that produces economically efficient land use and management at the fringes of rapidly urbanizing cities. As cities expand, the main zone of direct impact is the peri-urban area. The manifestation and impact of urban sprawl are therefore felt most in peri-urban communities. At these peri-urban communities, development is patchy, scattered and spread out, with a tendency for discontinuity [5].

There are three basic spatial forms of sprawl: low density sprawl which has an unfair

feature of use of land for housing purpose along the margins of existing urban areas associated with services like water, power and roads. Ribbon sprawl which is follow main road corridors away from the center leaving lands some distant from the roads. The third form of sprawl is Leapfrog development which is characterized by an irregular pattern piece of developed land that is widely separated [2].

Conversely, 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 sprawl if they are unplanned and unchecked [1].

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.

Therefore, the concept of urban sprawl is interrelated with urban growth because the increased population in urban area can cause urban sprawl unless it is managed and controlled.

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 [1]. 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 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 [21].

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 [21].

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.

### **2.3 Previous Studies in Ethiopia**

Now a days the use of Remote Sensing and Geographic Information Systems techniques has become important for quantifying the degree of urban sprawl, mapping, monitoring, and managing urban land-use/land cover changes. Mapping urban sprawl provides a picture of where this type of growth is occurring, and helps to identify the environmental and natural resources threatened by such sprawls, and it also suggests the likely future directions and patterns of sprawling growth.

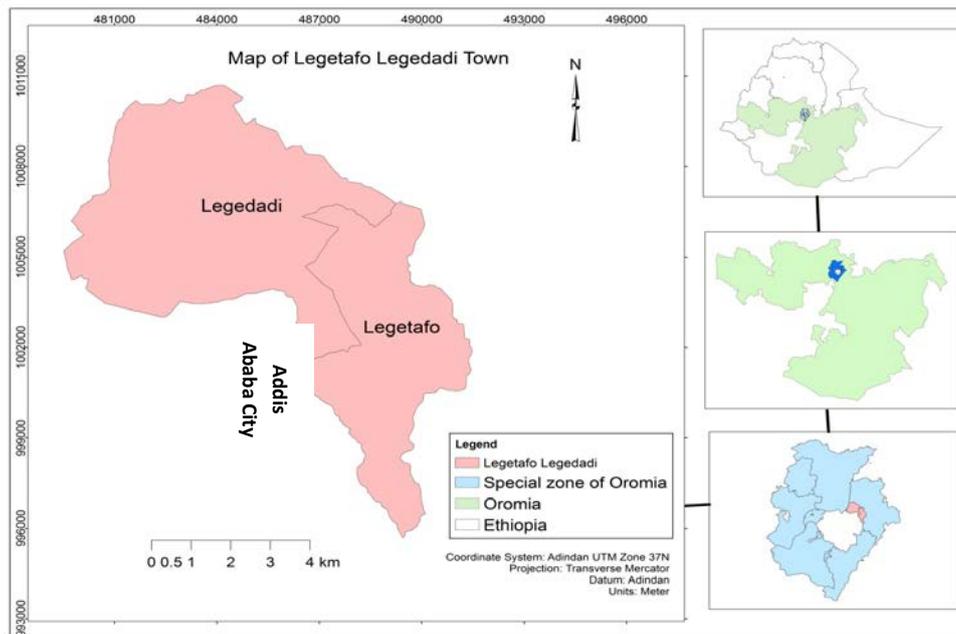
There are limited number of studies conducted on quantifying the extent and detecting the pattern of urban sprawl in Ethiopia using GIS and Remote Sensing. Contrary to this there are quite significant number of studies conducted on the impact of urban sprawl in altering land uses especially the impact it has on consumption of agricultural land on the outer skirts of cities. Notable contribution on quantifying the rate of urban sprawl and mapping was done by [16] for the city of Addis Ababa and its surroundings. Recently similar study was conducted in Ethiopia by [6] on the major drivers of urban sprawl and its impacts on land use conversion in the peri-urban kebeles of the Dukem town, one of the towns in the Oromia Special Zone surrounding Addis Ababa city, using GIS. In this study expansion of residential and industrial developments over agricultural land were mapped using GIS instead of detecting spatio-temporal land use/land cover dynamics in the study area. In the study, only a single period data was used and land uses are mapped. In such cases it is in fact difficult to analyze the extent and pattern of urban sprawl. LULC change maps.

Another study of urban sprawl in Ethiopia was conducted in DebreBerhan town which is located north-east of Addis Ababa [22]. This study focused on assessing urban sprawl of Debreberhan town using satellite imageries. The findings of the study showed that rapid population pressure has resulted in unplanned growth in the area which in turn led to urban sprawl. Urban sprawl has resulted in loss of productive agricultural lands. In this study, too major emphasis was given to how land use/land cover particularly the built-up area has been increasing between 1986-2009 than detecting the extent and pattern of sprawling of the town. [8] on his part studied the rate and effect of sprawling of Addis Ababa city. The study indicated that the rate of urban sprawl along the Mojo (south of Addis Ababa on the way to Adama city) and Jimma outlets, compared to other outlets, is high causing both positive and negative effects to the areas and the people. Similar to other studies, this study did not explicitly show the pattern of sprawl and emphasis was given to land use/land cover change due to urban growth.

In conclusion, survey of few similar studies conducted on urban sprawl in Ethiopia showed that there is a confusion between urban expansion, urban growth and urban sprawl. It is a natural and expected process that cities grow. However, the rate and pattern of conversion of other land uses/land cover into the built-up area is all about how land is utilized economically or uneconomically. In this regard, urban sprawl studies conducted in Ethiopia largely concentrate on the extent of land use/lover has been changing than how and what pattern of developments have been occurring.

### 3. Description of the Study Area

LagaTafu-LagaDadhi town is located in Oromia National Regional State, Oromia special Zone, Berek District, along the road to Debre Berhan at a distance of 21 km North East of Addis Ababa. It is located between 9°01'29" N - 9°06' N Latitude and between 38 ° 53'42" E - 38 ° 55'30" E longitude. The town is bordered by Addis Ababa city and Sululta Wereda from the west and Northwest, by Berek Aleltu Wereda from the North, East and South.



**Figure 1:** Location Map of the study area

The town has two Kebeles namely Tafo 01 and Laga Dadi 02 with a total area of 7444.53 hectares. Laga Tafu Laga Dadi town is found at an average elevation of 2350 meters above sea level; the mean annual maximum and minimum temperatures of the town are 23.76°C and 10.67°C, respectively with the Mean Annual Rainfall of 1,223.54 mms [13]. The total population of the town was estimated in 2016 to be 18,177 out of which 9157 were males, and 9020 were females [4]. However, the actual size of the population of the town soared in the last couple of years due to migration and increasing investment interests due to which the population is estimated to exceed thirty thousand.

### 4. Database and Methodology

#### 4.1 Data Types and Sources

The study has used time series data (Landsat TM 1996 with 30m resolution, SPOT- 5m image of 2006 and Landsat ETM+2016, 30m resolution) acquired from Ethiopian Mapping Agency (EMA) to analyze and detect the land use/land cover dynamics and urban growth trend of the town. In addition, GPS points and Google earth image of 2006 and 2016 were used to get ground truth point for accuracy assessment. Ancillary data from

different published and unpublished sources such as books, journals, internet sources, research reports and articles were also used.

#### 4.2 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.

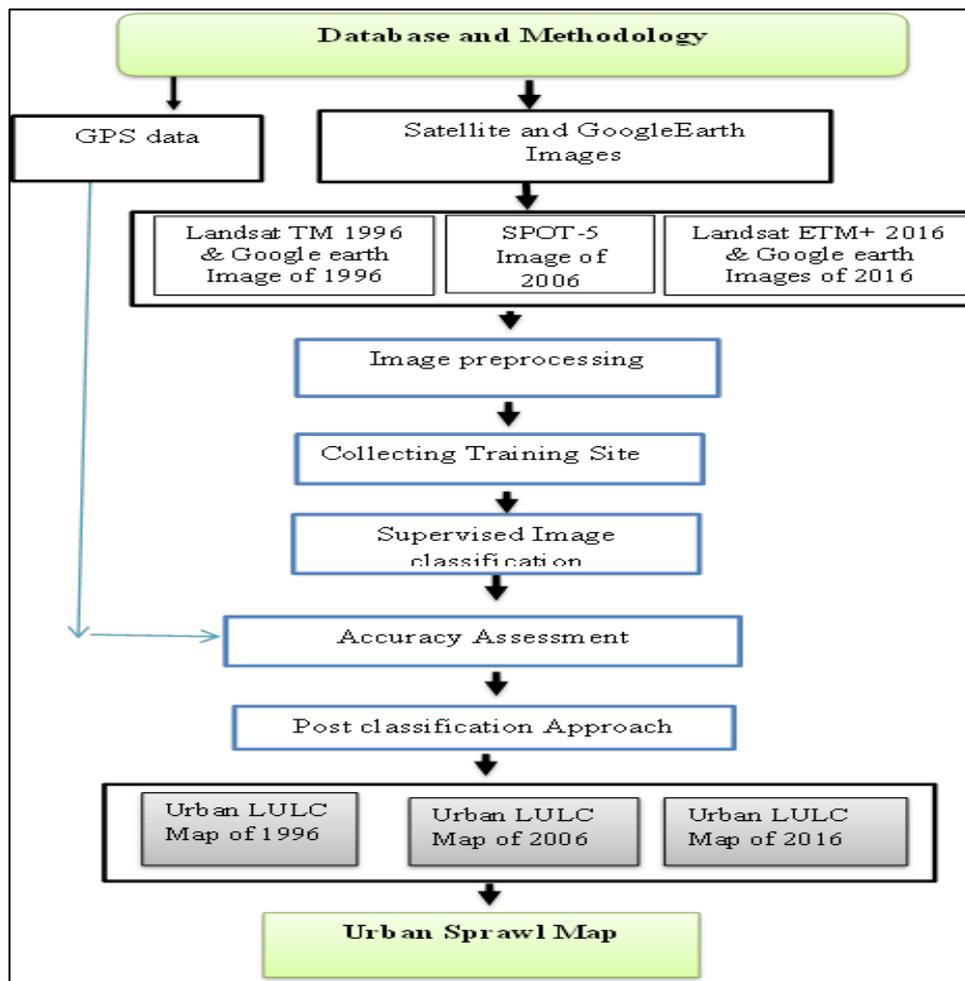


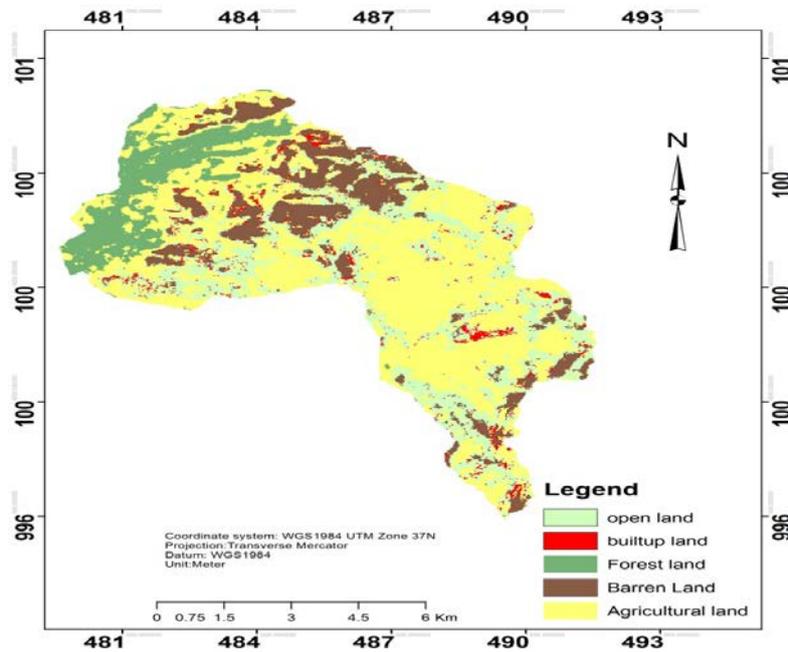
Figure 2: Database and Methodological Flow chart

## 5. Results and Discussions

### 5.1 Land Use/Land Cover Map of Laga Tafo Laga Dadi Town in 1996

Land use/land cover analysis of the study area in 1996 shows that there were five major land use classes namely open, built up, agricultural, forest and bare land. In this study period agricultural land use class was the dominant whereas the share of bare land was the lease in coverage. Following the agricultural land use, open

spaces, forest and built up area, respectively account for significant proportion of land use/land cover of the town (Fig.3 and Table 1). This implies that during the 1996 with only scattered and few clustered settlements found in study area more than half of the land was agricultural activities which is typical of the rural land use.



**Figure 3:** Land use/land cover map of study area (1996)

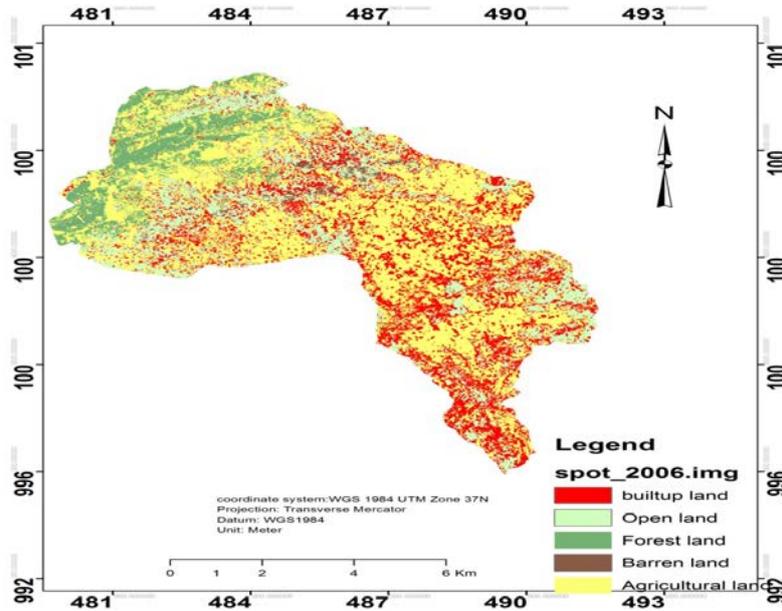
Table 1 below presents LULC classes analysis result, in hectares, for each land use considered in the study. Accordingly, agricultural land constitutes 55.74% of the entire study area. On the other hand, bare land accounts only for 8.51% being the least of all other land use classes. Open spaces, forest and built up land account for 12.71%, 12.09% and 10.93%, respectively.

**Table 1:** LULC percentage of LagaTafo LagaDadhi town in 1996

LC/LC type	Area in Hectares	Percent (%)
Open land	946.8	12.71
Built up land	813.87	10.93
Agricultural land	4149.9	55.74
Forest land	900.36	12.09
Bare land	633.60	8.51
<b>Total</b>	<b>7444.53</b>	<b>100</b>

**5.2 Land Use/Land Cover Map of Laga Tafo Laga Dadi Town in 2006**

Figure 4 below reveals that during the year 2006 area under agricultural land was still the leading compared to other land use classes but it was gradually decreasing. Open and forest land also decreased in their areal coverage. Conversely, built up and bare land increased indicating that the number of settlements and urban growth was gradually increasing at the cost of other land uses. Since the period was on the eve of the administrative restructuring of the special zone of Oromia surrounding Addis Ababa, Legetafo legedadhi town became one of the targets for new housing and industrial development centers.



**Figure 4:** Land use/land cover map of study area (2006)

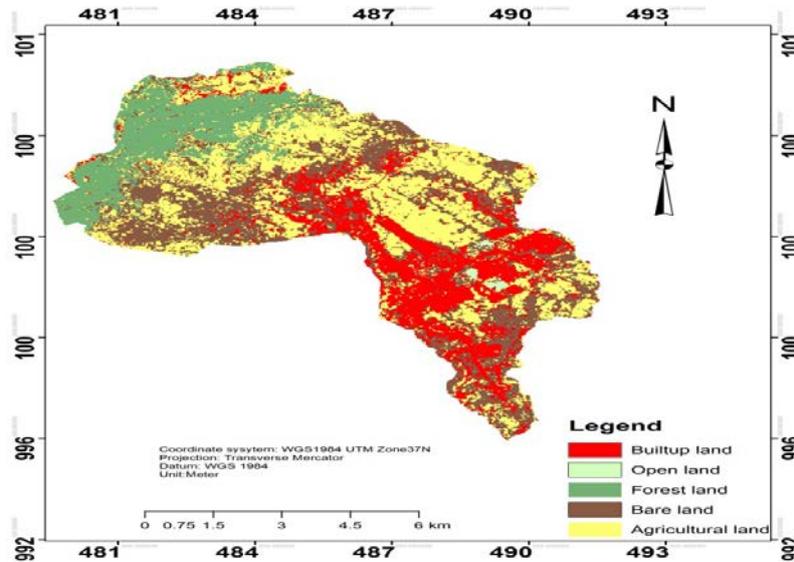
Data computed from land use/land cover analysis of the images and presented in Table 2 below shows that agriculture land significantly decreased to 43.84% but built up land increased to 23.93% in 2006. Open and bare land show decreasing and increasing trend of 10.73% and 10.01%, respectively. Forest land is approximately same with the size in the 1996.

**Table 2:** Percentages of Land use/Land cover in Laga Tafo Laga Dadhi Town in 2006

LU/LC type	Area in Hectares	Percent (%)
Open land	799.02	10.73
Built up land	1781.64	23.93
Agricultural land	3264.21	43.84
Forest land	853.83	11.46
Bare land	745.83	10.01
<b>Total</b>	<b>7444.53</b>	<b>100</b>

### 5.3 Land Use/Land Cover Map of Laga Tafo Laga Dadi Town in 2016

Analysis of land uses/ land cover data of the town in 2016 reveals that the occurrence of significant change in some of the land use/land cover classes particularly agricultural and built-up area. Most of agricultural and open land is being replaced by urban built up area due to an increase in number of population and human settlement through natural growth and migration especially from Addis Ababa city, other towns and rural village. Besides, built up area of the town was highly concentrated in LagaTafo 01 kebele as it is located near to capital city border.



**Figure 5:** Land use/land cover Map of study area (2016)

Data in Table 3 below illustrates that built up area progressively increased through the study period and it constitutes 59.23% whereas agricultural land decreased to 12.79%. There was no significant change in the forest land (11.11%) between 2006 and 2016. The share of open and bare lands was unfortunately same (8.42% each) by the year 2016.

**Table 3:** Percentages of Land use/Land cover of study area in 2016

LU/LC type	Area in Hectares	Percent (%)
Open land	627.03	8.42
Built up land	4409.82	59.23
Agricultural land	952.65	12.79
Forest land	827.73	11.11
Bare land	627.30	8.42
<b>Total</b>	<b>7444.53</b>	<b>100</b>

**5.4 Land use /Land Cover Change Analysis and its Implications**

Change detection, one of the post-classification approaches for monitoring the LU/LC change gives coherent information between the first and last LU/LC types in a complete matrix of change direction ([5]; [7], [17]). Classification of images of the study area over the study periods was essential in the detection of changes of different LU/LC categories. Thus, the LU/LC distribution of the study area for each study year (1996, 2006 and 2016) was shown in Table 4 below. The overall classification accuracies for the land use/land cover maps of 1996, 2006 and 2016 were 81.57%, 86.33%, and 87.43%, respectively.

**Table 4:** Areal extent of LU/LC categories of LTLD town in 1996, 2006 and 2016

LU/LC category	1996		2006		2016	
	Area(ha)	%	Area(ha)	%	Area(ha)	%
<b>Open land</b>	946.8	12.71	799.02	10.73	627.03	8.42
<b>Built up</b>	813.87	10.93	1781.64	23.93	4409.82	59.23
<b>Agricultural land</b>	4149.9	55.74	3264.21	43.84	952.65	12.79
<b>Forest land</b>	900.36	12.09	853.83	11.46	827.73	11.11
<b>Bare land</b>	633.60	8.51	745.83	10.01	627.30	8.42
<b>Total area</b>	7444.53	100.0	7444.53	100.0	7444.53	100.0

As shown in Table 4 above agricultural land constituted the largest LULC category through 1996 and 2006. On the other hand, the bare land accounted for the least cover in all years. It is also evident that agriculture LULC class showed a regular pattern of decrease over the study periods. It decreased from 55.74% in 1996 to 43.84% in 2006, and further declined from 43.84% in 2006 to 12.79% in 2016. The land use/land cover change of open land, forest and bare land was not comparable to agricultural and built up area i.e., the changes were not as such exaggerated. In all the study periods the built up LULC showed regular pattern of increase from 10.93% in 1996 to 23.93% in 2006 and from 23.93 in 2006 to 59.23% in 2016.

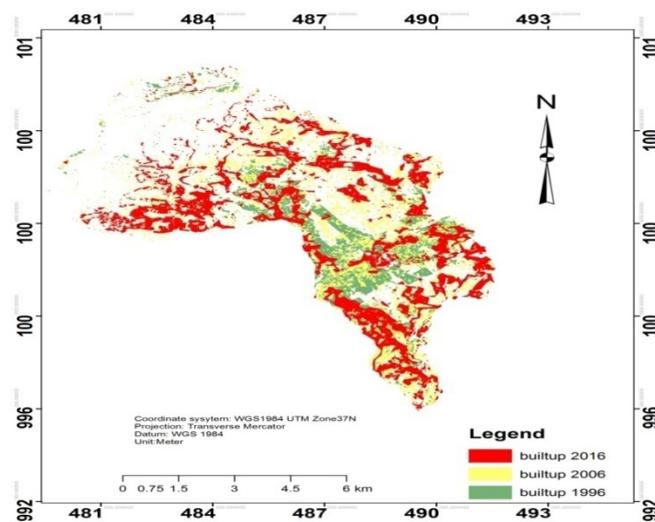
As indicated in Table 5 above agriculture and open land use categories experienced considerable loss in all the study period through 1996 to 2016. There was the highest rate of expansion in the built up area from 813.87 ha.(10.93%) in 1996 to 1781.64 ha.(23.93%) in 2006 and 48.3 % of gain from 1996 to 2016. Forest land shows a little change of decrease but as compared to other LULC it is relatively same within the study year from 900.36 ha.(12.09%) to 853.83 ha.(11.46%). Bare land and open land have lost their previous extent of land use/cover.

**Table 5:** Net Gain and Loss of LULC class of LTLD town in different periods

LULC category	1996-2006		2006-2016		1996-2016	
	Change (ha.)	Changes in percent	Change (ha.)	Changes in per cent	Change (ha.)	Changes in per cent
Bare land	+112.23	+1.5	-118.53	-1.59	-6.3	-0.09
Open land	-147.78	-1.98	-171.99	-2.31	-319.77	-4.29
Built up land	+967.77	+13	+2628.18	+35.3	+3595.95	+48.3
Agricultural	-885.69	-11.9	-2311.56	-31.05	-3197.25	-42.95
Forest land	-46.53	-0.63	-26.1	-0.35	-72.63	-0.98

**5.5 The Extent and Pattern of Urban Sprawl of LagaTafu LagaDadi Town**

The three periods land use/cover classes of the study area were overlaid to compare the extent of expansion in the built-up area from 1996-2016. The built-up area has been expanding in all directions during the study period consuming land from the other land uses in and around the town. As is common in other cities and towns of most of the developing countries, the nature of sprawl in the study area is characterized by an irregular and scattered pattern on one hand and urban development which follows a major outlet road from Addis Ababa that crosses the town.



**Figure 6:** Expansion of built up area of LagaTafu LagaDadi town Town (1996-2016)

The built-up area in the year 1996 was only 813.87 ha of the total land. This was grown to 1781.64 ha in 2006. It was increased by 13.0%. Big increment was recorded in 2016 with a total land cover of 4409.82 ha which means grown by 48.3% from 1996 and 35.3% from 2006. Besides the time interval between the study periods high rate of expansion of the built-up land was recorded in between 2006 and 2016 which was 10 years difference and 35.3% increment.

## **6. Conclusions and Recommendations**

The study is concerned with analyzing the spatio-temporal land use/cover change, extent and pattern of urban sprawl of Lagatafo Laga Dadi town between 1996 and 2016. The analysis was carried out based on satellite imageries of two decades (three periods). The result of the analysis reveals that built up area has been progressively increasing from the beginning to the end of the study period with a net gain of 48.3% against the other land uses/land covers. The impact of sprawl on agricultural land is higher than other land uses; it decreased by 42.95% through study period. Besides, open and forest lands have also decreased by 4.29 % and 0.98 %, respectively from 1996 to 2016. The increase in the built-up land has been resulted from intensified land use transformation due to urban land use encroachment to rural lands particularly new residential development in the town and increasing interest in real estate and industrial development. The developments in built up area is scattered and uncoordinated and thus it intensifies uneconomical use of land and created sprawling impact.

It was concluded that the built up 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 agricultural land which negatively affected the pattern of land use. Because of its geographical location and sharing a boundary with one the sprawling East African city, Addis Ababa, Laga Tafo Laga Dadhi town is expected to be highly affected by competing interests from both formal and informal developments. The landscape around the town encourages further sprawling development on one hand and the area is equally suitable for agriculture on the other.

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 Laga Tafo Laga Dadi town.

## **7. Limitations of the Study**

Though this paper gives insights to spatio-temporal analysis of land use/land cover change and detection of urban sprawl patterns, it is not without limitations. Geographically, the study is conducted on an emerging town created due to the impact of a sprawling city which shares a boundary with it. So, the spillover effect of the city of Addis Ababa in the vicinity should have been studied together. Quantifying urban sprawl requires high-resolution satellite imageries such as IKONOS. However, in this study Landsat imageries with low to moderate resolutions were used. Methodologically, the study indicates that further quantitative indices are required to

explicitly detect urban sprawl patterns of LTLD town. The study of impact of urban sprawl on the socio-economic development of households in the study area, particularly the impacts on the agricultural community, was not included in this study.

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### **8. Conflict of Interest**

The authors declare that there is no conflict of interest regarding this paper.

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