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Spatio-temporal analysis of Urban Expansion and impacts on land use LAND COVER Dynamics: the case of Gelan Town Administration

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Abstract

Gelan town has experienced extensive conversion of non-impervious land categories, especially the agricultural area, into built-up land due to the suitability of the area to attract investors and workers. This study's purpose is to investigate the dynamics of built-up that were seen in the Gelan town administration between 2003 and 2023, as well as the effects on the other non-impervious LULC categories. Three images, one from Landsat 5 Thematic Mapper and two from Landsat 8 Operational Land Imager, were used to extract the built-up and general land cover maps. Results indicated that the study area has undergone a tremendous change in built-up expansion and pattern during the study period. Built-up area expanded from 369.8 ha (4.46%) in 2003 to 2269.12 ha in 2023, while agricultural areas decreased from 5,367.28 to 4,486.44 ha during the same period. In the last two decades, the direction of the built-up expansion has been mainly in the directions E, ESE, SE, and SSE. The analysis result shows that a large amount of agricultural land has decreased and been mostly converted to build-up throughout the study period. While, built up area increased by sextuple mainly at the expense of other land uses. Within the last two decades, Gelan town experienced a rapid built-up expansion intensity rate with an approximate UEII value of 1.145. Due to the geographic proximity of the town, where most investors seek sites for constructing factories and housing, and workers are also attracted to this area, which has caused to expand of the town. So as to alleviate the rapid built-up expansion of the town, it is better to introduce the use of remote sensing for developers in order to reduce unplanned urban sprawls and the associated loss of non-impervious land categories, especially agricultural lands.

Keywords: Built up; Change detection; Remote sensing; GIS; Gelan

Introduction

Urban expansion is defined as rapid expansion of the geographic extent of cities and towns, often characterized as the physical pattern of low-density growth of urban areas, mainly into other non-built-up land use land cover areas (Zhang, and Su, 2016).

Land use land cover change is the best way to measure and monitor available pressures on terrestrial ecosystems and biodiversity (Organization for Economic Co-operation and Development (OECD), 2018).

Growing human populations exert increased pressure on terrestrial ecosystems as demands increase for such resources as food, fuel, fiber, and wat (Ojima, and Turner, 1994).

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Rapid urban population growth is leading to massive unplanned spatial expansion on the peripheries of cities (Lamson-Hall and Martin,2022) and (Hiluf & Alemayehu, 2022). In Ethiopia, urban areas have been highly expanded for the last two or more decades (Terfa et al., 2019). The rapid urban expansion poses enormous effects on ecosystem services. With such expansion rate, Ethiopia is a challenging policy problem with few demonstrated solutions. Undoubtedly, gigantic transitions in LULC patterns have a significant impact on urban natural and anthropogenic ecosystem (Mengistie et al., 2013).

Addis Ababa urbanizing very fast due to population increase, changes in economic policy measures, and introduction of urban development policy. The city's urban landscape has been rapidly transformed due to these policy formulation and subsequent implementation over the past decades. Illustratively, the city exhibited two types of urban landscape transformation i.e., out-ward expansion and inner-city redevelopment program. The former contributed to rapid horizontal expansion while the later resulted in revitalization of inner neighborhoods, which caused relocation of residents to the public buildings called condominium houses in the peripheral sites. The city urban expansion was flushed out urban green space available in the city (Zewdie et al., 2018).

Previously, few studies have been done in relation to Gelan town expansion and socio-economic impact, planning, management and governance. For instance, Fraol et al. (2021) conducted a study on the Urban public land management from governance dimension in Gelan town, was focused mainly the urban land management public intervention and good governance. Others like Dadi et al. (2017) the environmental impact of industries, (Diriba, 2025) impact of industrialization in agricultural sector, and (Woldemichael,1973) urban plan implementation challenges. According to Henok (Mengistu, 2014), industrialization, highway road construction, hotels, residential development and other formal and informal businesses undertaking in the town at a great pace, and affects the livelihood of the community by taking their farmland.

The study area has experienced extensive conversion of agriculture land to various developmental purposes, but data and documentation detailing this transformation of the Gelan town are limited. To the best of my knowledge, long-term built-up expansion and the conversion dynamic of other natural land features of the study area has been paid less attention and or the extent and spatial characteristics of the land scape of the town was poorly documented, although they have great implication to manage and implement proper decisions towards creating ecologically sustainable town. Breakthroughs in remote sensing data improved spatial accuracy and the availability of free to low-cost satellite images in conjunction with a GIS, allowing quantitative analyses of the rate and spatio temporal pattern of urban growth and LULC change at a reasonable cost and with greater accuracy (Herold et al., 2003).

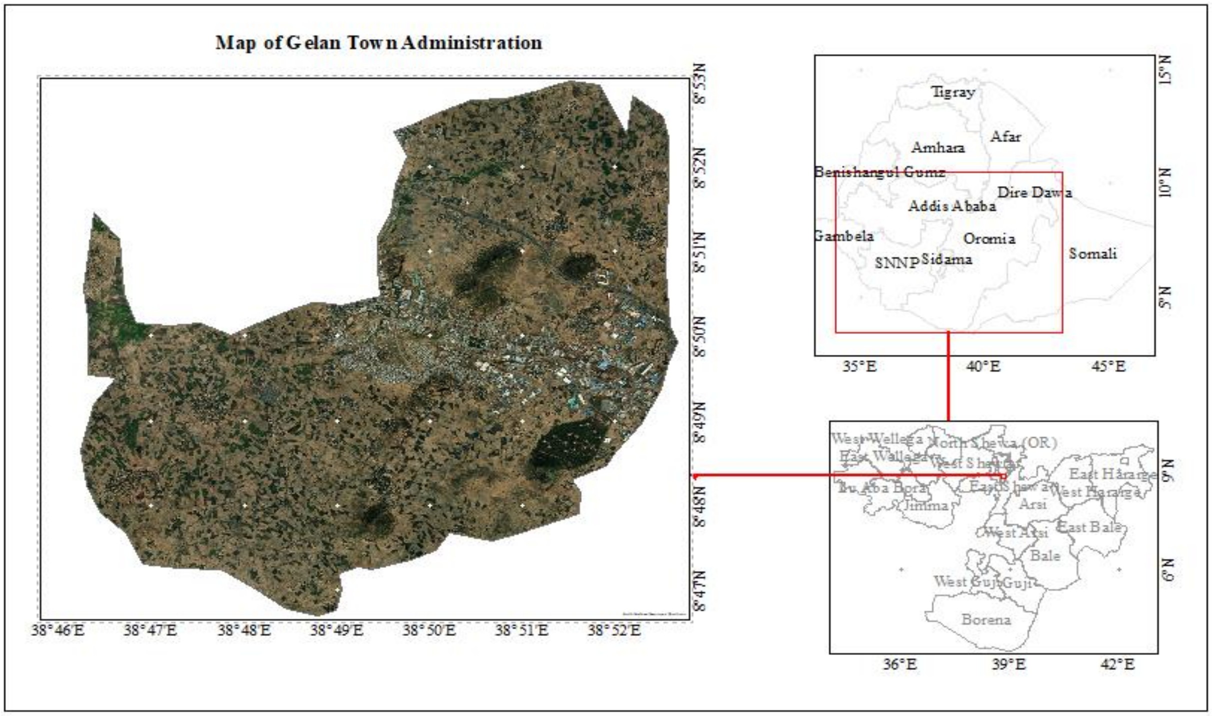
Therefore, this paper aimed to investigate long-term spatiotemporal trends of built-up expansion and the dynamics of other non-built-up land features of the case of Gelan town administration, based on the GIS and Remote Sensing perspectives. The result of this study would be a guide for urban planners, decision-makers and citizens who want to create a healthy, affordable and sustainable urban future.

Research Methods

Description of the Study Area

Gelan was formed as a town at the end of 2008 (Henok M., 2014). The town was located in Central Ethiopia, Oromia Regional State, 25 km south of Addis Ababa the capital of Ethiopia and lie directly along the highway between Addis Ababa and Djibouti. Currently, Gelan was among the five towns that were formed a new administrative city known as Sheger City Administration (SCA). Geographically, the town lie between 8^{o} 53'N – 8^{o}445'N latitudes and 38^{o} 46" E – 38^{o} 56'E longitudes (Figure 3).

Figure 1: Location and map of Gelan town administration



Source: Extracted from Google Earth (2023), Debela, et. al. (2020), and Open Street Map (2023).

Data Sources and Method of Data Collection and Analysis

The researcher was collected data from both primary and secondary sources using different data collection instruments.

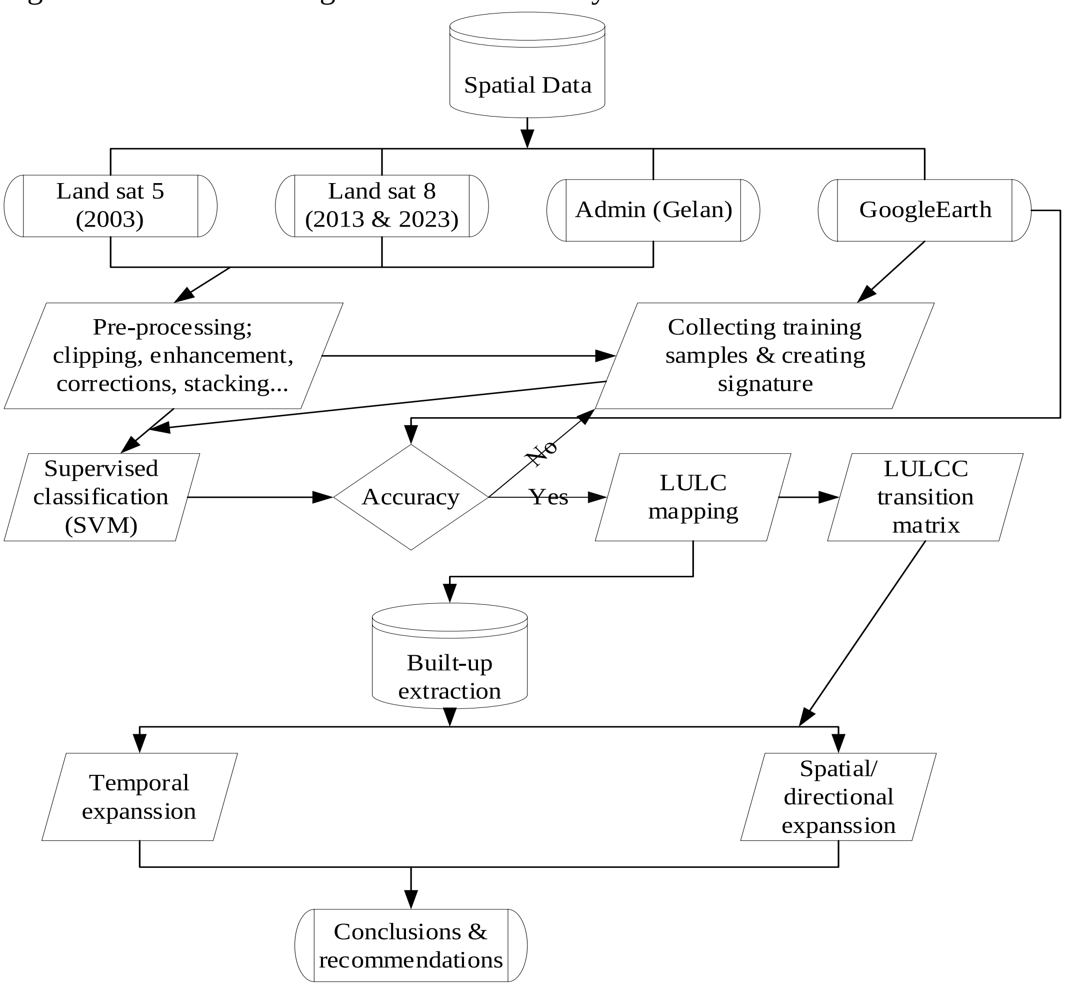
Primary Data Sources: remote sensing data, Global Positioning System measurement, and surveying are among the primary data spatial analysis. Thus, this study used raster data downloaded from USGS Earth Explorer, where free satellite image was found and delivered within the accurate spatiotemporal resolution. And field observation was taken for verification by the researcher. Google Earth map have been used as a base map for visual interpretation and classification of corresponding data and will also use to extract coordinates for sample points,

Secondary Data Sources: The major sources of secondary data for this research were include statistical data (population, and metrological data), previous researches made by a research institution, and reports. Observed daily and monthly historical data for rainfall and temperature were collected from the National Meteorological Station. The population data was collected from the Town Administration and Central Statistical Agency.

In this study, the satellite image analysis was performed using two approaches: the first approach involves the use of supervised image classification techniques and the extraction of NDVI values to obtain, urban sprawl and other land use land cover condition. Using digital satellite images are used to examine the emerging urbanization of cities. A supervised classification algorithm is used to classify land use and land cover of the study area from the satellite images.

The second method converts and inputs the raster files into the GIS environment for easy calculation and the numerical results are manipulated through attribute table functions in ArcGIS software. The following schematic flow chart depicts the overall procedures of the study (Figure 2).

Figure 2: The methodological flow of the study.



Source: Author, 2023.

Data Analysis

To process satellite imageries and analyze urban expansion and land-use land-cover changes, normalized difference vegetation index, using software packages like ENVI 5.3, ERDAS IMAGINE 2015, Arc Map 10.7 and MICROSOFT EXCEL 2016.

Image Classification

Data Pre-processing

In the context of digital analysis of remotely sensed data, preprocessing is generally characterized by two types of data correction: First, radiometric pre-processing, which addresses variations in pixel intensities (digital numbers, DN), and the second is a geometric correction, which addresses errors in the relative positions of pixels, primarily due to sensor viewing geometry and terrain variations (Themistocleous and Hadjimitsis, 2008).

Radiometric correction

Top atmospheric correction of all Landsat bands is required to avoid path radiance and band noise (Gebru, 2022). Without the need for additional data, it calculates atmospheric correction parameters directly from scene data (observed pixel spectra) (Bernstein et al., 2005). In addition, the metadata file includes the thermal constants required to convert thermal band data to TOA brightness temperature (USGS, 2016). As a result, image pixels are converted from DN to absolute radiance units.

Geometric correction: This is all about spatial positional accuracy to avoid distortion of an images (USGS, 2016). Separate band images are layered and then stacked to form a multi-band image in Landsat5 TM, and Landsat 8 OLI (TIRS). All of these datasets were projected to WGS 84/UTM zone 37N.

Image Stacking and Sub-setting

The downloaded, and pre-processed all year period of Landsat images was stacked and the subset based on the area boundary of Gelan Town Administration.

Supervised classification

For this study, Maximum Likelihood Classification (MLC) method was used to classify land use landcover. According to (Ahmad, and Quegan, 2012), Maximum Likelihood Classification (MLC) is a supervised classification method derived from the Bayes theorem, having the general procedures as follows:

a. The number of land cover types within the study area is determined.

b. The training pixels for each of the desired classes are chosen using land cover information for the study area.

Accuracy Assessment: In this study visual interpretation of Google Earth will be used as ground truth data used as a reference to check the accuracy of the classified image. The kappa coefficient, user accuracy (accounting for errors of commission), and producer accuracy (accounting for errors of omission) will be computed for each year by using a confusion matrix (Lillesand et al, 2015). According to Lillesand et al (2015); Congalton., and Green, (2019), the formula for accuracy assessment:

$$\text{Overall accuracy} = \frac{\text{Total number of correctly classified pixels}}{\text{Total number of reference pixels}} * 100 \ldots\ldots\ldots\ldots\ldots Eq.(1)$$

$$\text{User Accuracy} = \frac{\text{Number of correctly classified pixels in each classes}}{\text{Total number of classified pixels in that land classes}} * 100 \ldots\ldots \text{Eq.}(2)$$

$$\text{Producer Accura} = \frac{\text{Number of correctly classified pixels in each classes}}{\text{Total number of classified pixels in that land classes}} * 100 \ldots \text{Eq.}(3)$$

$$\text{Kappa Coefficient(K)} = \frac{\text{N}(\sum_{i=1}^{r} \text{xii}) - (\sum_{i=1}^{r}(xi+.x+i)}{N^2 - \sum_{i=1}^{r}(xi+.x+i)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots Eq.(4)$$

Where;

r= number of rows in the error matrix

Xii= number of observations in row i and column I (on major diagonal)

Xi+=total of observations in row i (shown as marginal total to right of the matrix)

X+i= total of observation in column i (shown as margin total at bottom of the matrix)

N= total number of observations included in the matrix

The Kappa coefficient, developed by Cohen (1960) for classification accuracy, is widely used. According to Cohen, any Kappa value below 0.60 indicates insufficient compliance, and the results of the study in question are highly unreliable. A Kappa value between 0.60-0.79 indicates a reasonable relationship, while a Kappa value between 0.80-0.90 points to a strong relationship. A Kappa value of 0.91 or higher indicates that there is an almost perfect fit and the reliability of the data obtained ranges between 82-100% (Cohen, 1960; McHugh, 2012).

Quantification of LULCC Based on Transition Matrix

To analyze the spatial differentiation and morphological evolution of urban land expansion in the Gelan Town Administration over the last 20 years, the dimension and intensity of urban land expansion in the town was analyzed using the following equations.

Annual Urban Expansion Rate (AUER)

This is the method to understand temporal dynamics of the urban area during the study period and to predict its change. The AUER calculates the mean annual rate of expansion of built-up land for the entire study area between two periods—the base year and the final year. In this study, the years of 2003 and 2023 were taken as base year and final year respectively. The index yields an estimate depicting the quantum rate at which built-up land of a given region is changing. This index is one of the easiest ways of measuring urban sprawl by normalizing the growth rate from the initial urban area (Acheampong, and Agyemang, 2017).

$$AUER = [\left(\frac{ULAt2}{ULAt1}\right)^{\frac{1}{t2}-t1} - 1\,] * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq.(5)$$

Where;

AUER: Annual Urban Expansion Rate

ULAt1: The area of urban built-up land at time t_1

ULAt2: The area of urban built-up land at time t_2

Urban Expansion Intensity Index (UEII)

It is used to describe the intensity or speed of urban expansion in different periods. This index characterizes the degree of differentiation of urban expansion and illustrates the proportion of urban expansion of a spatial unit in relation to the total study area and study duration (Hu, et.al, 2007).

$$UEII = \frac{(ULAt2 - ULAt1)}{(TLA * \Delta t)} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq.(6)$$

Where;

UEII: Urban expansion intensity index
ULAt1: The area of urban built-up land at time t1
ULAt2: The area of urban built-up land at time t2
TLA: Total land area of the study area
Δt: The difference of urban land at base year and ending year

The UEII result depicts the urban expansion intensity of a spatial unit relative to the entire study area. The UEII can be divided into highly rapid, rapid, moderate, slow, and very slow or decreasing intensity with corresponding values of greater than 1.92; 1.92 to 1.05; 1.05 to 0.59; 0.59 to 0.28; 0.28 to 0; and 0 to negative (Bian& Xie, Eds.). (2016)).

The direction of urban expansion

The cardinal and intercardinal directions of the study area were drawn using a bearing distance tool in ArcGIS 10.2. The lines extended from the city built-up starting point with equal intervals of 45° starting from the north (N) in a clockwise direction. Buffer zones were generated for each city with equal distance intervals of 1 km from the built-up starting point centre.

Result and Discussion

Built-up Expansion Analysis

Accuracy Assessment

The land use landcover classification accuracy evaluation for the study area in 2003, 2013, and 2023 was done by establishing confusion matrices and computing the producer's accuracy, user's accuracy, overall accuracy, and Kappa coefficient. The accuracy assessment results in Table (8) show that the overall accuracy obtained from the random sampling process for the 2023 image is 92.21%. For the land classes of agriculture, bare land, built-up, and vegetation, the user's accuracy ranges 100%, 90 %, 95.5 %, and 86.6 %, respectively. Thus, the range of user accuracy is ranges from 86.6% to 100%, which shows the reliability of the classification in the study. Vegetation, on the other hand, was found to be more reliable, having with 1000 % user accuracy.

The commission error reflects the points that are in the category but do not actually belong there (Corves and Place, 1994). For instance, the finding showed that the commission error is highest in case of bare land areas and vegetation areas which meant that relatively a greater number of points (2) for each class which do not fall under their category are classified as bare land and vegetation area.

On the other hand, the omission error represents the number of points that are not included in the category even though they should be (Corves and Place, 1994). From the result agricultural area has more omission errors than the other land features which accounted four (4) points, which actually belong in this category but are categorized as other land feature categories. In this study an overall Kappa coefficient of 91.27% was obtained which is which is recognized excellent classification. Apart from overall classification accuracy, the above individualized parameters give a classifier a more detailed description of model performance of the particular class or category of his field of interest or study. Therefore, based on the findings of evaluation of classification accuracy results in Table (4), it is possible to proceed it the analysis of urban expansion and other landscape changes in the study area using the time series classified land use landcover change data. Clearly, these data have reasonably high accuracy, and thus are sufficient for urban growth detection

Table 1: evaluation of classification accuracy data obtained from references and data determined from classified map through error matrix report for the year of 2023.

LULC classes	**Ag**	**Bl**	**Bu**	**Vg**	**Total (User)**	**User Accuracy**
Ag	20	0	0	0	20	100%
Bl	2	18	0	0	20	90%
Bu	0	1	21	0	22	95.50%
Vg	2	0	0	13	15	86.60%
Total (Producer)	24	19	21	13	77	
Producer Accuracy	83.33	94.74%	100%	100%		91.27%

Source: Computed from Landsat image of 2023

Spatial - temporal Analysis of Built-up Expansion

Temporal Analysis of Built-up Expansion

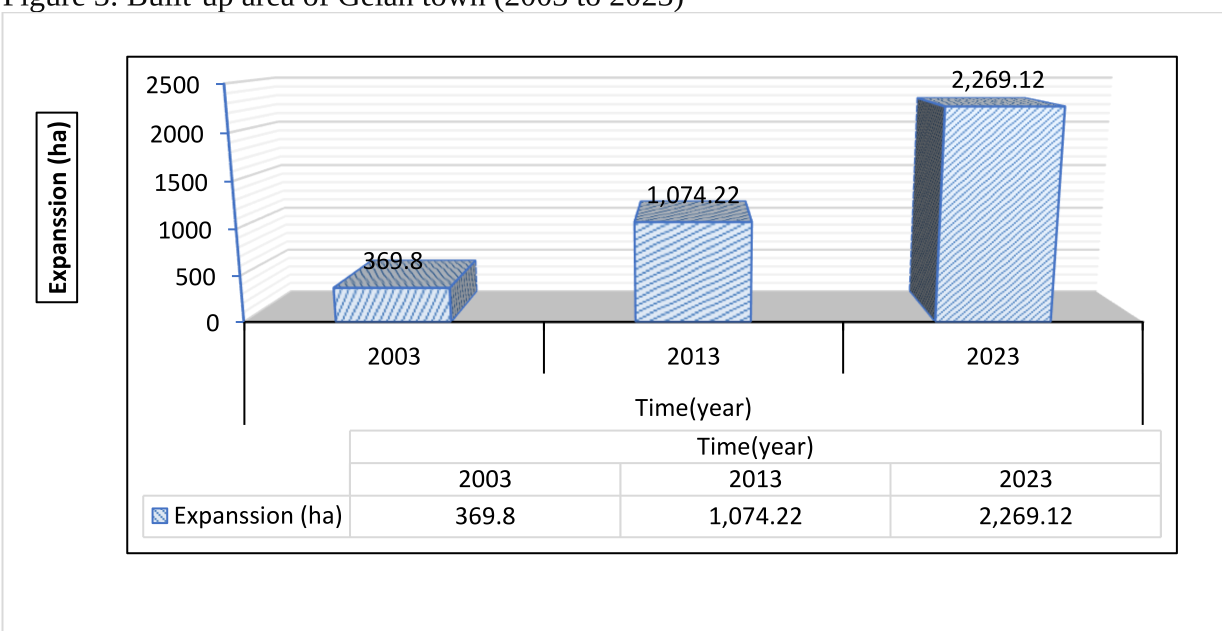
Gelan Town Administration, which was currently formed as one part of the Sheger City Administration in Oromia region, shows a rather interesting trend of built-up expansion.

Over the last two decades, built-up feature class expansion in the study area has been massive and very rapid. Thus, between the years of 2003 and 2023, the town increased the size of its built-up area at a rate of 9.46 %, extracted using the AUER (Eq. (5)). The total built-up land of the town during the study period was more than sextuple from an estimated 369.8 ha in 2003 to 2269.12 ha in 2023 (Figure 10). Thus, whereas in 2003 only 4.46% of the total land area of the town administration was built-up, this increased to 27.35% in 2023 (Figure 10). This implies that the town has been attracting a significant share of new physical development since the beginning of the study and annually about 1.37% land of non-built-up areas were converted in to developed land (built-up) feat.

In absolute terms, the total built-up land in the town administration increased by approximately 1899.32 ha over the last twenty years. Out of this, approximately 1194.9 ha occurred during the last decade (2013 to 2023) as compared with 704.42 ha during the first decade (2003 to 2013). Thus, the quantum of urban expansion that occurred over the last 10-year period was almost two and half times that of the first 10 years period of the study.

On the other hand, over the course of twenty years, the expansion intensity of Gelan town administration was calculated using UEII equation (Eq.6). Based on that, from the year of 2003 to 2013, the study area had a UEII approximate value of 0.89 which is fall in to the category of 1.05 to 0.59. This implies that, during the first one decade the study area experienced a moderate level of built-up expansion intensity. However, in the last ten years (between the year 2013 and 2023), the study area built up expansion intensity had experienced a rapid rate of built-up expansion intensity having a UEII approximate value of 1.44. From the UEII's findings of the study area, with in the last two decades the built-up area of Gelan town administration was classified as having a rapid urban expansion intensity rate with UEII approximate value of 1.145.

Figure 3: Built-up area of Gelan town (2003 to 2023)



Source: Computed from Landsat images 2003, 2013, and 2023

Over the last two decades, the town experienced two types of urban growths. In the first 10 years linear expansion type of growth, whereas in the last 10 years the town experienced intensifying infill types of urban expansion (Figure 11). Despite there are developments here and there around the peripherals of the town, the result indicates that the density of built-up expansion decreases as the distance increases away from a major road (Figure 11). Most built-up expansion can be observed to the both direction following the roads crossing the town to stretching east to west. This rapid urban expansion pattern is vividly illustrated along the high- way from Addis Ababa to Hawassa highway and to some extent along to the newly constructed Addis-Adama express highway as seen in Figure 3, where most investors seek sites for constructing factories and housing.

The result is in line with Addis Ababa situation, where extensive process along the urban edge was the major form of urban development from 1991 to 2023 (Gebru, 2022). Therefore, decision makers should advocate urban land densification to reverse the trend of built-up expansion and minimize urban ecosystem degradation (Han et al., 2017).

The accelerated investment development and the town was namely called industry hub; had contributed significantly to the expansion of built-up area in Gelan (Figure 11). For instance, the establishment of various industries which is owned by chines investors opened a gate to the expansion of investments at a greater pace in the town. Despite there are high rate of urbanization in terms of built-up expansion, the southern and eastern tip of the town was still less rapid development. Unlike the others, these areas were covered by agriculture at large and vegetation to a small amount.

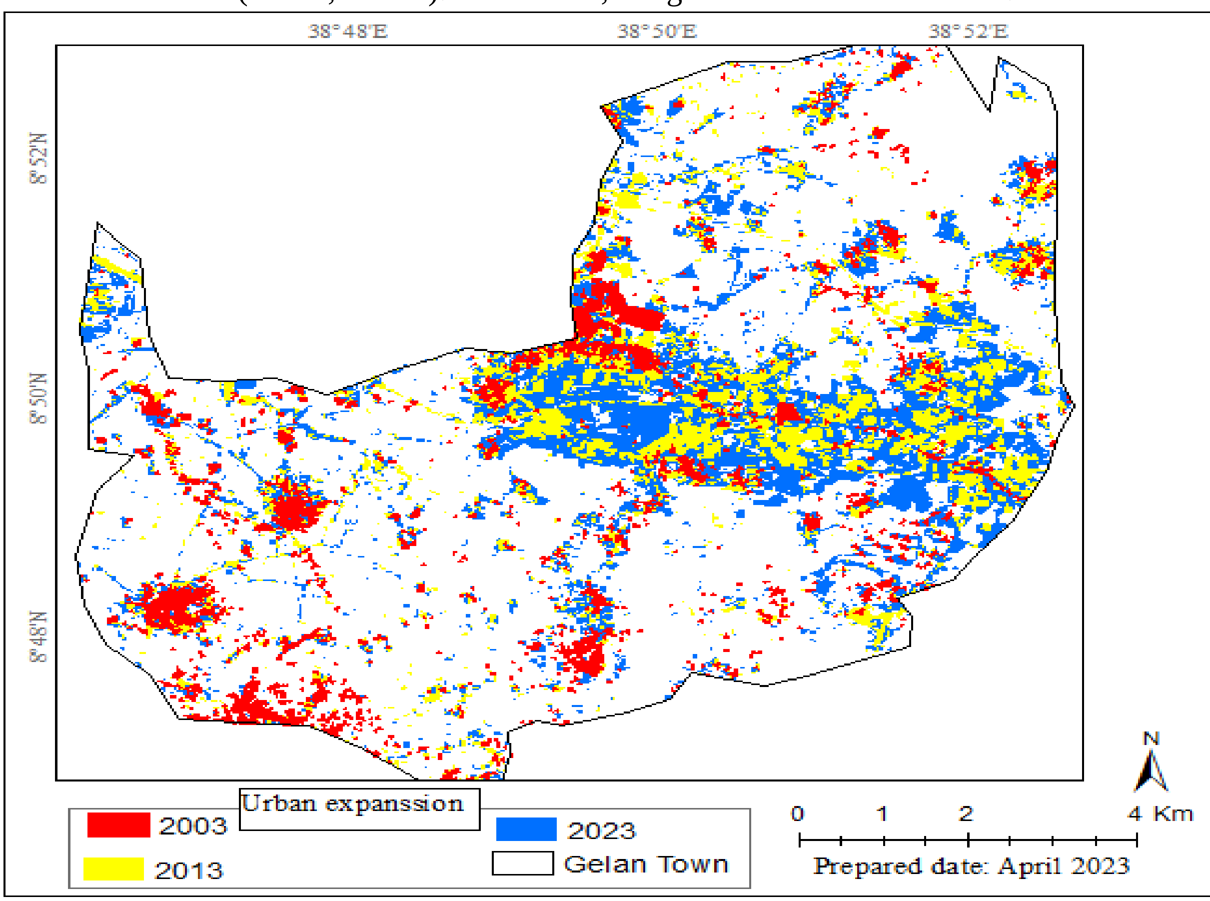


Figure 4: Built-up expansion map of Gelan town (2003 to 2023) Source: Extracted from Landsat images 2003, 2013, and 2023

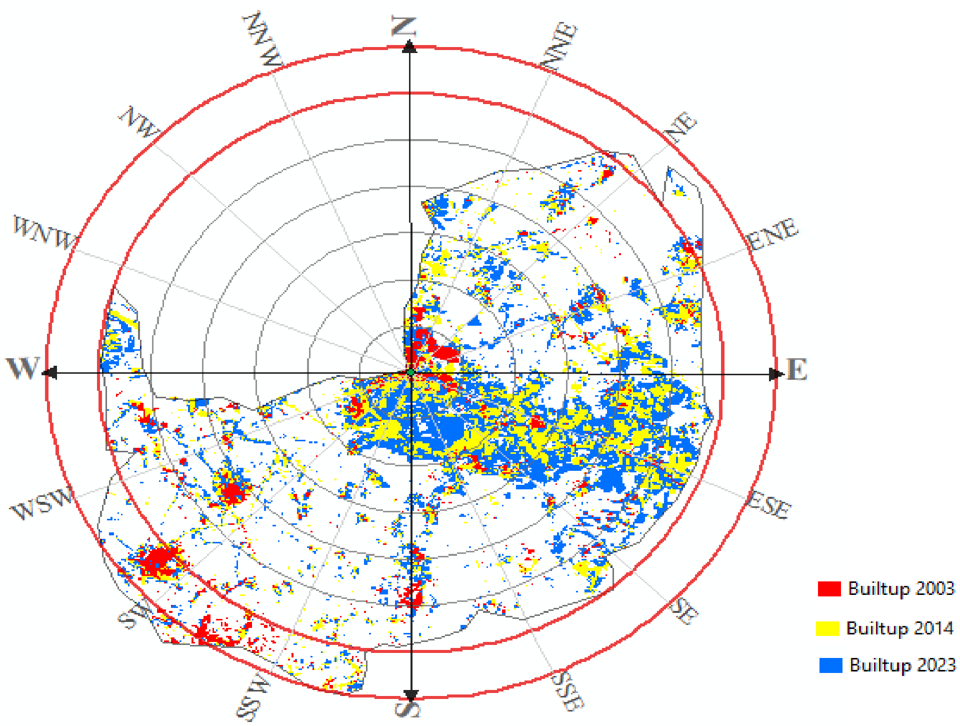
Spatial Analysis of Built-Up Expansion

Figures 12 show the spatial or direction of built-up expansion in 2003, 2013, and 2023 in the study area. The built-up development at the initial time period of the study (2003) was taken as the center. This can to easily observe and identify the expansion direction of the built-up area. During these last two decades the direction of the built-up expansion in the town concentrated mainly to four directions E, ESE, SE and SSE.

In 2003, the built-up area was mainly concentrated by extended from the center up to 1km to the directions of N, NNE, NE, and ENE, and sparsely located at SW and WSW of the town. After a decade i.e., the built-up area expansion in 2013 was extended towards all directions. However, the expansion towards ESE and SE directions is more than in other directions in 2013 (Figure 12). For the town the built-up development after 2013 was continued to these directions intensively, while mainly concentrated at this time, it appears that the formerly dispersed advancements are deeply and abundantly crowded. In the past decade, the built-up development was sparsely edged along the road, but in the last decade (2013 to 2023) the expansion was encroaching on the surrounding area much wider than previous. Thus, in 2023, the expansion of the city is mainly to the expanding to the E and S directions. While in 2023 the built-up area expansion towards SSW, SW, WSW, and W directions at approximately up to 2km from the starting area is due to launch of various residential buildings programs.

The well-developed road and rail network connected from Addis Ababa to Adama, Hawassa and Djibouti; commercial activities, institutions as well as the increasing industrial activities in the Gelan town hasten the spread of built-up area in E, ESE, SE, and S directions.

Figure 5: Radar chart shows the built-up expansion of Gelan town from 2003 to 2023

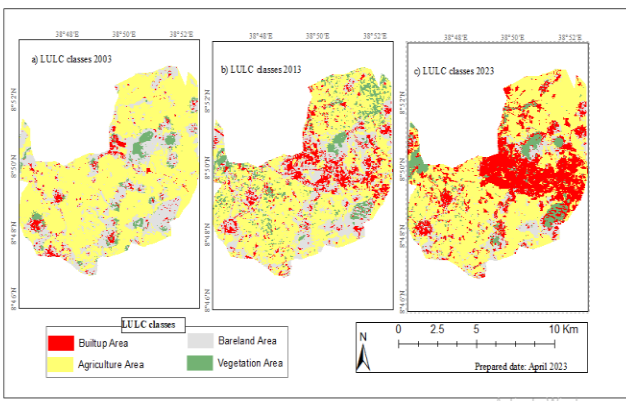


Source: Extracted and computed from Landsat images 2003, 2013, and 2023

Land Use and Land Cover Change (LULCC)

Understanding and revealing the status of urban land use landcover is important to smart city, nature conservation, sustainable development, and balance cooling and heating effect. In order to evaluate the landscape, change due to high-speed urbanization in the recent years, especially after the establishment of Gelan as a city administration i.e., in 2003, 2013, and 2023, two scenes of TM and OLS/TRS images were used for land use land cover classification as described earlier, and the land use and land cover change was then detected and analyzed. After producing a complete land use land cover product (Figure13), the total coverage of different features classes in the study area was determined. Using this information, features classes such as built up, vegetation, agriculture, and bare land area per capita for all the study years was calculated (Table 5).

Figure 6: Shows the LULC map of Gelan Town for 2003, 2013, and 2023



Source: Extracted from Landsat images 2003, 2013, and 2023

According to the results produced in Figure (13), in comparison landscape change is significant: the built-up area is largely broadened; the agricultural lands have largely decreased; bare land areas have shrinking, and vegetation area shows slightly increments. Through change detection analysis, the land use/land cover conversion matrix between 2003 and 2013; and between 2013 and 2023 was produced (Table 6 and 7). Figure 14, demonstrates the conversion relationship of some major land use land cover types in the study area.

Table 5 shows that, since 2003, tremendous land cover conversion, mainly from agricultural area and bare land area, witnessed built up expansion across the Gelan town administration landscape. The results from the study illustrate extensive built-up expansion between 2003 and 2023, with a 22.89% growth (approximately 1.15% per year). On the other hand, the results indicate that unlike built up; agriculture, bare land, and vegetation classes have faced fluctuating status during the past two decades. Meanwhile, the general tendency has inclined given horizontal development expansion in the study area (Figure 14 and Table 5), which has caused built up expansion conditions, leading to natural surface change in the town.

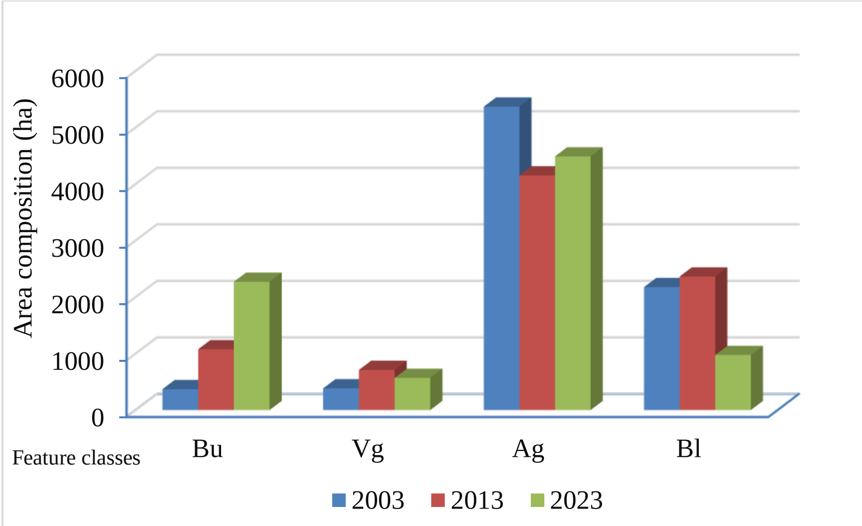
Spatially, in the year of 2003 the built-up area which is denoted by red color in the map (Figure13a) was mostly concentrated at the western (entrance from Addis Ababa) and somehow settlements at the southwestern part of the study area. Tiny amount of vegetation land was found along the mountainous and river side of the town. On the other hand, almost in most parts of the town was covered by agriculture area. After 10 years (in 2013), built up area started to expand eastward of the town along the Addis to Hawassa highway (Figure13b). This is due to its geographic proximity to Main city of Addis Ababa and the abundance of land, developments (factories) have been more attracted (Annex 1); and they also helped by polices and regulations. Such pull factor makes the expansion of built up at the expense of agricultural land and bare land areas in the study area. In the same year remnant of vegetations were found at the top mountains, river sides, religious institutions, and some governmental garrison.

The land invasion or conversion of one feature type to another land feature category was extended and in 2023, built-up was seen in abundance expansion at the expense of agriculture and bare land. After two decades i.e., in 2023, an agricultural land and bare land areas found especially along the geographical proximity of road infrastructures were encroached by the built-up expansion. According to Figure 13c, in the last one decade the town experienced fill type of urban expansion although there was linear expansion nature of built-up development was seen. As Figure 13 showed, the built-up area was expanded and invaded more and more land area as the agriculture and bare land area getting shirked. However, most of the eastern and western part of the town have still dominantly covered by agricultural area. This might be due to the fact that around this location there is no or less infrastructure to attract developments (built-up).

Quantitatively, built-up area was expanded from 369.8 ha in 2003 to 1,074.22 ha in 2023 and finally reached to 2,269.12 ha in 2023 (Table 4). If we see these changes in percentage composition, the result represents 4.46%, 12.95%, and 27.35% respectively for the years of 2003, 2013, and 2023. This implies that, the built-up area has grown by factor 6 over the past two decades. While the agriculture area which is the giant or lion share in terms of areal coverage or size in the study area has decreased from 5,367.28 ha (64.7%) in 2003 to 4,486.44 ha (54.08%) in 2023. The vegetation area has first increased from 383.3 ha (24.62%) in 2003 to 709.58 ha (8.55%) in 2013 and then goes to shrinking to 567.91ha (6.85%) in 2023. The result also revealed that, the bare land area was showed an increase in the base year i.e., from 2,175.08 ha (26.22%) in 2003 to 2,361.99 ha (28.47%) in 2013, while in 2023 this land cover was reduced to 973.15 ha (11.73%) (Table 5). This showed that, the bare land area has faced the same fate like the vegetation land in the study area.

Currently, due to the presence of large area share of farm land area in the town, the attitude towards the conversion of agriculture land which have a significant impact on controlling urban ecology get still less attention. But at the long run, if the expansion of built-up area grows at this rate, it may put the natural resources of the city in danger. Furthermore, the researcher argued that, with the increasing alteration of natural surfaces into built-up land is can alter city life sustainability and local economic growth of the town after a while. In line with this study, Weng, (2001), concluded that, such alteration of non-impervious land features would in urban ecology change such as urban surface temperature increase. Nevertheless, such built-up expansion to nearby non-impervious areas pose serious threats to the regular environment and nearby rural communities because of its strong connection with the loss of agricultural lands and vegetation (Zewdie, et.al, 2018). Relatively, built-up expansion rate towards vegetation land was lower in the study area.

Figure 7: Shows the LULC graph of Gelan town for 2003, 2013, and 2023



Where: Bu=Built-up, Vg=Vegetation, Ag= Agriculture, and Bl= Bare land

Source: Computed from Landsat images 2003, 2013, and 202

Table 2: Areal composition of Gelan Town land use land cover change (ha) from 2003 to 2023 based on classified Landsat data.

Feature classes	2003		2013		2023	
	Area(ha)	Percent	Area(ha)	Percent	Area(ha)	Percent
Built-up	369.8	4.46%	1,074.22	12.95%	2,269.12	27.35%
Vegetation	383.32	4.62%	709.58	8.55%	567.91	6.85%
Agriculture	5,367.28	64.70%	4,150.23	50.03%	4,486.44	54.08%
Bare land	2,175.08	26.22%	2,361.99	28.47%	973.15	11.73%
Total	8295.48	100%	8,296.02	100%	8,296.62	100%

Source: Computed from Landsat images 2003, 2013, and 2023

From the above spatio temporal result on the built-up expansion, the researcher argued that if the expansion of built-up expansion continues at the current rate and growth with/out controlling mechanisms, other non-built-up land features that contribute greatly to the urban ecosystem, such as agriculture and forest cover, may aggressively affected and or deteriorated. This is mainly with the increasing need of more land for development purposes. Similar studies showed that, with the attraction of investment, employment (population), economic diversification, and other social services needed by the urban dwellers, additional land for development was needed; and this was mostly come from the conversion of mostly neighboring agriculture and vegetation lands (Naikoo, et.al, 2020).

Land Use Land Cover (LULC) Transitions Matrix: The land use and land cover conversion transmission of the study area was statistically computed using the matrix error. The computed result illustrates the amount of land in ha that has been converted to or gained from other LULC feature classes. Table 6 and 7; and 8, shows the land use and land cover change matrix of Gelan town for the last two decades. The diagonal values shaded in gray from cross tabulation matrix (Tables 6, 7, and 8) indicated that land-use/land-covers that were unchanged or preserved in the given years.

With the exception of built-up; the conversion of bare land and vegetation area conversion to other classes were greater accounting for about 1826.25 and 726.19 ha respectively for the last 10 years (Table 6). This table also showed that, over the last decade about 1,439.22ha of the non-impervious land features in the study area was invaded by the rapid and fast expansionist nature of built-up development. From this, bare land had contributed the highest land, with over 963.97 ha bare land converted to built-up area. Agriculture and vegetation followed at around 416.49 ha and 58.76, respectively.

It indicated in Table 6 agriculture had experienced not only lose but also gained large amount of land from bare land and vegetation having 533.38 and 407.40 ha respectively. From this table, it is clear that there has been a considerable change in built-up and bare land area mostly to agriculture area. This may due to two reasons. One reason is that, the lands that were previously fenced off for housing are now being used for agriculture. Another thing is that the area where previously used as quarrying carried out was now modified and or changed to agricultural development. Such changes were mostly located at the western part of the study area.

Table 3: The conversion matrix of land use land cover change from 2013 to 2023 (unit: hectare)

Feature classes		**Feature classes 2023**				
		Agriculture	Bare land	Built-up	Vegetation	**Total**
Feature Classes 2013	**Ag**	3,419.85	188.04	416.49	121.66	**4,146.04**
	Bl	533.38	681.27	963.97	181.02	**2,359.63**
	Bu	120.97	85.70	827.74	38.94	**1,073.35**
	Vg	407.40	17.05	58.76	225.45	**708.67**
	Total	**4,481.60**	**972.07**	**2,266.96**	**567.06**	**8,287.69**

Source: Computed from Landsat images 2013 and 2023

Table 7 depicts the amount of land classes converted and or gained from one to another feature and vice versa from 2003 to 2023. Over the entire two decades about 2,030.01ha of land was converted from non-urban areas to built-up area in Gelan. This means that the built-up area expanded noticeably by five times its initial size in 2003 (369.69 ha) to neighbouring other non-impervious land uses. Thus, almost 24.45% of the natural land surface converted in to paved surface or built-up area during the last two decades in the study area. From this the conversion of agriculture area to built-up takes largest share which is more than half 1,102.54 ha (54.31%) of the total converted non-impervious land surface features. Bare land and vegetation followed having 828.79 and 98.68 ha respectively. Here, unlike the first decade vegetation area inclined to 566.81 ha in 2023 from 382.89 ha in 2003. This is due to the planting of permanent crops (e.g., fruits) and the tree plantation program in which currently advocated through the green legacy initiative (ground observation). According Zahoor and Hou, (2022), urban permanent crops can improve environmental sustainability by balancing agriculture with environment while urbanization and manufacturing value-added deteriorate that environmental. However, the general tendency of the change detection result indicates that agricultural land is being edged out slowly by other land uses, especially by built-up land. The implication of these rapid changes of land use is a decline in area under agricultural land. This can affect the local economy based urban life sustainability.

Table 4: The conversion matrix of land use land cover change from 2003 to 2023 (unit: hectare)

Feature classes		**Feature class 2023**				
		Agriculture	Bare land	Built-up,	Vegetation	**Total**
Feature class 2003	**Ag**	3,882.83	230.11	1,102.54	147.18	**5,362.66**
	Bl	498.24	565.98	828.79	279.10	**2,172.11**
	Bu	47.78	65.86	236.47	19.25	**369.36**
	Vg	53.27	109.66	98.68	121.28	**382.89**
	Total	**4,482.11**	**971.62**	**2,266.48**	**566.81**	**8,287.02**

Source: Computed from Landsat images 2003 and 2023

The 2003 and 2023 land use land cover intersection result indicate that of the 2,030.01 ha (85%) increase in built-up land, most results from agriculture area (54.3%) and bare land (40.8%) (Table 8). Agriculture area accounts the highest proportion of land change in the study area (both gain and loss) having 1,479.83 and 599.29 ha of lose and gain respectively. For instance, as described above 54.3% of the total expanded urban land (1102.54ha) was originated from agriculture area during 2003 to 2023. Thus, the conversion of agriculture area and bare land area at a greater extent and other land cover types to build up area has resulted in the transformation of economic activities. Table 8, further indicated that agriculture and built-up classes gained 498.24 and 828.79 ha of land, respectively, from the bare land area. In the same manner, about 109.66 ha of vegetation land was converted to bare land area. This is in line with the study conducted by Kocur-Bera and Pszenny (2020), stated that urban development (the Population growth, economic globalization and the launch of market economy instruments) have become the main triggers other non-impervious surfaces especially agriculture land. Farmland was recognized as the main areas of urban transition at both the national level (Liu et al., 2018) and in smaller spatial units of the country such as the Yangetez River delta (Han et al., 2017).

Table 5: Show the LULC class's coverage change matrix (2003 to 2023)

LULC classes		**LULC classes 2023**									
		Agriculture		Bare land		Built-up		Vegetation		**Total**	
		ha	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
LULC classes 2003	**Ag**	3,882.83	72%	230.11	4%	1102.54	21%	147.18	3%	5362.66	100%
	Bl	498.24	23%	565.98	26%	828.79	38%	279.1	13%	2172.11	100%
	Bu	47.78	13%	65.863	18%	236.47	77%	19.25	5%	369.36	100%
	Vg	53.27	14%	109.66	29%	98.68	26%	121.28	0.34	382.89	100%
	Total	4,482.12	54%	971.62	12%	2266.48	27%	566.81	7%	8287.02	100%

Source: Computed from Landsat images 2003 and 2023

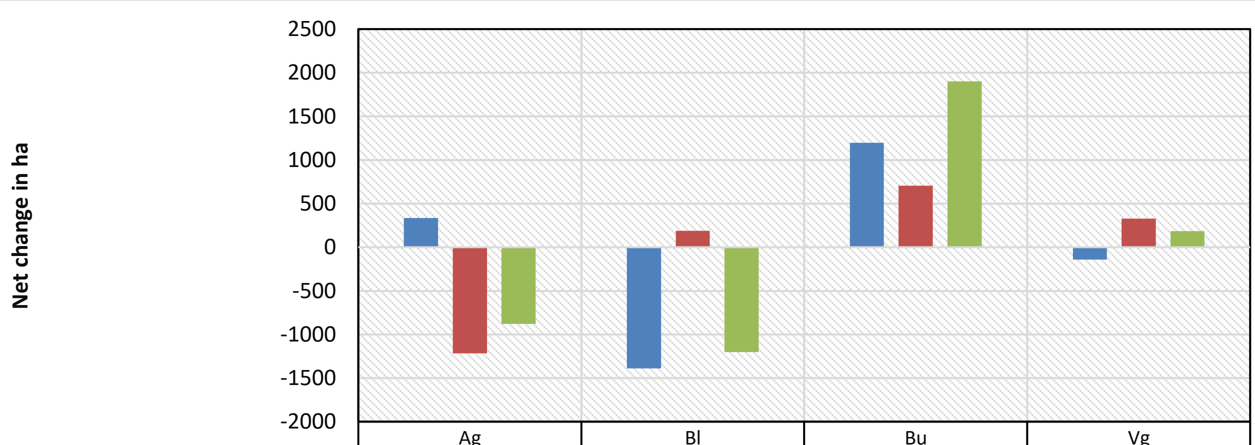
During the last two decades, agriculture land has been lost 28% and gained 13% with a net loss of 15% while the approximate lose and gain value of built-up area at the same given decade was 36% (132.89ha) and 90% (2030.01ha), respectively. This implied that, over the study period built up area gained more land area unlike the other land use land cover classes, having a net gain of 54% (1897.12ha) (Table 8). This also means that, approximately 94.86ha of non-built-up land was converted to built-up development annually for the last two decades. This means that, annually twice as much land as Addis Ababa National Stadium is converted into built-up development in the study area. This was merely due to the rising demand for land for different developmental purposes.

This result is also consistent with several recent research findings (Naim and Kafy 2021), which state that natural land cover is rapidly being replaced by built-up areas. Therefore, it should not be taken as lightly. Urgent and participatory land management and planning decisions are needed. The impact of the rapid process of anthropogenies space was considered by many scholars. For instance, as of Arulbalaji et al. (2020) rapid urbanization and unscientific developments have resulted in widespread environmental degradation. By significantly warming local or global cities, urbanization hastens ecological stress (Fu and Weng, 2016, and Liu et al., 2018).

Gain and Loss of Land-Use and Land-Cover (LULC): Figure 15 shows the net change in the form of gains and losses for each feature class in the study area over the last two decades. The net changes result reveals that, the highest loss was recorded in the bare land area (1201.93 ha) during the during the last two decades from 2003 to 2023, followed by agriculture land (880.84ha), while a significant gain was observed in built up area (1899.32ha) and vegetation area (184.89ha). During the first decade (2003 to 2013), except agriculture which recorded over all loss of 1217.05ha, the rest surface features of the study area showed a net gain of 704.42, 326.26, and 186.91 of built-up area, vegetation land and bare land respectively.

For the last decade (2013 to 2023), a significant shift was occurred especially for the vegetation land. Thus, the vegetation land was recorded a loss of 141.67 ha which is a dramatical change than the first decade. Thus, the town has been experiencing rapid built-up expansion, which has led to an ever-increasing demand for land in peripheral areas for housing and other nonagricultural activities that pervades agricultural land. There is a high demand for informal and illegal peri-urban land which has been held by surrounding farmers, and this plays a vital role in the unauthorized and substandard house construction on agricultural land. On the other hand, the highest lose was also observed in bare land accounted about 1388.84ha. During this time built up area showed a net gain of 1194.9ha of land from other feature classes.

Figure 8: Net change (i.e., gains and minus losses) for each LULC of 2003 to 2023



	Ag	Bl	Bu	Vg
Net change(gain-lose) (2013 - 2023)	336.21	-1388.84	1194.9	-141.67
Net change(gain-lose) (2003 - 2013)	-1217.05	186.91	704.42	326.26
Net change(gain-lose) (2003 - 2023)	-880.84	-1201.93	1899.32	184.59

Source: Computed from Landsat images 2003, 2013, and 2023

The outcome is consistent with research by Ayele and Tarekegn, 2020, which found that urban growth has diminished the quantity of land that can be used for agricultural, negatively affecting peri-urban farmers. Due to the fact that they typically have little to no land to cultivate their crops, these farmers are increasingly more susceptible. According to research done in 2016 by Dejene, urban expansion resulted the loss of farmland and displacement of the households who had been involved in farming,

Conclusion and Recommendations

Conclusion

The major thrust of this thesis has been to examine the spatiotemporal built-up expansion and its impact on non-built-up landcovers in Gelan town administration. Based on the GIS and remote sensing perspectives, it can be concluded that satellite images are important factors to consider when analyzing the built-up expansion. The results indicate that a large amount of agricultural land has been transformed in to build-up land throughout the study period. Thus, built up area increased by sextuple, i.e., from an estimated 369.8 ha in 2003 to 2269.12 ha in 2023. The built-up expansion of the town mainly followed in the directions of E, ESE, SE and SSE. While the southern and eastern tips of the town were covered by agriculture at large.

Results reviled that; built-up land expanded from 369.8 ha in 2003 to 2,269.12 ha in 2023. While the agriculture land has decreased from 5,367.28 ha in 2003 to 4,486.44 ha in 2023. The vegetation area has shrinked from 709.58 ha in 2013 to 567.91ha in 2023. Similarly, the bare land area was showed an increase in the base year i.e., from 2,175.08 ha in 2003 to 2,361.99 ha in 2013, while in 2023 this land cover was reduced to 973.15 ha.

This research has also shown that, the loss and gain result of land use land cover. For instance, built up land increased by 2,030.01 ha (85%), mostly resulted from agriculture area (54.3%) and bare land (40.8%). Agriculture land has been lost 28% (1479.83 ha) and gained 13% (599.29ha), with a net loss of 15% (880.54ha); while the approximate lose and gain value of built-up area at the same given decade was 36% (132.89ha) and 90% (2030.01ha), respectively, having a net gain of 54% (1897.12ha) land. In this agricultural land was recognized as the main areas of urban transition.

Therefore, the GIS and remote sensing based mainly using Landsat image to analyses the built-up expansion and impacts on non-impervious features might have greater potential for the detection of expansion and transformation or conversion of feature categories, but further research on the applications of different high resolution satellite images such as sentinel image for the extraction of built-up expansion is needed due to the limitations of the current study.

Recommendations

Based on the study’s findings, the researcher made the following recommendations;

- Infill development of high-rise buildings to meet the increasing demand of the increasing populations in the town.
- The city's investment bureau and federal authorities, prioritize technology intensive factories than land intensive ones by considering the importance of agriculture for the urban ecology sustainability when making investments permissions.
- Implementing and enforcing integrated urban land management by considering the surrounding agricultural land and other land covers features.
- The administration & other concerned bodies need to encourage, strengthen, support the activity and give recognition to

the impact and role of urban agriculture on household wellbeing in urban planning and development.

- Improvements in the land use planning of town including spatial planning for economic and efficient use of scarce land recourse
- Training at every level in the urban land planning development sector should be considered as a strategic factor to improve the land management knowledge and skills of urban planners and administrations, and therefore to balance the increasing land demand and the loss of agricultural lands.
- The town has to be exhaustively and economically utilized existing land stock available in its land use planning before statutorily acquiring additional land from nearby agricultural lands.

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