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Research Article

Spatiotemporal Analysis of Land Use and Land Cover Change over 25 Years Using Landsat Image in Case of Ura District (Assosa), Ethiopia

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Abstract

Land use/ Land cover (LULC) classification plays a vital role in understanding environmental changes and for supporting sustainable land management in Ura District (Assosa town). This study aims to analyse the spatial distribution and patterns of LULC in study area using remote sensing and GIS techniques. Multispectral satellite imagery's (Landsat 7, Landsat 8 and Landsat 9) was classified using supervised image classification method into major classes including agricultural land, forest, built-up, grassland and bare land. Accuracy assessment was performed using Confusion matrix, resulting overall accuracy (88.00%, 92.00% and 96.00%) and a Kappa Coefficient of (0.8507, 0.8355 and 0.9232) in 2001, 2013 and 2025 respectively. The result indicates that the dominant class forest cover the large portion of the study area 48.934451%, followed by Grassland (25.297372%) and agriculture (13.247733%) in 2001. Built-up, bare land and agricultural areas have increased by 12.970652%, 22.792803% and 2.390367% respectively while forest cover and grassland has decreased by 20.805041% and 17.348774 in past 25 years (2001 – 2025). The study highlights significant land use changes and their environmental implications. These findings provide valuable information for land use planning and sustainable resource management. The integration of advanced approaches such as GIS, Remote sensing and Machin learning technologies are recommended for improving future LULC analysis.

Keywords

LULC, GIS and Remote Sensing, Supervised Image Classification, Accuracy Assessment, Change Detection, Ura District (Assosa Town)

1. Introduction

Background of the Study

Land is a fundamental natural resource that supports human livelihoods and ecosystem functions. Over time, the Earth's surface has undergone significant transformations due to both natural processes and human activities, commonly referred to as Land Use and Land Cover (LULC) change. Land cover represents the physical characteristics of the Earth's surface such as forests, water bodies, and grasslands, while land use describes how humans utilize land for activities like agriculture and settlement. [1, 13, 15]

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LULC dynamics is one of the foremost causes of land degradation, including deforestation and forest degradation, deterioration of soil and water quality, decline in natural resources base, and ultimately the disruption of Earth's ecosystem services [2]. In many parts of the world, Earth's basic attributes and processes like land productivity, diversity of flora and fauna as well as biochemical cycles have been changing as a result of natural and human land use/cover dynamics [3]. Particularly, the contribution of human induced factors in LULC dynamics and impacts at a local scale is significant [4]. For example, haphazard expansion of farm lands at the expenses of natural LULC categories e.g. forest land aggravates the loss of biodiversity [5].

In recent decades, LULC changes have accelerated due to rapid population growth, agricultural expansion and urbanization. These changes have led to serious environmental problems such as deforestation, biodiversity loss and soil degradation. According to the food and agriculture organization, agricultural expansion remains one of the leading causes of global deforestation. [6]

In Ethiopia, LULC dynamics are widespread, driven by human actions, and the consequences of such changes ultimately affects humans [7] biophysical resources including water, soil, vegetation, and The country is at a crossroads and needs to improve its biophysical resources to feed its growing population [8].

In developing countries such as Ethiopia, LULC change is particularly significant because livelihoods depend heavily on natural resources. Increasing demand for farmland and settlement areas has resulted in the conversion of forest and grazing lands into cultivated land, which contributes to environmental degradation and reduced ecosystem services. [9, 10]

Recent advancement in Geographic Information system and Remote sensing (GIS and RS) have made it possible to monitor and analyze LULC changes effectively. Satellite data from programs such as the Landsat program and sentinel-2 provide reliable and cost-effective tools for detecting land cover change over time. [11, 12]

In western Ethiopia, particularly in Ura District (Assosa), LULC change has become increasingly evident due to agricultural expansion, population pressure and infrastructure development. However, there is still limited detailed spatial analysis of these changes using modern GIS and Remote sensing techniques, which creates a need for further study. [14, 16]

2. Method and Material

2.1. Study Area

Assosa is the capital city of Benishangul-Gumuz Region, Ethiopia. Located in the Asosa Zone, this town has a latitude and longitude of 10°04′N 34°31′E, with an elevation of 1,570 meters.

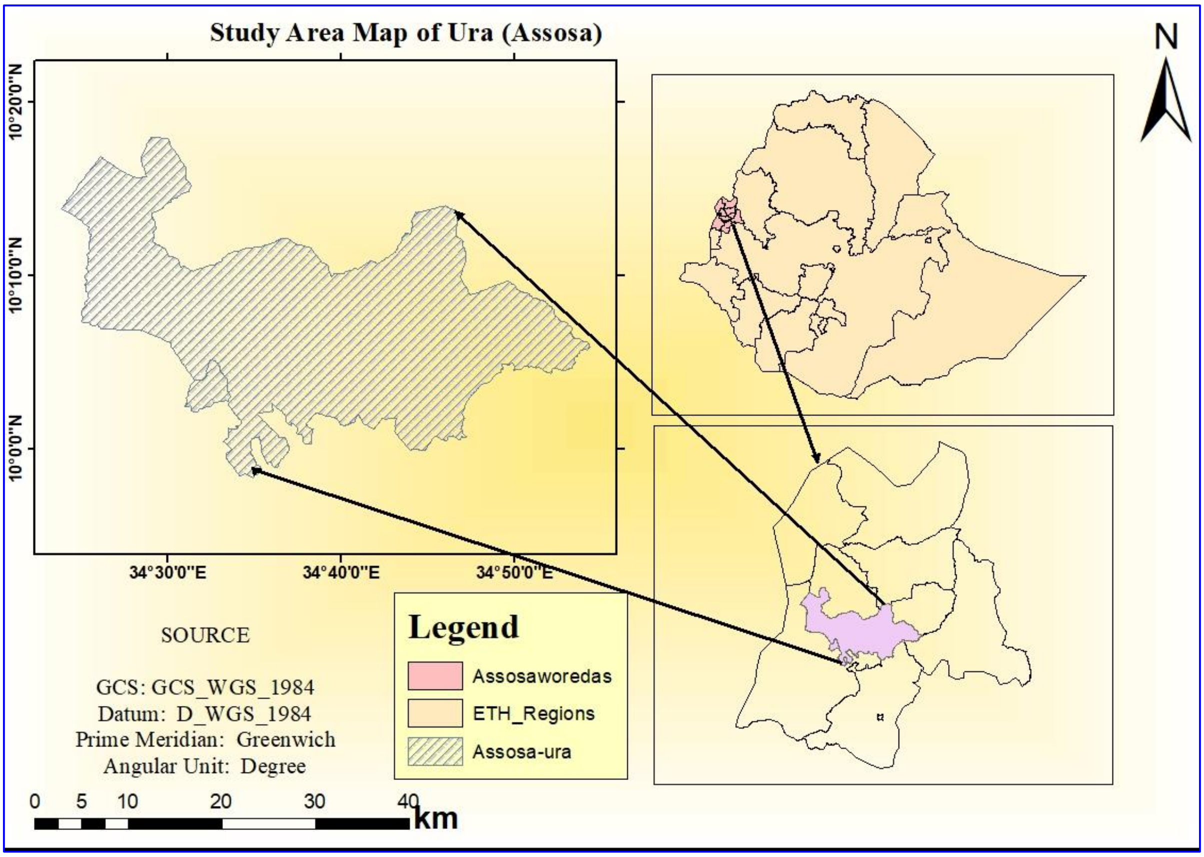

Figure 1. Study area map.

Ura District is a recently established district in the Assosa Zone of Ethiopia's Benishangul-Gumuz Region, created to decentralize administration and hosting a significant Sudanese refugee settlement.

2.2. Data and Method

2.2.1. Data

Techniques for geographical data acquisition have advanced and it is possible now to create data that can be directly integrated into GIS. Data sources that produce data ready for use in GIS are called primary data sources. Those that generate data that has to be adapted or converted are called secondary data sources.

Primary data in GIS and remote sensing is firsthand, directly collected information (e.g., satellite imagery, GNSS/GPS surveys) designed for a specific project. Secondary data refers to existing, repurposed data (e.g., scanned maps, historical reports). Both are essential for spatial analysis, with primary data providing high accuracy and secondary data offering cost-effective historical.

In this study both primary and secondary data has been used. Those are:

Satellite image ……………..Primary data

Shape file of the study area…….Secondary data

2.2.2. Source of Data

The sources of data that we use in the study were listed below in the table.

Table 1. *Source and data types.*

Sources	Data type
USGS Earth Explorer	Landsat image
Ethio administration boundary	Shape file of the study area

2.2.3. Material and Software

Materials and software used in the study were listed in the following table.

Table 2. *Material and Software's.*

software's	Function
ArcMap	For visualizing and displaying compose maps
ERDAS IMAGIN 2015	For image preprocessing and analysis
Google Earth	For visualizing the study area (to identify what was existed and what is existed on the area for each time periods).
MS office	For writing, preparing charts, graphs and statistical analysis

2.3. Methodology

Different approaches underlying the Accuracy assessment and LU/LC change analysis process was applied in the study. These entail mostly the theoretical and practical implication of Remote Sensing and Geographic Information System knowledge to make use of spatial and temporal data sets for acquiring feature information, analyzing the dynamics on land surfaces to use for the future assumptions of LU/LC. The major landmark processes of the study can be summarized by the flow chart presented as under (Figure 2).

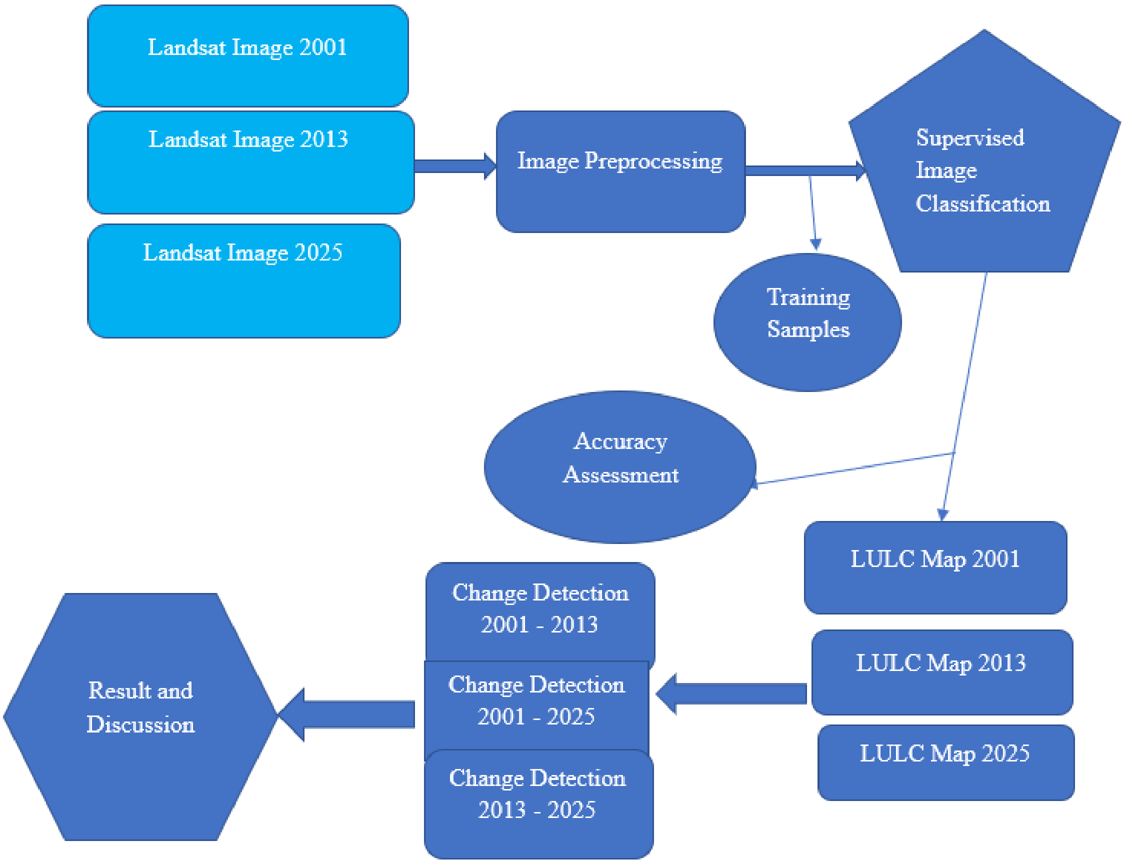

Figure 2. *The Methodology of the overall study.*

2.4. Image Classification

Five land-use and land-cover classes were determined for supervised classification in the study. This was done by using the Anderson Land Use/Land Cover Classification System. The broadest or most aggregated classification (level I) covers categories like "agriculture," "urban and built- up," "forested," "bare land " and grasslands.

Table 3. *Image classification details.*

LULC class types	Methods of category
Agricultural land	All land areas with agricultural crops
Built up	Individual and clusters of building (Residential, Commercial and services, Industrial), road networks.
Forest	Characterized by relatively dense forest vegetative
Bare land	agricultural lands without crops and exposed areas
Grassland	The land areas with small vegetative ground covers (grasses).

3. Result and Discussion

3.1. Image Classification

Images from the years 2001, 2013, and 2025 were divided into five categories (Figures 3, 4 and 5). The total area of the study area's land-use and land-cover classes was 85035 hectare. Here are maps and detailed statistics about the classification outcomes.

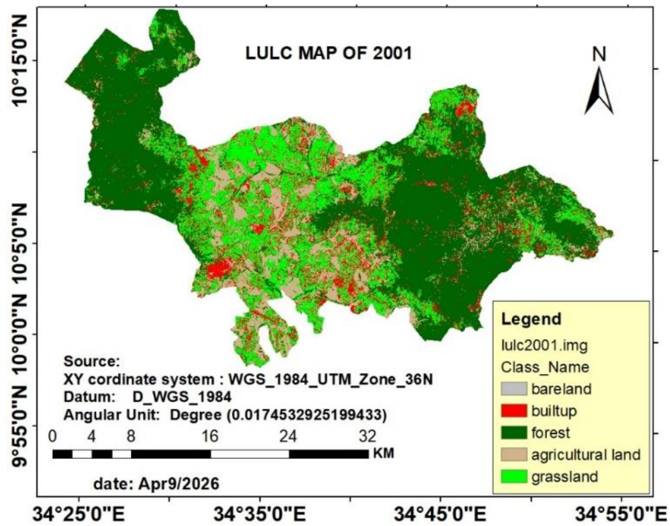

Figure 3. *LULC Classification map of Ura (Assosa) 2001.*

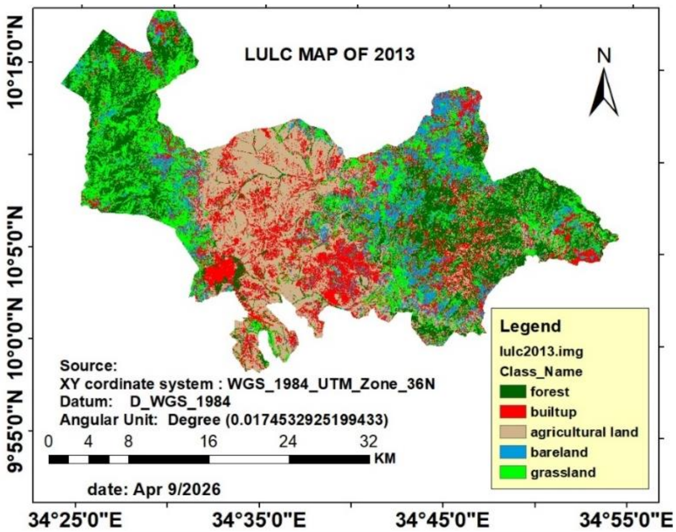

Figure 4. *LULC Classification map of Ura (Assosa) 2013.*

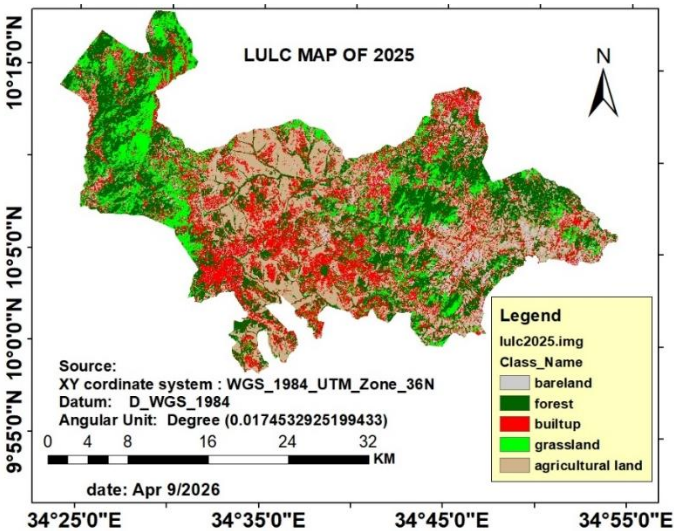

Figure 5. *LULC Classification map of Ura (Assosa) 2025.*

The following Table 4 lists the land-use and land-cover classifications and the areas generated from the classification of images from 2001, 2013, and 2025. If understood using visual support rather than numerical help, the area statistics of the land uses and land coverings might be quantified more effectively.

Table 4. *Land-use and land-cover class types of class areas in hectare.*

CLASS_NAME	AREA 2001	AREA 2013	AREA 2025
agricultural land	11265.21	20978.28	19509.75
Bare land	127.89	9649.71	6759.09
Built-up	10518.87	17789.07	21548.46
forest	41611.41	18902.16	23919.84
grassland	21511.62	17715.78	13297.86
Grand Total	85035	85035	85035

The five land uses in each date are shown visually in the bar chart below, which also shows transitions between various land use classes (Figure 6). For the whole study period, both the built-up area (since buildings, road networks and different constructions are highly increased) and bare land area increased (this is because of the forest type found on the study area is totally used by unplanned urban growth and it is the source of income for the local communities and they cultivate it highly. The chart demonstrates that the forest class was also the land class that experienced the greatest loss, followed by grassland and agricultural land classes.

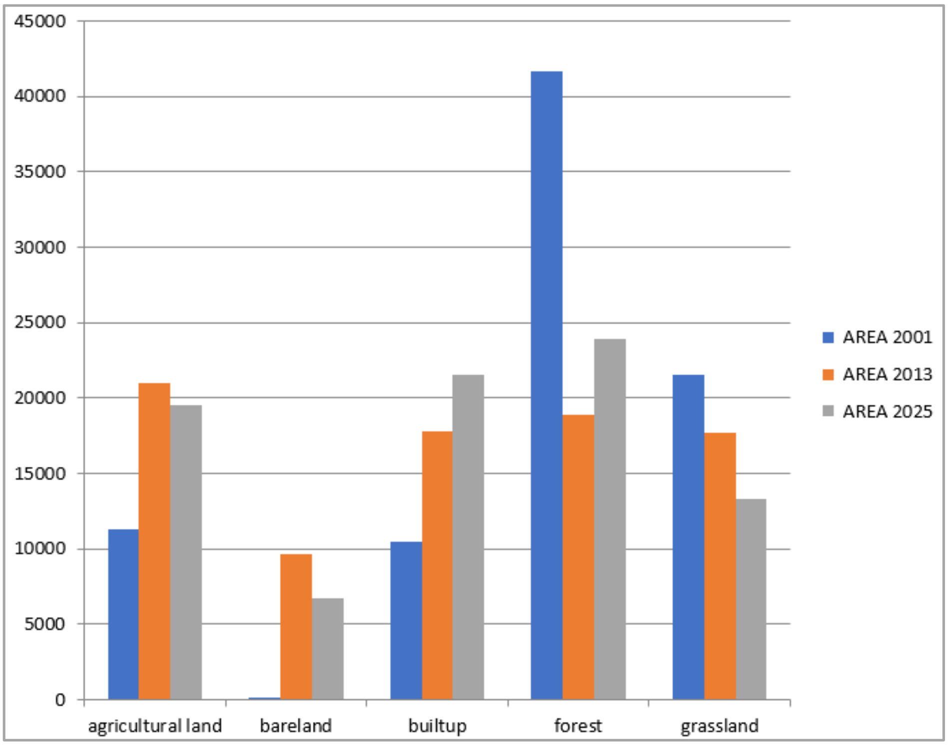

Figure 6. *Bar chart of LULC quantization in Hectare for 2001, 2013 and 2025.*

The following Table 5 lists the land use classifications and the areas in percent generated from the classification of images from 2001, 2013, and 2025.

Table 5. Land use class types of class areas in percent.

Class Name	AREA in 2001	Area in Percentage 2001	AREA 2013	Area in Percentage 2013	Area in 2025	Area in Percentage 2025
Agricultural land	11265.21	13.247733	20978.28	24.670171	13297.86	15.6381%
Bare land	127.89	0.150397	9649.71	11.347927	19509.75	22.9432
Built-up	10518.87	12.370048	17789.07	20.919704	21548.46	25.3407
Forest	41611.41	48.934451	18902.16	22.228682	23919.84	28.12941
Grassland	21511.62	25.297372	17715.78	20.833516	6759.09	7.948598
Grand Total	85035	100	85035	100	85035	100

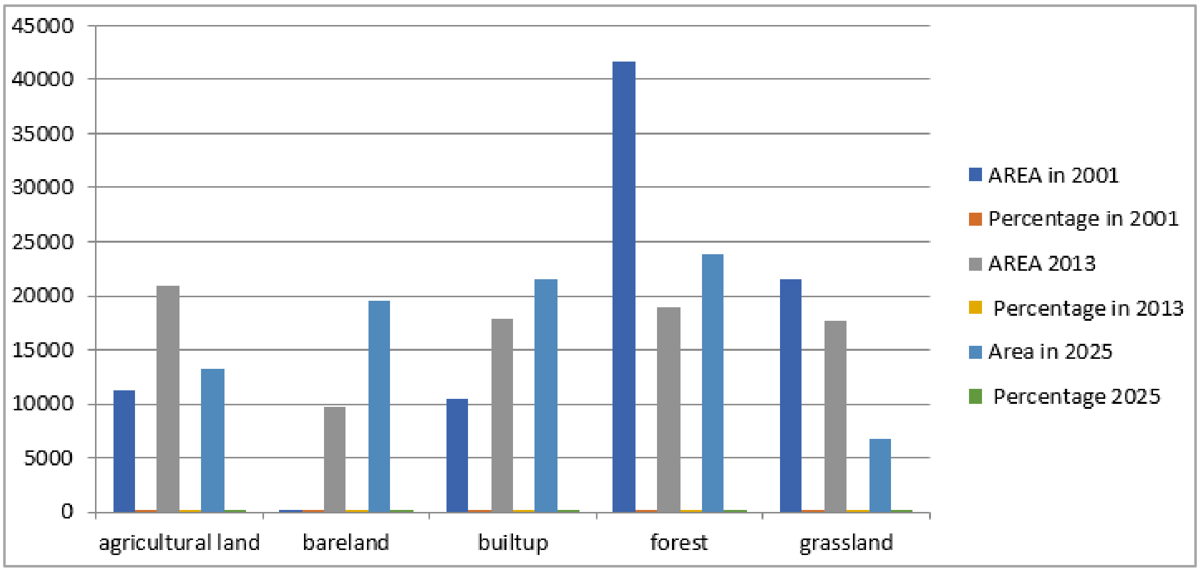

Figure 7. Bar chart of LULC quantization in Percent for 2001, 2013 and 2025.

3.2. Accuracy Assessment

Through the accuracy assessment process, the classifications of the 2001, 2013, and 2025 images were assessed. The accuracy assessment method began with the collection of test samples from an image that was used for classification, followed by sample verification using a high resolution image as a reference. Overall accuracy, overall Kappa (κ), as well as producer and user accuracy for certain land classes, were the indices used for the assessment. The outcomes are displayed below (Table 6).

Table 6. Overall accuracy and Kappa (κ) statistics for the classifications.

	2001	2013	2025
Overall Classification Accuracy%	88.00%	92.00%	96.00%
Overall Kappa (k) Statistics	0.8507	0.8355	0.9232

The outcomes show that for the classification of images from 2001, 2013, and 2025, the attained overall classification accuracies were 88%, 92%, and 96%, respectively, while the overall Kappa (k) values were 0.8507, 0.8355, and 0.9232. For specific land classifications, the accuracy of the producer and the user was as follows: (Table 7).

Table 7. Producer's and User's accuracy for individual land classes.

Class Name	2001%		2013%		2025%	
	Producer Accuracy	User Accuracy	Producer Accuracy	User Accuracy	Producer Accuracy	User Accuracy
Forest	100%	90%	100%	100%	100%	83.33%
Built-up	83.33%	100%	91.67%	97.06%	100%	97.06%
Bare land	100%	70%	50%	50%	100%	100%
Agriculture	100%	90%	100%	60%	83.33%	100%
Grassland	75%	90%	100%	100%	75%	100%

3.3. LULC Change Detections

This is LULC change detection map for in 2001, 2013 and 2025 for show the change happen in past 25 years.

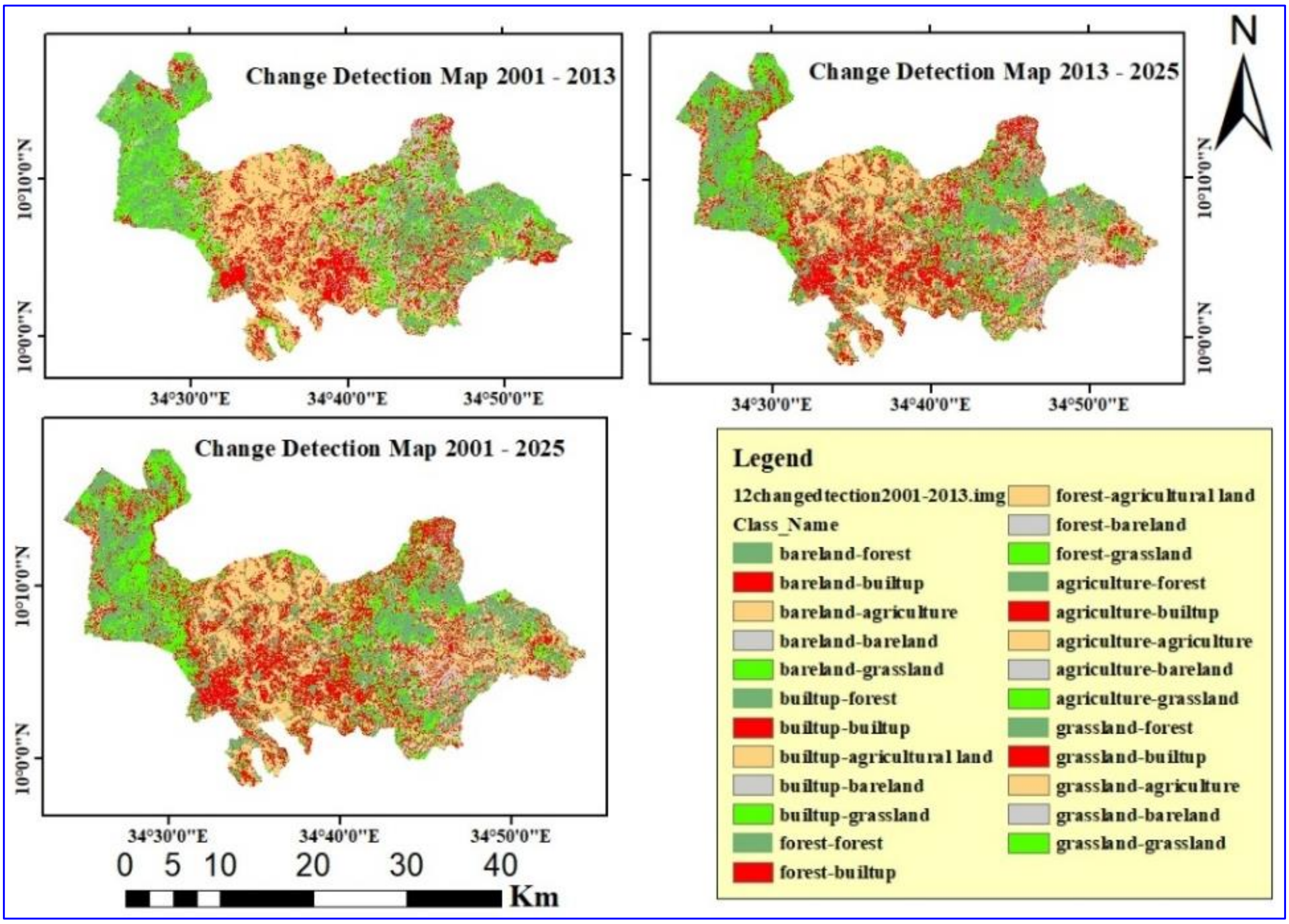

Figure 8. LULC Change Detection Map.

The following table shows change in percentage and area in hectare across all land use classes.

3.3.1. LULC Changes for Land Use Classes from 2001 to 2013 in Ura (Assosa)

Table 8. LULC change for land use classes from 2001 to 2013.

Land use classes	2001		2013		Area Change	
	Area in Ha	Area in%	Area in Ha	Area in%	Area in Ha	Area in%
Agriculture	11265.21	13.247733	20978.28	24.670171	+9,713.07	+11.422438
Bare land	127.89	0.150397	9649.71	11.347927	+9,521.82	+11.19753
Built-up	10518.87	12.370048	17789.07	20.919704	+7,270.2	+8.549656
Forest	41611.41	48.934451	18902.16	22.228682	-22,709.25	-26.705769
Grassland	21511.62	25.297372	17715.78	20.833516	-3,795.84	-4.463856

As shown on the Table 8 above for the years 2001-2013 Agriculture, Bare land and built up are increased by 11.422438%, 11.19753% and +8.549656% respectively. Whereas the land classes Forest and Grassland are decreased by 26.705769% and 4.463856% respectively.

3.3.2. LULC Changes for Land Use Classes from 2001 to 2025 in Ura (Assosa)

Table 9. LULC change for land use classes from 2001 to 2025.

Land use classes	2001		2025		Area Change	
	Area in Ha	Area in%	Area in Ha	Area in%	Area in Ha	Area in%
Agriculture	11265.21	13.247733	13297.86	15.6381	+2,032.65	+2.390367
Bare land	127.89	0.150397	19509.75	22.9432	+19,381.86	+22.792803
Built-up	10518.87	12.370048	21548.46	25.3407	+11,029.59	+12.970652
Forest	41611.41	48.934451	23919.84	28.12941	-17,691.57	-20.805041
Grassland	21511.62	25.297372	6759.09	7.948598	-14,752.53	-17.348774

As shown on the Table 9 above for the years 2001-2025 Agriculture, Bare land and built up are increased by 2.390367%, 22.792803% and 12.970652% respectively. Whereas the land classes Forest and Grassland are decreased by 20.805041% and 17.348774% respectively.

3.3.3. LULC Changes for Land Use Classes from 2013 to 2025 in Ura (Assosa)

Table 10. LULC change for land use classes from 2013 to 2025.

Land use classes	2013		2025		Area Change	
	Area in Ha	Area in%	Area in Ha	Area in%	Area in Ha	Area in%
Agriculture	20978.28	24.670171	13297.86	15.6381	-7,680.42	-9.032071
Bare land	9649.71	11.347927	19509.75	22.9432	+9,860.04	+11.595273

Land use classes	2013		2025		Area Change	
	Area in Ha	Area in%	Area in Ha	Area in%	Area in Ha	Area in%
Built-up	17789.07	20.919704	21548.46	25.3407	+3,759.39	+4.420996
Forest	18902.16	22.228682	23919.84	28.12941	+5,017.68	+5.900728
Grassland	17715.78	20.833516	6759.09	7.948598	-10,956.69	-12.884918

As shown on the Table 10 above for the years 2013-2025 Bare land, built up and Forest are increased by 11.595273%, 4.420996% and 5.900728% respectively. Whereas the lands use classes Agriculture and Grassland are decreased by 9.032071% and 12.884918% respectively.

4. Conclusion

This study has tried to identify LULC change and its impact on urban growth from 2001-2025 time periods. The study used Geographic Information System (GIS), Remote Sensing (RS), and Earth Resource Data Analysis System (ERDAS) and ArcGIS techniques.

LULC is one of the important factors for Environmental monitoring. In this study the urban growth has increased by 12.970652% from 2001 to 2025 on the study area. The study showed that Forest is the dominant land-use and land cover class which cover 48.934451% in 2001 which is changed to built-up area and bare land due to unplanned management of urban growth on the study area and misuse of forest resources. Generally, most of the land area is changed to built-up area and the built up area is increasing from year to year from 2001 - 2025, to the contrary the forest land use class is decreasing from year to year by 20.805041%. Due to this fact it can be concluded that the LULC change has negative influence on the forest sector of the study area. The result of this study is useful for the decision makers to have proper policy for managing the land-use and land-cover change on the area.

This study successfully carried out Land Use/Land Cover (LULC) classification using remote sensing and GIS techniques to analyse the spatial distribution of different land cover types in the study area. The results revealed that forest is the dominant class, followed by agriculture and grassland areas in 2001, indicating significant human influence on land resources. The classification achieved a satisfactory level of overall accuracy, supported by the use of a Confusion Matrix and a strong Kappa Coefficient, confirming the reliability of the results.

The study highlights the on-going changes in land use patterns, particularly the expansion of built-up areas and the reduction of natural vegetation, which may have important environmental and socio-economic implications. Overall, the findings demonstrate the effectiveness of geospatial technologies for LULC mapping and provide valuable information for sustainable land management and planning. Continuous monitoring and improved classification approaches are essential to better understand future land dynamics.

Abbreviations

GIS	Geographic Information System
LULC	Land Use and Land Cover
RS	Remote Sensing
ERDAS	Earth Resource Data Analysis System

Author Contributions

Tariku Tamiru Gemechu: Conceptualization, Data curation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing

Conflicts of Interest

The author declares no conflicts of interest.

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