

Research/Technical Note

GIS-Based Land Use and Land Cover Change Assessment Around Assosa District, Upper Blue Nile Basin, Ethiopia

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Abstract

Land, with its intricate blend of geological, topographical, hydrological, and ecological elements, reflects the interplay of natural processes and human activities. In Ethiopia, traditional agricultural practices often lack systematic planning based on land suitability and physical characteristics, hindering agricultural productivity and economic progress. Understanding shifts in land use and cover is crucial for comprehending broader global transformations. Early studies have unveiled significant alterations in land use and cover between 2009 and 2013. Our investigation extends from 2013 to 2023, employing Landsat 8 imagery at three-year intervals (2013, 2018, and 2023) to analyze five key land cover categories: forests, farmland, built-up areas, barren land, and water bodies. Notably, farmland and built-up areas witnessed substantial expansion over these periods, juxtaposed with a significant decline in forest cover. Forests decreased by 27% from 2013 to 2018, with an additional 7% decrease from 2018 to 2023. Conversely, farmland expanded by 19% from 2013 to 2018 and by 2% from 2018 to 2023, while built-up areas saw respective increases of 4% and 10% over the same periods. These trends underscore potential environmental challenges if unaddressed. Effective land management strategies are crucial to mitigate adverse impacts on ecosystems, agricultural productivity, and overall socio-economic stability. By integrating scientific insights with sustainable practices, we can navigate the intricate dynamics of land use, paving the way for a resilient and prosperous future.

Keywords

Land Cover Change, Land Cover Types, Landsat 8, Land Use

1. Introduction

1.1. Background of the Study

The land is a complex and dynamic factor that consists of, geology, topography, hydrology, soil and microclimate, and a community of plants and animals that are continually interacting under the influence of climate and people activi-

ties [1]. In Ethiopia, farmers mainly use this basic resource in traditional ways without any logical organization of different types of land according to their agricultural potential or their physical configurations [2]. This leads to further performance of agricultural sectors in particular and the whole economy in general. Land use / Land cover change

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Received: 7 March 2024; **Accepted:** 23 March 2024; **Published:** 20 September 2024



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plays a vital role in the study of global change [3]. Land use / Land cover and human or natural modification have largely resulted in deforestation, biodiversity loss, global warming, and increasing natural flooding [4]. Thus environmental problems are often related to Land use/ Land cover change. LULC change refers to the conversion of one type of LULC to another [5]. It also refers to human modification of the terrestrial surface of the Earth and reflects the role of human activities on natural resources and the environment [6].

The interaction between nature and humans has transformed the face of the earth for their demands as no other living species ever done [7]. Usually, the development of LU/LCC is relied on the two broader groups of man-made agents, i.e., proximate drivers and underlying causes. The proximate drivers explain the direct action of humans on local land covers and include expansion of agriculture, unsustainable exploitation of forest resources and infrastructure development [8]. Deforestation is an important cause of LULC elsewhere in the world [9]. The major drivers of deforestation in Ethiopia are settlements, agriculture (both small scale and commercial), extraction of construction materials, grazing, and firewood and charcoal collection [10]. Ethiopia is among the countries characterized by diverse vegetation [11]. However, the high demand for agricultural land due to growing human population has contributed to the deterioration and depletion of forest resources of the country [12].

In Ethiopia, forest losses of 140,000 hectares each year are driven by conversion into agricultural lands, and unsustainable forest management, underpinned by poor governance, uncertain land tenure and a rapidly growing population [13]. The average annual deforestation rate is 1% which is high compared to other Sub-Saharan African countries (0.6%) [14]. Benishangul-Gumuz Regional State (BGRS), which is located in Western Ethiopia, is one of the highly forested regions in the country. The larger portion of the region is covered by the Combretum-Terminalia vegetation type in which lowland bamboo is also the major resource in the region. However, studies from the year 1985 to 2011 in some districts of the region reported the decline of forest resources at an alarming rate [15]. In the 1960s, the total area of bamboo in Ethiopia was estimated at less than 2 million hectares. The 1997 Global Forest Resources Assessment, estimated 0.8 million hectares of bamboo re-

sources in the region. The lowland bamboo forest cover in the region has been devastated due to anthropogenic and natural factors. This result implies that if the same trend continues, the available bamboo stock will vanish in a shorter period of time [15].

1.2. Objectives of the Study

The objective of the project is mapping of land use land cover for those three years and detecting the land use land cover change in areas and percent between this five years interval.

1.3. Statement of the Problem

Assosa woreda has faced the difficult challenge of rapid change of land use land cover, especially a dramatic decrease of vegetation due to deforestation for agriculture. [15] as they stated Woodland, bamboo forest and bushlands have declined by 31.7 percent, 53.9 percent, and 39.3 percent, respectively. A rapid decline in woodland which means forest could be due to ever-increasing firewood demand in the study area and also they also deforest for agricultural land. Moreover, increasing the number of human population coupled with climate change may contribute to the problem. Local communities in the study area largely depend on wood and charcoal for cooking meals and heating homes. This problem can lead the area to higher risks. my intention is to detect how the problem has it reduced or still increasing since the early researchers detected it in 2013, and I tried to test from 2013 to 2023 within five years intervals.

2. Data and Methodology

2.1. Description of the Study Area

The study area, Assosa Woreda, is located in western Ethiopia and it is located Northing of between 9° 45' 00" and 10° 50' 60.00" and Easting of between 34° 00' and 34° 50' 00". The region has a total area of approximately 50,380 km², ranging from 580 to 2,731 meters above sea level (masl). Assosa is located at a distance of 687 km west of Addis Ababa, the capital city of Ethiopia.

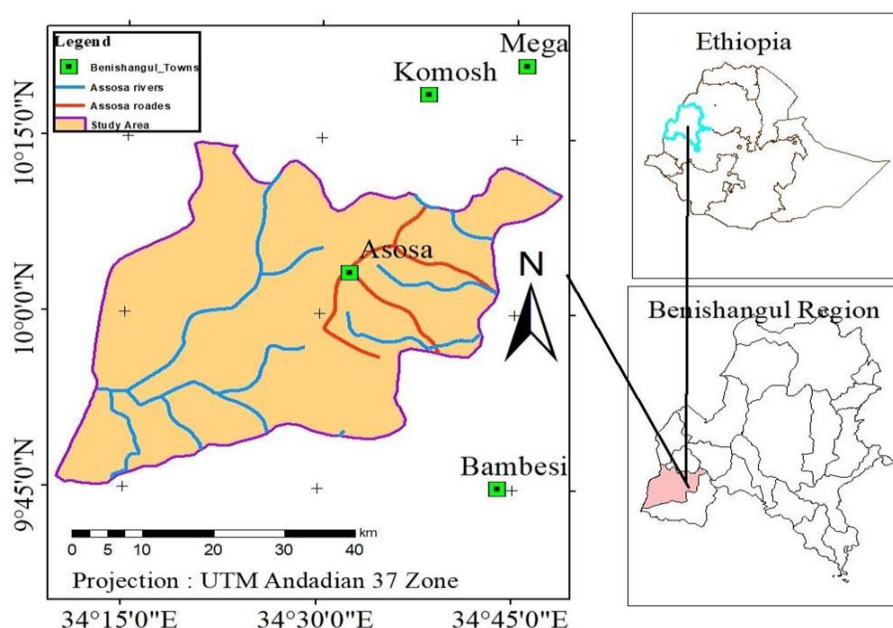


Figure 1. Location map of study area.

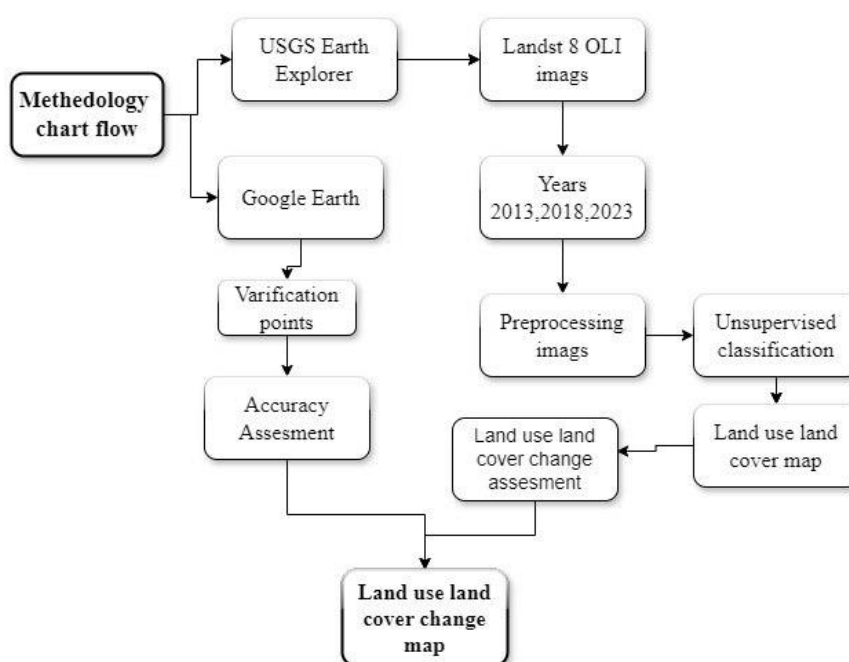


Figure 2. The methodology chart of the project.

2.2. Research Design

Firstly Landsat 8 images were downloaded for the years 2013, 2018, and 2023 from USGS earth explorer. Then by using ArcGIS software bands were composited. Then by using ArcGIS extraction of the area of interest that is Assosa worda for each year respectively. Then in ArcGIS arc toolbox special analyst tools, iso cluster unsupervised classification was done, the input is those three years respectively. A number of classes that were taken were initially, six class

were taken for each by overlaying on a base map and it is difficult to identify one feature class from another therefore the number were increased to ten, which was best for the identification of one class from another when a class of ten were used, there were two or more colors indicating one feature, for this reason, those features were grouped as one since it is on a base map. By this method, the features were classified into five main classes, Forest, Bare land, Farmland, built-up, and water body lastly the area was calculated for all those features for each year respectively.

3. Result and Discussion

The findings of the project demonstrated five major land-cover types on the basis of 2013, 2018, and 2023 Landsat images taken for Assosa woreda. These classifications were forest, farmland, bare land, built, and water body. From those

classes, forest shows the highest decrement, and also built and farmland shows a high increase from 2013 up to 2023. This change could be due to the increase in population since when the population increases the need for agricultural land and built- up areas increases which led to the decrease of forest since both increases the rate of deforestation.

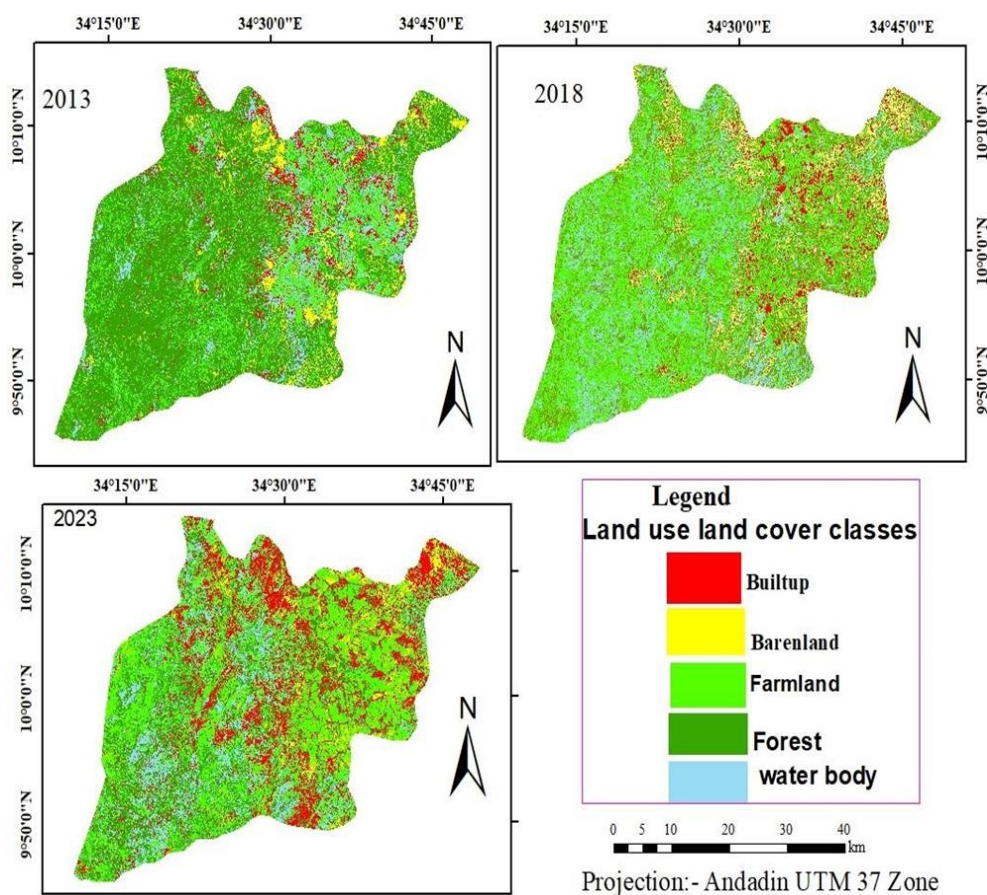


Figure 3. The land use and land cover change map for 2013, 2018, and 2023.

Table 1. The area and percent cover for each year interval.

LULC type	2013 Area (hec-tare)	2013 Area (%)	2018 Area (hec-tare)	2018 Area (%)	2023 Area (hec-tare)	2023 Area(%)
Forest	116129.7	57%	64182.4	30%	47829.2	23%
Barren land	8790.07	6%	17003.5	8%	8790	4%
waterbody	28439.2	14%	35849.2	17%	29785.2	15%
farmland	35950.9	18%	77698.6	36%	79016.5	38%
Built-up	12383.3	6%	20604.8	10%	39906.87	19%

The land use and land cover (LULC) dynamics between 2013, 2018, and 2023 reveal significant changes in the landscape. This analysis focuses on the alterations in different land cover types and their implications.

Forest Cover: The forest cover has shown a noticeable decline from 2013 to 2023, with a reduction of approximately 57,347.5 hectares, representing a decrease of 34%.

Barren Land: The area of barren land has experienced

fluctuations over the years, with a slight increase between 2013 and 2018 followed by a decrease in 2023. While the decrease in barren land from 2018 to 2023 is a positive sign, further analysis is needed to understand the underlying reasons behind these changes.

Water Bodies: Water bodies have exhibited a gradual increase in area from 2013 to 2023, indicating potential improvements in water resource management and conservation efforts. However, it is essential to monitor the quality and health of these water bodies to ensure sustainable water availability for various human and ecological needs. Strategies to mitigate pollution, habitat degradation, and over-extraction should be implemented to safeguard these vital ecosystems.

Farmland: The expansion of farmland is evident in the data, with a significant increase in area from 2013 to 2023. This expansion suggests intensification of agricultural activities to meet growing food demands. While agricultural development is essential for food security and economic growth, it may also lead to adverse environmental consequences such as habitat loss, soil degradation, and water pollution. Therefore, sustainable agricultural practices and land management strategies must be adopted to balance agricultural productivity with environmental conservation goals.

Built-up Area: The built-up area has experienced rapid expansion over the years, nearly tripling in size from 2013 to 2023. This expansion is indicative of urbanization and infrastructure development driven by population growth and economic activities. While urbanization brings socio-economic

benefits, it also poses significant challenges such as habitat fragmentation, air and water pollution, and increased vulnerability to natural hazards. Urban planning policies focused on promoting compact, efficient, and sustainable urban development are essential to mitigate these negative impacts and ensure the livability and resilience of urban areas.

To achieve sustainable development and environmental conservation goals, integrated land use planning, informed policy interventions, and community engagement are imperative. Continued monitoring and assessment of land cover changes are necessary to inform evidence-based decision-making and promote the long-term health and resilience of ecosystems and societies.

Table 2. The change in percentage between the years.

Land use	per (%) change 2013-2018	per (%) change 2018-2023
Forest	-27%	-7%
Barren land	2%	-4%
Waterbody	3%	-2%
Farmland	19%	30%
Built-up	4%	15%

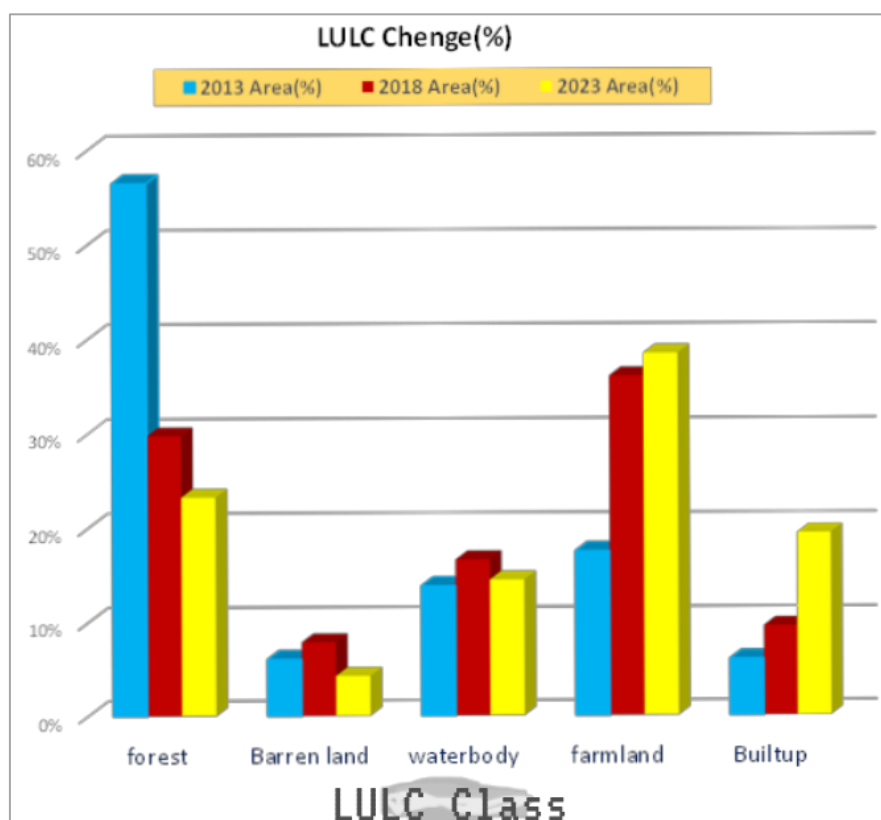


Figure 4. The Land use and land cover change in percent for each year.

The land use dynamics between 2013 and 2023 exhibit significant changes across various categories.

Forest: Between 2013 and 2018, there was a substantial decrease (-27%) in forest cover, indicating significant deforestation during this period. However, from 2018 to 2023, the rate of deforestation slowed down, with a smaller decrease of -7%. This could be attributed to conservation efforts, stricter regulations, or natural forest regeneration processes. The continued loss of forest cover remains concerning, emphasizing the need for continued conservation measures to protect biodiversity and ecosystem services.

Barren Land: Barren land witnessed a slight increase of 2% between 2013 and 2018, indicating land degradation or abandonment. However, from 2018 to 2023, there was a reversal in this trend, with barren land decreasing by -4%. This could be due to reclamation efforts or changes in land use practices. Efforts to rehabilitate barren land should be encouraged to restore ecosystems and prevent further degradation.

Water body: Water bodies experienced a modest increase of 3% between 2013 and 2018, which could be attributed to natural factors such as precipitation patterns or human interventions such as reservoir construction. However, from 2018 to 2023, there was a slight decline of -2% in water body coverage. This could be a result of anthropogenic activities like land reclamation or climate-induced changes. Maintaining and preserving water bodies is crucial for biodiversity conservation, freshwater supply, and flood regulation.

Farmland: Farmland saw a substantial increase of 19% between 2013 and 2018, indicating expansion of agricultural activities, possibly driven by population growth and food demand. This trend continued from 2018 to 2023, with an even higher increase of 30%, highlighting the ongoing conversion of natural landscapes into agricultural land. While agricultural expansion is essential for food security, it also raises concerns about habitat loss, soil degradation, and water resource depletion.

Built-Up Areas: Built-up areas experienced moderate growth, with a 4% increase between 2013 and 2018, likely driven by urbanization and infrastructure development. From 2018 to 2023, this growth accelerated, with a 15% increase in built-up areas. Rapid urbanization can lead to various environmental challenges, including habitat fragmentation, pollution, and resource depletion. Sustainable urban planning strategies are essential to mitigate the adverse impacts of urban expansion on ecosystems and human well-being.

Overall, the data reveals complex dynamics in land use changes over the study period. Effective land management policies and conservation initiatives are imperative to balance the competing demands of development, agriculture, and environmental protection. Long-term monitoring and adaptive management strategies are crucial for maintaining ecosystem resilience and ensuring sustainable land use practices in the face of evolving socio-economic and environmental pressures.

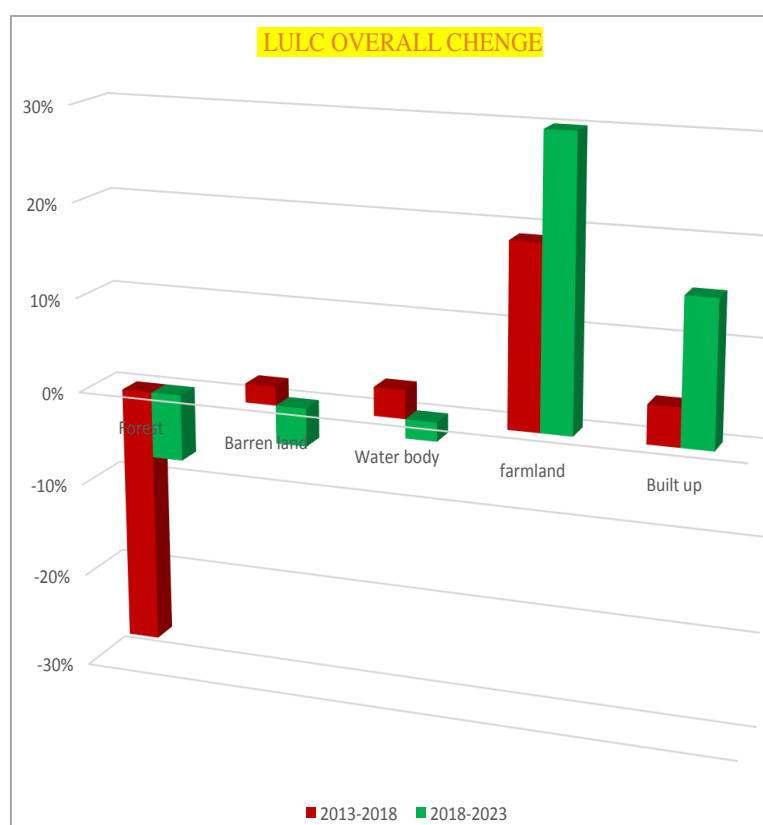


Figure 5. The overall change indicator in percent.

Accuracy Assessment

The accuracy assessment for this project is done by taking samples from the classified LULC and dragging those points to google earth to detect their accuracy. We have taken twelve sample points in each land cover class the result that we found is almost eight up to ten is accurate. Since it is an unsupervised classification it could have some limitations. Even though almost the samples are indicators of the land use land cover classes.

4. Conclusion

Environmental and natural resource degradation is a major concern in Ethiopia. This project shows the major decrease in land use land covers around Assosa Woreda. A large number of immigrants were resettled around Assosa woreda in case of famine encountered due to severe droughts in 1984/85. If this problem continued as this it has the probability to lead to vulnerable climate change as well as famine in order to mitigate this problem appropriate policy should be designed.

Abbreviations

GIS	Geographic Information System
BGRS	Benishangul-Gumuz Regional State
LULC	Land Use and Land Cover
masl	Meters Above Sea Level
RWH	Rainwater Harvesting
USGS	United States Geological Survey

Author Contributions

Genet Amsalu: Conceptualization, Resources, Software, Formal Analysis, Funding acquisition, Writing – original draft, Project administration

Yimam Mekonen: Data curation, Supervision, Validation, Investigation, Visualization, Methodology, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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