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GIS-based land use and land cover change assessment around Assosa district, Upper Blue Nile Basin, Ethiopia

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Abstract

Early researchers have reported the high land use land cover change by using years 2009-2013. We try to detect the land use land cover change from the years 2013-2023 by taking three years 2013, 2018, and 2023 by using Landsat 8 images of each year. We have taken five land cover types. They are forest, farmland, built-up, barren land, and water body. From this land covers farmland and built up areas shows a dramatic increase in this three-year gap. Especially forests show a high decrement, the rest water body, and barren land show some change. We found that the decrement of forests from 2013 up to 2018 is -27% and also from 2018-2023 is -7% additionally the percentage change of increase of farmland between 2013-2018 is 19% and between 2018-2023 is 2%, built- up area increases by 4% between 2013-2018 also in between 2018-2023 it increased by 10%.this change indicates that it can cause a serious problem unless it cannot be resolved.

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 activities [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 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 2011in 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 resources 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. Material and Method

2.1. Description of the Study Area

The study area, Assosa Woreda, is located in western Ethiopia and it is located Northing of between 90 45′ 00 and100 50′60.00 and Easting of between 34° 00′ and 34° 50′ 00′′. The region has a total area of approximately 50,380 km, ranging from 580 to 2,731 meters above sea level (masl). Asossa is located at a distance of 687 km west of Addis Ababa, the capital city of Ethiopia (Figure 1).

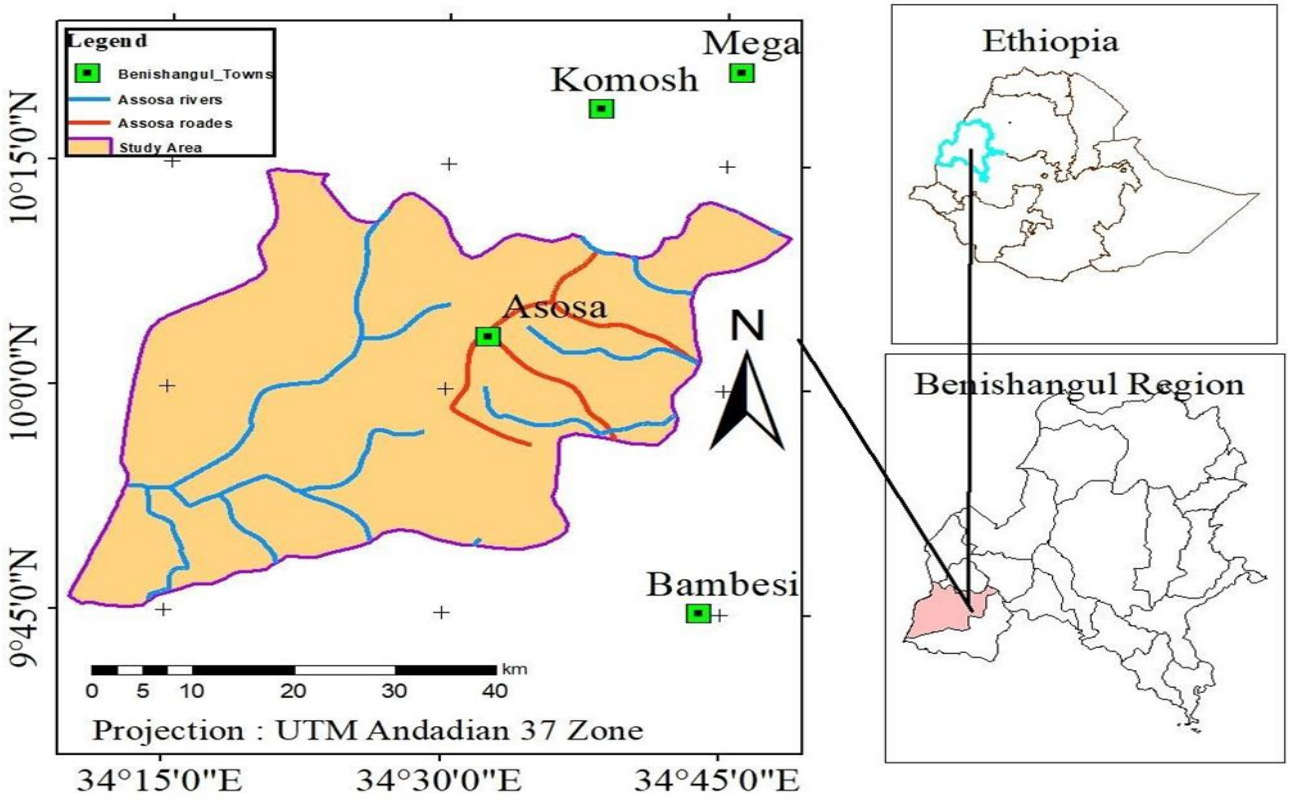

Figure 1. Location map of study area

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 woreda 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.

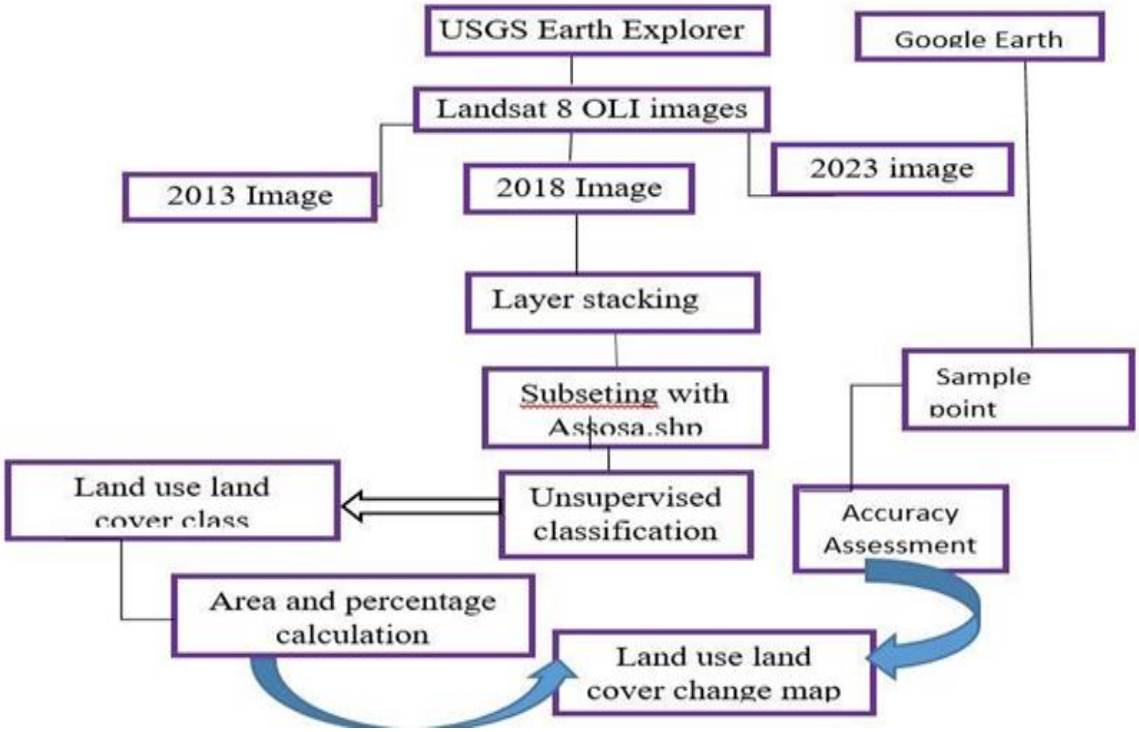

Figure 2. The methodology chart of the project

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 (Figure 2).

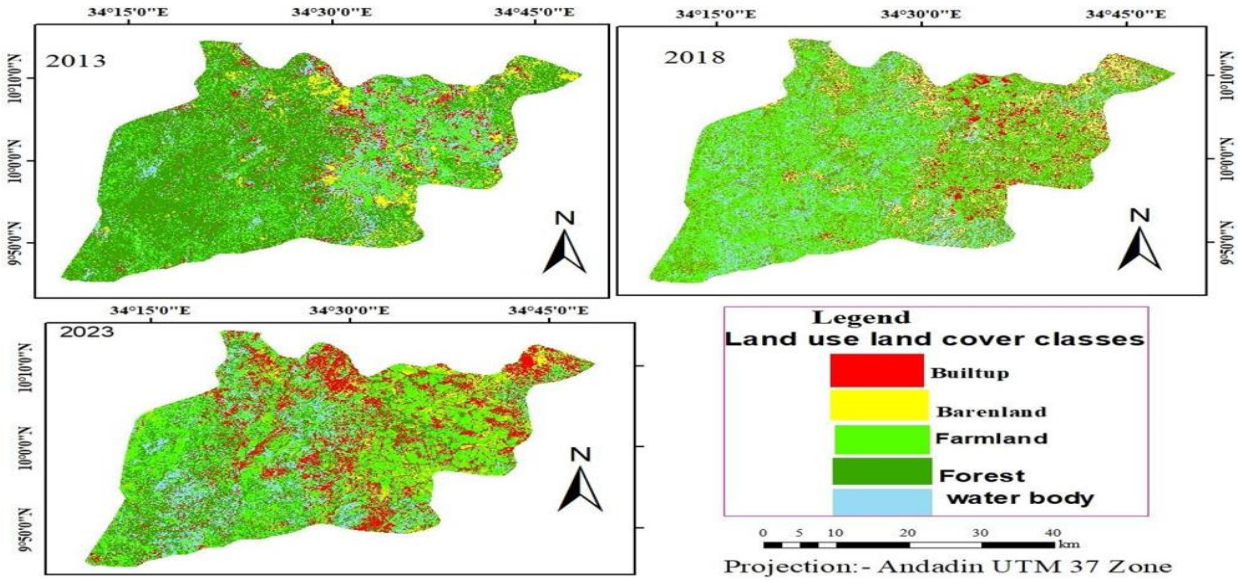

Figure 3. The land use and land cover change map for 2013, 2018, and 2023

3. Results 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).

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

LULC type	2013 Area(hectare)	2013 Area (%)	2018 Area(hectare)	2018 Area (%)	2023 Area(hectare)	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 (Table 1 and Figure 4).

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.

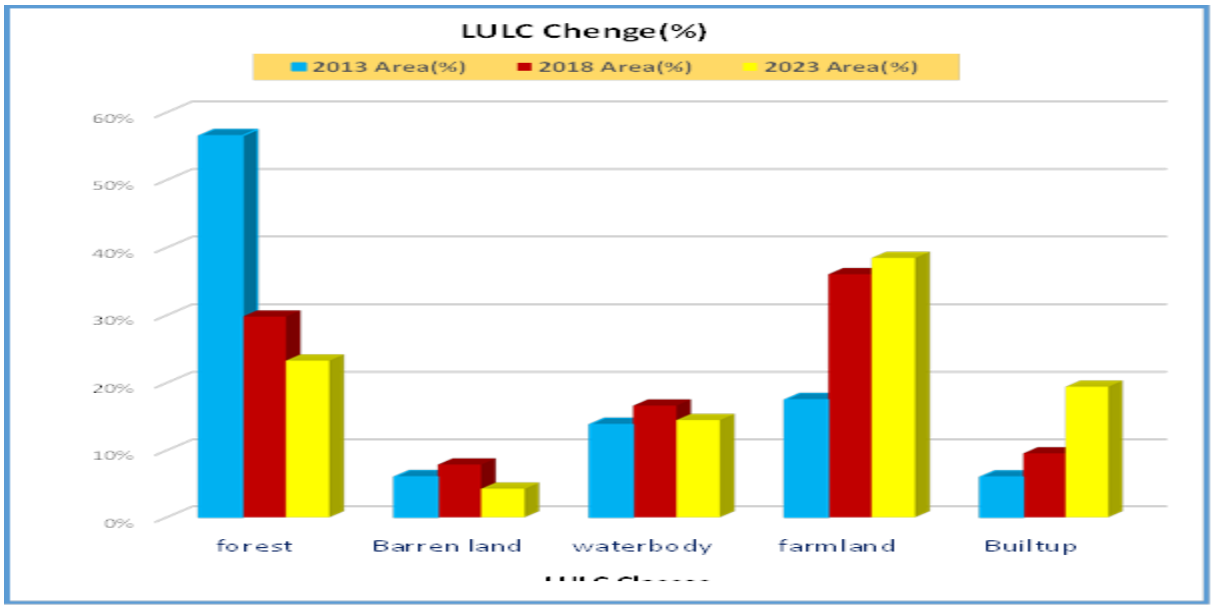

Figure 4. The Land use and land cover change in percent for each year

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%

The land use dynamics between 2013 and 2023 exhibit significant changes across various categories (Table 2).

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.

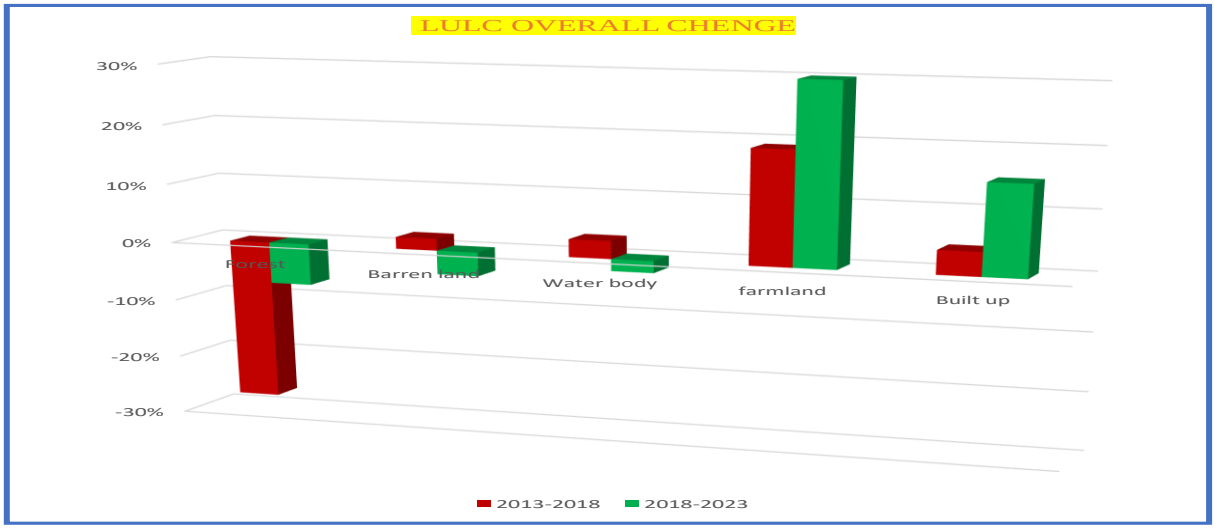

Figure 5. The overall change indicator in percent

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).

3.1. 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. I have taken twelve sample points in each land cover class the result that I 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. (Bessie et al., 2016) as they described 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.

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Author contributions:

Genet Amsalu: Conceptualization, Methodology, Software **Yimam Mekonen:** Data curation, Software, Validation.

Conflicts of interest:

The authors declare no conflicts of interest.

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