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Forest cover change, driving forces and its implication for livelihoods in Bure district of Illubabor zone, southwest Ethiopia

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Abstract
Developing sustainable forest management strategies requires careful understanding of changes in forest cover and its driving forces. Therefore, this study was conducted to detect the spatial extent and trends of forest cover change, identify driving forces, and its implication for livelihoods in the Bure district of Illubabor zone, southwest Ethiopia. Landsat images of 1986, 2000, and 2023 were used to detect the forest cover changes. Focus group discussions, survey questionnaire, key informant interviews and field observation were used to identify the drivers for forest cover change. Results identified four different land use and land cover classes, namely forestland, cultivated land, grassland and wetland. The results of the change detection showed that there has been a notable spatiotemporal change in the forest cover in the study district from 1986 to 2023. The forest's initial extent was 52,800 ha in 1986; between 1986 and 2000, it reduced by 3,300 ha, between 2000 and 2023, it shrunk by 30,200 ha, and between 1986 and 2023, it minimized by 33,500 ha. There were several factors that contributed to the observed changes in forest cover, including the expansion of farmland, rapid population growth, demand for fuelwood and construction materials, charcoal making and timber production, and overgrazing. Reduced agricultural productivity, soil erosion, climate change, and biodiversity loss were all caused by changes in the forest cover. Based on the study findings, it is recommended that afforestation and reforestation programs be put in place in order to increase forest cover in the study area.

Keywords
Change detection, drivers, remote sensing, vegetation cover

Introduction

Over the past years, the total area covered by forests worldwide has been alarmingly decreasing (Food and Agricultural Organization of the United Nations [FAO], 2016). According to recent studies, the rate of forest loss globally has reached 13 million hectares annually (FAO, 2010). The tropics, especially South America and Africa, saw the greatest loss of forest (FAO, 2010). With a net loss of roughly 3.4 million hectares annually, Africa has the second-highest rate of deforestation globally (FAO, 2016). According to Takahashi & Todo (2012), Ethiopia has also seen a significant loss of forest cover, with deforestation rates range from 140,000-200,000 ha per year (Reusing, 1998). The northern and central highlands of Ethiopia are where the decline in forest cover is most noticeable, and it is progressively moving to the south and southwest, where there are still relatively dense forests (Lemenih & Negassa, 2012).

According to Woldemariam (2003), the montane rainforest in southwest Ethiopia have been deforested and the remaining forest areas are highly fragmented.

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According to this author, during the last 30 years, the highland plateau of southwest Ethiopia has lost more than 60% of its forest cover. Forest areas in Bure district is one of such area where deforestation and forest degradation is occurring at an alarming rate due to the expansion of tea, coffee and eucalyptus tree plantations in the area. Ethiopia's deforestation and forest degradation are caused by a variety of dynamic and complex factors that change over time and space, including topography, livelihood, environmental history, and the diversity of vegetation types (Assefa & Bork, 2023). Several empirical studies (e.g., Lemenih & Bekele, 2008; FAO, 2010; Lemenih et al., 2015; Gebrelibanos & Assen, 2015) conducted in Ethiopia have reported that the human factor is responsible for the change in forest cover in the country. This factor includes the demand for agricultural land expansion, a high reliance on biomass energy, population growth, uncontrolled fuelwood extraction, overgrazing, poverty, lack of policies regarding forests and land use, unstable land-tenure system, and socio-political instability. Changes in forest cover have a negative impact on soil erosion, crop yield, biodiversity loss, and climate change (Gete & Hurni, 2001). According to Gebrelibanos &Assen (2015) empirical evidences on the extent, patterns, its drivers and implications of forest cover changes at specific location level can contribute to design more effective forest management. options. However, studies of forest cover change, its drivers, and implications in the Bure district have received less attention. Thus, the main objective of this study was to quantify the spatial extent and trends of forest cover change, identify the major drivers, and its implication for livelihoods in the Bure district of Illubabor zone, Ethiopia.

Materials and methods

Study area description

The present study was carried out in the Bure district of Illubabor administrative zone of Oromia Regional State, southwest Ethiopia (Fig. 1). The landscape feature of the study area is characterized by rugged terrain, deep gorges and extensive dissected plateaus.. According to the Ethiopian traditional agro-climatic classification system which mainly relies on altitude and temperature, more than 85% of the study area falls within *kolla* (temperate) agro-climatic zone (500–1500 m a.s.l). Elevations vary greatly in the study area, with the lowest locations at approximately 619 meter above sea level and the highest at 1844 m. The district has various types of vegetation resources that include *Albizia gummifera*, *Millittia ferruginea, Sapim ellipticum, Syzygium guineense*, *Acacia lahai steud* and *Eucalyptus spp.*

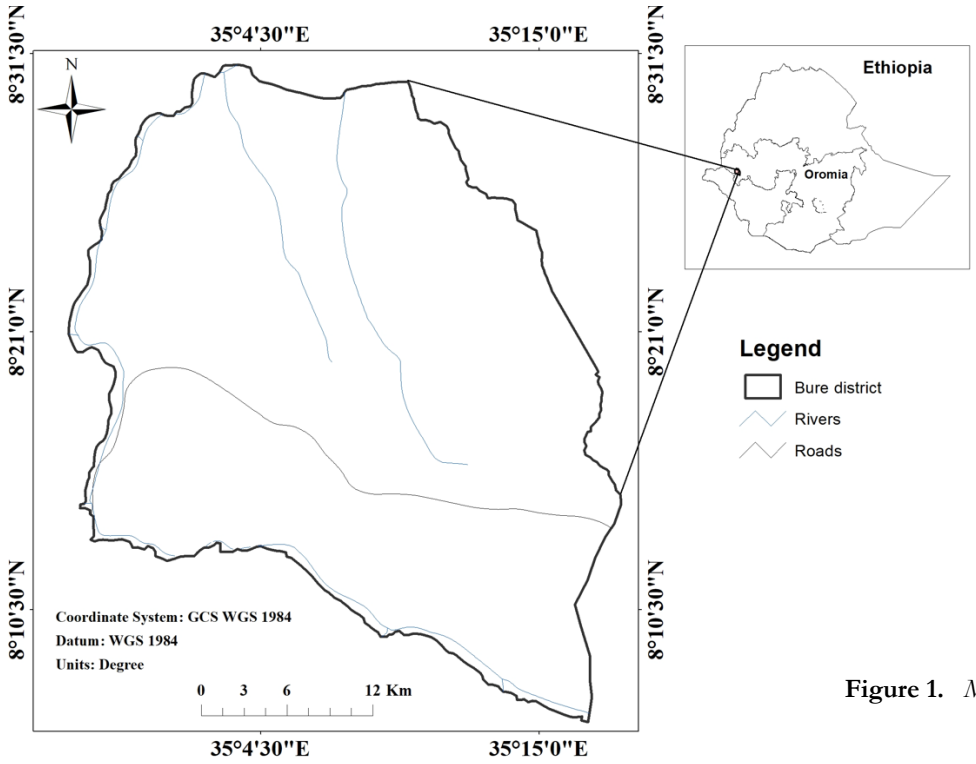

Figure 1. *Map showing the study area*

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According to the FAO's classification of soil types, dystric nitisols make up the majority of the district's land area. The majority of the soils have low levels of organic matter, little nutrient availability, and a pH range of 4.5 to 5.5. The mean temperature and mean annual rainfall of the area were 20.9c° and 1450 mm, respectively (NMA, 2023). The rainfall pattern is unimodal, with short rains from January to February, and the long rains from June to September. The vegetation of the study area is characterized by tropical montane rainforest. Crop production, mainly rain-fed cereal-based production systems and modest livestock rearing are the mainstays of livelihoods for households in the area. Forests are essential to the livelihoods and household income of a significant number of the people in the Bure district, who reside in and around them.

Sources of data

The study used both spatial and non-spatial (socio-economic) datasets from both primary and secondary sources. The primary data was collected using household survey, key informant interviews, focus group discussion, and field observations. Secondary data was collected from Landsat images, Google Earth, published and unpublished documents.

Remote sensing data and analysis

Three sets of satellite imageries (Landsat TM 1986, Landsat ETM+ 2000, and Landsat OLI 2023) with 30m spatial resolution were used to quantify forest cover change over the last 37 years. These images were obtained from the Landsat archive in the Earth Explorer services of the United States Geological Survey (USGS) website (http://earthexplorer.usgs.gov/). Details of the images characteristics are tabulated in Table 1. The reasons behind for choosing of years and seasons were: (1) the availability of cloud free and; (2) good quality satellite images. For the purpose of pre-processing, processing, classifying, and post-classifying images as well as creating the final land cover maps for the study period, ArcGIS 10.5 and Earth Resource Data Analysis System (ERDAS) Imagine 2016 were used. To assist the supervised image classification, a total of 24 ground truths were collected from each land use as a classification training site by using a Garmin 72 Geographical Position System.

Table 1
Description of imagery data used for forest cover change

Satellite images	Sensor	Path/Row	Date of acquisition	Resolution (m)	Source
Landsat 5	TM	171/54	January10, 1986	30	USGS
Landsat 7	ETM+	171/54	January 8, 2000	30	USGS
Landsat 8	OLI	171/54	February 6, 2023	30	USGS

Accuracy assessment determines the quality of the information derived from the remotely sensed data. The overall accuracy values were 82%, 80% and 87% for images of 1986, 2000 and 2023, respectively. These accuracies were sufficient for the analysis of the forest cover change because they satisfy the minimum accuracy reported (Anderson et al.,1976) for satellite-derived land use/cover maps. All Geographic Information System (GIS) data were projected to the Universal Transverse Mercator (UTM) projection system zone 37N zone and datum of World Geodetic System 84 (WGS84), ensuring consistency between data-sets during analysis. The percentage of land cover change detection was conducted using the following formula (Kindu et al., 2013).

Positive percentage values suggest an increase whereas negative values imply a decrease in area coverage.

$$\text{Land use/cover change (\%)} = \frac{\textit{Area final year} - \textit{Area initial year}}{\textit{Area initial year}} \times 100 \quad [1]$$

Socio-economic data collection and analysis

In order to understand the major drivers of forest cover change, socio-economic data were collected from a structured household survey, focus group discussions, key informants interviews and field observations. The survey was adopted a combination of purposive (to select the district) and random sampling (to select sample rural kebeles and household heads). In the first stage of the sampling procedure, Bure district was selected purposively because of its decline in overall forest cover due to the expansion of tea, coffee and eucalyptus tree planta-

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tions in the area. Then, three rural *kebeles* were randomly selected for the study. In the second stage, using a list of household heads available at each sample rural *kebele*, sample size was determined through probability proportional to size technique. Accordingly, 71, 44 and 133 households were randomly selected from an existing register of households from Kufi, Chora Degoye and Nebo Miriga rural kebeles, respectively, making the total sample size 248. Additionally, key informant interviews were held with local elders, rural kebele administrators and extension agents working in these kebeles. Accordingly, a total of 27 key informants were interviewed during field work. The study also employed focus group discussions to generate important qualitative data from the community who can provide reliable information for the study. Accordingly, three focus group discussions were conducted with an average of eight household heads in each selected rural kebele. The selection of the discussants for focus group and key interviews were made purposively to obtain accurate information. Checklist was used to facilitate the discussion and to guide the focus of the research on the drivers of forest cover change. Information generated during focus group discussions was used to consolidate and triangulate the data obtained through household survey. Furthermore, direct observation of forest cover and utilization of forest resources was made during field visit. The quantitative data gathered from the household survey was analyzed using the Statistical Package for Social Science (SPSS) software version 25. Descriptive statistics such as frequencies and percentages were used to summarize and categorize the quantitative data gathered. The information obtained through focus group discussions and key informant interview analyzed using narratives

Results and Discussion

Forest cover change analysis

The area distribution of the four land use and land cover categories of the study area derived from the classification maps of 1986, 2000 and 2023 is provided in Table 2. Grassland, wetland, forest land, and cultivated land were the four categories into which the land use and cover in the study district was divided using GIS techniques, in accordance with the supervised image classification method system. The result of satellite image analysis showed that cultivated land increased six folds from 11,900 ha in 1986 to about 78,900 ha in 2023. This may be related to the need for arable land brought about by small-scale subsistence farming, large-scale farming such as coffee and tea plantations, and the fast population growth in rural areas. The spatial extent of cultivated land has increased from 10.31% to 68.37% during the study period. This indicates cultivated land has increased by about 58.06%, with an average annual increase of 1.57% at the expense of forest, grazing and wetland lands. In contrast, forestland experienced a nearly 29.03% loss over the entire period analysis, indicating significant change. This suggested that, between 1986 and 2023, approximately 33,500 ha of the forest cover were converted to different land uses, making it one of the most affected land covers. According to the annual rate of change, the forestland declined by 0.78% (905 ha), over the course of the three decadal periods (1986–2023).

Table 2
Spatial distribution of land cover classes from 1986 to 2023 in Bure district

Land cover classes	1986		2000		2023	
	Area(ha)	(%)	Area(ha)	(%)	Area(ha)	(%)
Cultivated land	11,900	10.31	21,200	18.37	78,900	68.37
Forest land	52,800	45.75	49,500	42.89	19,300	16.72
Grassland	49,100	42.55	43,500	37.69	17,100	14.82
Wetland	1,600	1.39	1,200	1.04	100	0.09
Total	115,400	100	115,400	100	115,400	100

Similar to the changes seen during 1986–2023 grassland coverage dropped from 49,100 ha to 17,100 ha, with an average loss of 0.75%, while wetland areas declined from 1.39% in 1986 to 0.09% in 2023, with a net loss of 1.3%. This indicated that wetland areas in

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Land use category	Trends of land use and cover change					
	1986-2000		2000-2023		1986-2023	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Cultivated land	9,300	8.06	57,700	50	67,000	58.06
Forest land	-3,300	-2.86	-30,200	-26.17	-33,500	-29.03
Grassland	-5,600	-4.86	-26,400	-22.87	-32,000	-27.73
Wetland	-400	-0.35	-1,100	-0.95	-1,500	-1.3

Notes: The negative numbers (-) indicates a reduction in area while positive number (+) indicates increase in area

Table 3
Trends of land use and land cover change in Bure district of Ethiopia

the study area that are farmed in the dry season produce a more reliable crop yield that can be utilized to supplement harvests from rain fed areas. The spatial map of the land use and cover change for the Bure district between 1986 and 2023 were displayed in Figures 4, 5 and 6.

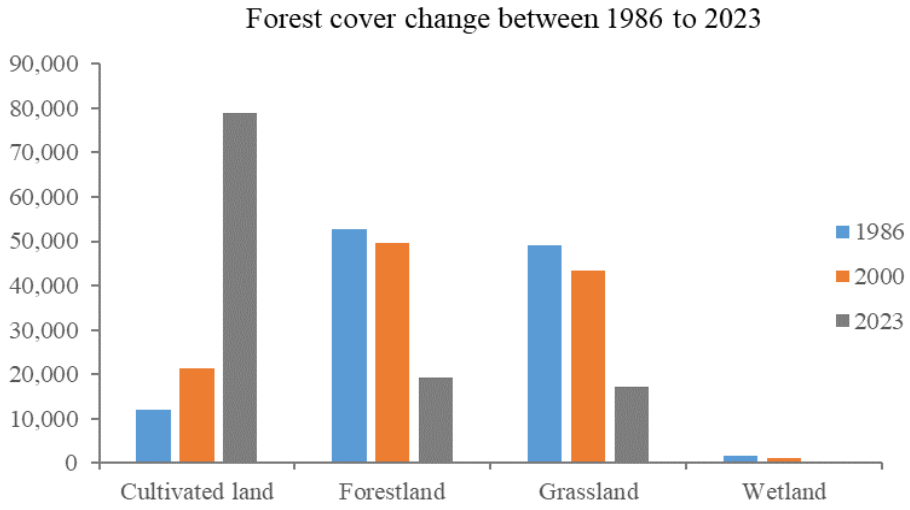

Figure 2
Overall comparison of forest cover change from 1986 to 2023 in Bure district

Rate of land use and land cover changes from 1986 to 2023

Three periods were identified based on the rates of land use and land cover. The results for the first period (1986 to 2000), indicated that, on average, cultivated land increased at a rate of 0.58%, while wetland, grassland, and forest cover all saw declines of 0.03%, 0.35% and 0.20%, respectively. Among the four land use and land cover classes, cultivated land increased at the fastest rate during the second period (2000 to 2023) by 2.17% per year. On the other hand, there was a negative decrease of 1.14%, 0.99%, and 0.04% in forest land, grassland, and wetland, respectively. Table 4 shows that during the third study period (1986 to 2023), the percentage of cultivable land increased steadily at a rate of 1.57%. The forest areas demonstrated a decreasing rate of change from the base year to the last study year by 0.78%, in contrast to the four land use land cover classes. The expansion of cropland cause of the decline in forest land in the study area. The present finding aligns with the findings of Gebrelibanos & Assen (2015), who documented a 10.6% annual decline in forest land.

Land use classes	1986-2000		2000-2023		1986-2023	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Cultivated land	664	0.58	2,509	2.17	1,811	1.57
Forest land	-236	-0.20	-1,313	-1.14	-905	-0.78
Grassland	-400	-0.35	-1,148	-0.99	-865	-0.75
Wetland	-28.57	-0.03	-48	-0.04	-41	-0.04

Table 4
Rate of land use and cover change in ha and % per year

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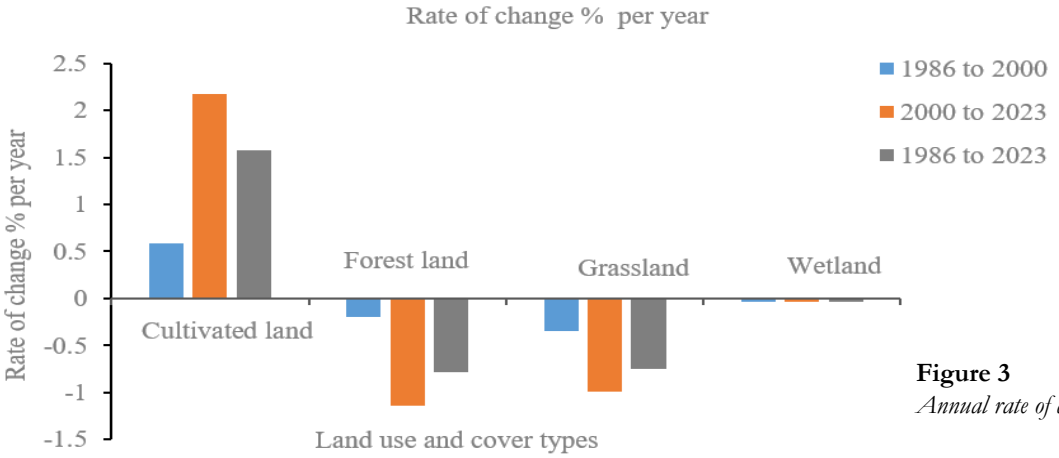

Figure 3
Annual rate of change % per year

Matrix of the land use and cover change from 1986 to 2023

The land use and land cover matrix presented in Table 5, indicated the proportion of land use and land cover classes that showed different dynamics throughout the study period (1986 to 2023).

Table 5
Land use land cover change matrix between 1986 to 2023

Land use classes	Change area in (ha)				
	Cultivated land	Forest land	Grassland	Wetland	Total
Cultivated land	35.73	153.72	2.52	0.53	192.50
Forest land	402.63	289.64	83.96	12.25	788.48
Grassland	88.33	470.4	32.41	2.88	170.66
Wetland	0.04	0.33	0.00	0.20	0.57
Total	526.73	490.72	118.89	158.6	1152.2

The study's findings showed that there has been a notable transformation of formerly forested, wetland, and grassland areas into cultivated land. The cross-tabulation matrices demonstrated that the conversionof forestland to cultivated land is the most notable change between 1986 and 2023. For instance, during the period the forest land changed to cultivated land by 402.63 ha. This sug-gests that the decline of the study area's forests, wetland, and grasslands was mostly caused by the expansion of cultivated land. The patterns of land use and cover for year 2023 of Bure district portrayed that the dominant cover types in the study area was radically converted to cultivated land at alarming rate. While the forest, grassland and wetland were degraded down from the amount of coverage of year 1986 classification. The highest shrinkage and the highest rise in the share of cover class were forest land and cultivated land.

Drivers of forest cover changes

In the present study area, there are many intertwined and connected factors or drivers for forest dynamics. Drivers of forest cover change are presented in Table 4. The survey results showed that 96.1% of the respondents were reported that farmland expansion as the most important source of deforestation and forest degradation in the study area. Focus group discussions and key informant interviews revealed instances of intentional clearing and expansion of natural forests for agricultural purposes, with the aim of boosting crop productivity. One participant explained, that 'due to the insufficient yield of the land, the farmers were forced to relocate to other forest area in search of better land, which resulted in the expansion of cultivated areas'. They further stated that the need for farmland and grazing areas by the local population to support an increasing population

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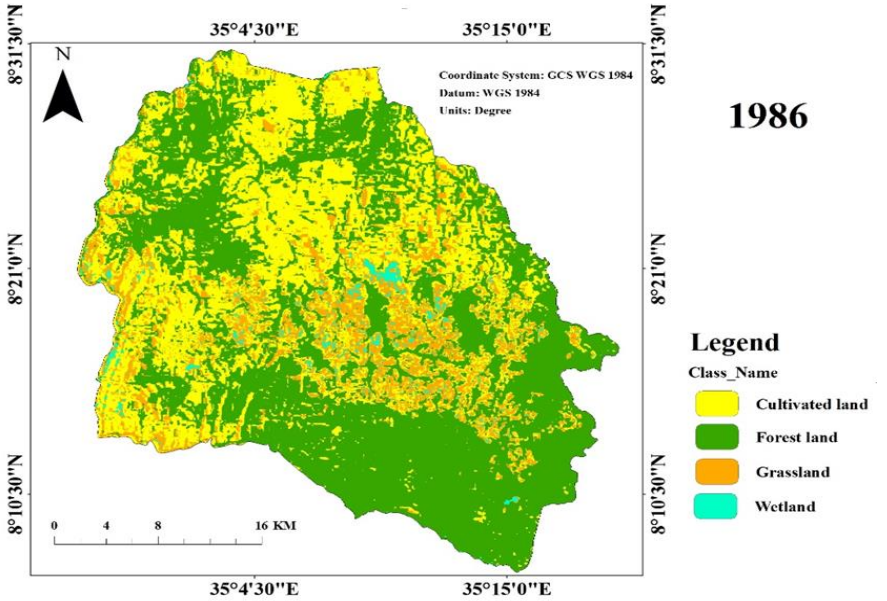

Figure 4
Land cover change map of 1986 in Bure district

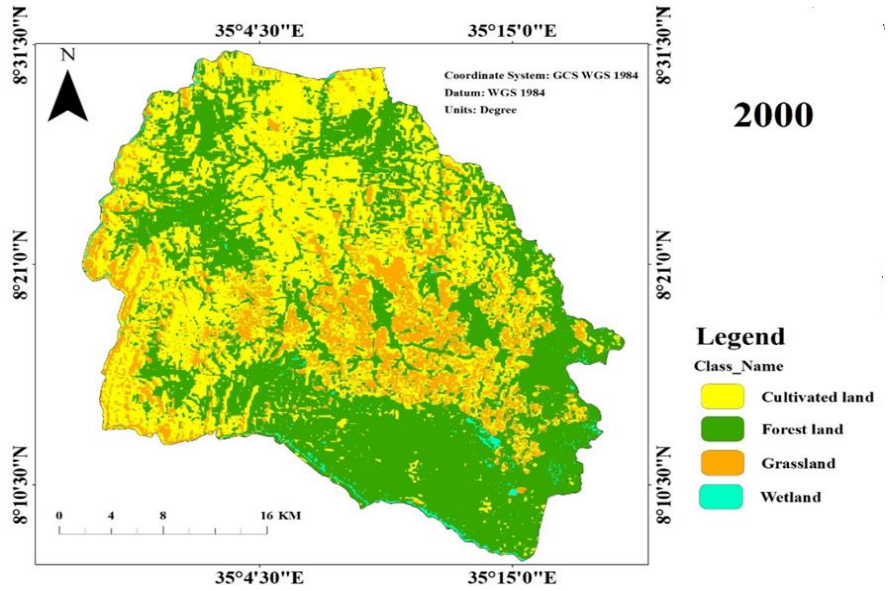

Figure 5
Land cover change map of 2000 in Bure district

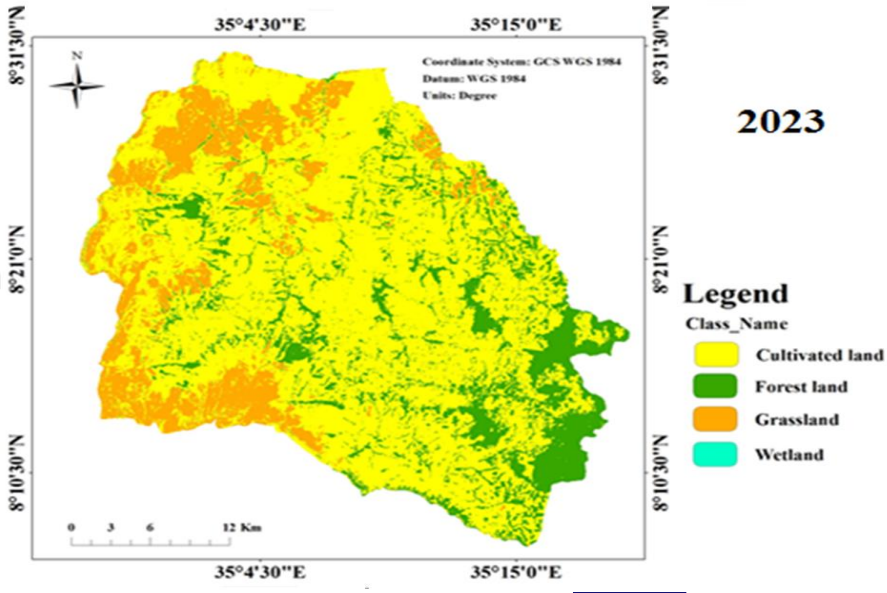

Figure 6
Land cover change map of 2023 in Bure district

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is the main cause of the encroachment into natural forests. Agricultural land expansion was found to be a significant contributing factor to deforestation in a similar study conducted in north-western Ethiopia (Alemu et al., 2015). A similar related study conducted in Ethiopia by Bekele et al. (2015) reported that the forest sector is seriously threatened by the area being cleared for new crops due to the country's rapid population growth. Rapid population growth is the second important factor as perceived among 92.9% of the respondents (Table 4). It was also evident from field observations and remote sensing that the cultivated land had spread to the boundaries of the National Forest Priority Areas. The outcomes of focus group discussions and the reports from important informants further supported this. They reported that population growth was another factor that was responsible for the observed deforestation in the area. Increasing the deforestation rate with increasing population densities have been reported in several other studies in Ethiopia. For instance, a study conducted by Gebrelibanos & Assen, 2015 reported that population growth is a major driving force in land use and land cover dynamics in the Hirmi watershed and the nearby agro-ecosystem in the highlands of Northern Ethiopia. Another study by Alemu et al. (2015) in north-western Ethiopia also reported that population pressure is the most important driver for deforestation.

Charcoal making and timber production was viewed as other most important drivers of deforestation by 91.1% of the respondents in the study area. Focus group participants also mentioned that one of the key drivers of forest cover change is high demand for charcoal making and timber production as most of the study area population depend on forest resource for their livelihoods. Investment for coffee and tea plantation was also contributed to increase forest cover loss as mentioned by 89.9% of the respondents. In line with this Alemu et al. (2015) argued that implementation of investment and settlement policies without assessing environmental impact is a major problem of deforestation and forest degradation in Ethiopia. The majority (80.5%) of survey respondents stated that the extraction of fuel wood for construction materials and firewood is another important factor contributing to the deforestation in the area. High dependence on biomass energy was shown by the study of (Moges et al., 2010) as 90% cooking energy supply for the country and 99.9% rural energy supply. According to the information obtained from the focus group discussion and key informants interviews, the great majority of the household fuel, utensil and furniture were derived from forests.

Table 6
Drivers of forest cover change perceived by respondents in Bure district

Drivers of forest cover change	Responses (%)	Rank
	Yes	
Farm land expansion	96.1	1st
Population growth	92.9	2nd
Charcoal making and timber production	91.1	3rd
Investment for coffee and tea plantation	89.9	4th
Demand for fuelwood and construction materials	80.5	5th
Overgrazing	77.3	6th
Weak law enforcement	75.5	7th
Settlement	74.4	8th
Forest fire	44.9	9th

Another important factor that contributed to the decline of forest cover was overgrazing as mentioned by majority (77.3%) of the respondents. Livestock is the integral component of the agriculture on which the majority of the population depends in the study area. According to KII interviews and focus group discussions results poor livestock management which mainly based on the free grazing system as another causes of deforestation. A study conducted by Legesse et al. (2019) also reported that overgrazing is one of the factors contributing to Ethiopia's deforestation and forest degradation.

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More than 75% of respondents mentioned that weak law enforcement as main causes of deforestation in the area. Focus-group participants also reported that even though laws are enacted, deforestation has been increasing alarmingly in the study area due to weak law enforcement by concerned body. The result obtained in this study is thus similar to the one conducted north-western Ethiopia (Alemu et al., 2015), which report that weak regulatory and enforcement was ranked as the fourth driver by 69.4% of the respondents. Unclear institutional mandate between differrent institutions, lack of proper managements and poor tenure right were also recognized as the major cause that aggravating forest loss of forest in an area under study. According to interview with key informants of the study area weak forest management was the critical problem related to forest degradation and deforestation. The participants in the focus group discussion also added that inadequate tenure rights for forest land prevented the communities from efficiently managing the forests. Demographic shifts reinforced by the resettlement programs (74.4%) are them most frequently cited causes of deforestation (Table4). Forest fire (44.9%) was perceived by respondents as the least preferred drivers of forest dynamics in the study district. The result of this study is further supported by focus group discussion, who reported that forest fire occasionally occurred, particularly during the dry season started when clearing debris on their farm plots and during honey harvesting, which it quickly spread to the forests and grasslands, resulting in deforestation.

Impacts of forest cover change on rural livelihoods

The impacts of forest cover change on rural livelihoods are displayed in Figure 7. The majority of respondents (88.6%) mentioned decline of agricultural productivity as the primary effect of deforestation in the study area. The findings from key informant interviews and focus groups further supported the idea that declining agricultural productivity over the past few years has been caused by changes in forest cover. Likewise, a higher percentage of participants (85.1%) stated that losses in forest cover led to a decrease in biodiversity. The greatest percentage of respondents (81.2%) also stated that changes in forest cover have an impact on climate change. According to participants in focus groups and key informant interviews, deforestation plays a significant role in contributing to global climate change. It is also frequently identified as a primary cause of the enhanced greenhouse effect. Moreover, a considerable portion of the participants (78.5%) indicated that soil erosion was the primary outcome of forest degradation and deforestation in the study area. Participants in focus groups and key informant interviews also stated that the rate of soil erosion has

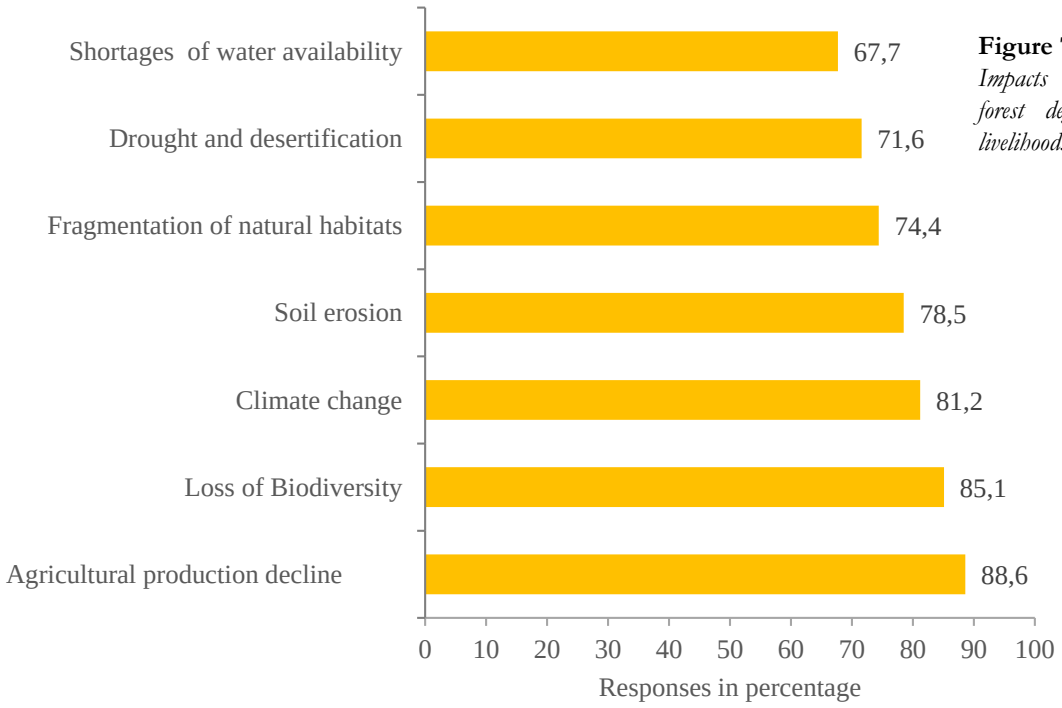

Figure 7
Impacts of deforestation and forest degradation on rural livelihoods

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been significantly impacted by changes in forest cover over the past few years. They added that the topsoil is now exposed to water erosion due to the rapid removal of vegetation in the area.

Conclusions and policy implications

The main objective of this study was to examine extent of forest cover change, its drivers and impacts in Bure district of Illubabor zone, southwest of Ethiopia. This study revealed that forest had experienced significant spatio-temporal changes over the last three and half decades (1986–2023). The satellite image analysis showed that the area under cultivated land dramatically increased, but the area of the forestland, grassland and wetland declined from its original size over the last 37 years. According to the data, there was a 29.03% decrease in forest cover from 1986 to 2023 in the study area. The study of land cover change revealed that the extension of cultivated area had mostly expanded from areas of grazing and forest lands. The expansion of farmland into forested areas, population pressure, the production of charcoal and timber, the need for fuelwood and building materials, overgrazing, settlement, forest fires, and investments in coffee and tea plantations were identified as the major causes for the deforestation in the area. The results further demonstrated that declining agricultural productivity, loss of biodiversity, climate change and soil erosion were among the main effects noted by local households in the study area. Therefore, this study suggests that increasing conservation measures through the implementation of afforestation and reforestation programs on degraded and deforested land is important to maintain the forest cover. Besides, effective law enforcement and more patrols should lessen the likelihood that people will intrude into the forests.

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