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Spatiotemporal forest cover change and its implication for environmental sustainability in Dedo district of Jimma zone, southwest Ethiopia

Nigus Tekleselassie Tsegaye [a,c,*], Wakjira Takala Dibaba [b], Dessalegn Obsi Gemeda [a]

[a] Jimma University College of Agriculture and Veterinary Medicine, Department of Natural Resource Management, Jimma, Ethiopia
[b] Jimma University Faculty of Civil and Environmental Engineering, Jimma, Ethiopia
[c] Ethiopian Forestry Development, Jimma Center, Ethiopia

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A B S T R A C T

Forest is one of the key precious resources that support human well-being by providing ecosystem services. Unfortunately, the forest cover has decreased over time due to natural and anthropogenic factors. The present study aims to assess the spatiotemporal forest cover changes and its implication on environmental sustainability in Dedo district in southwestern parts of Ethiopia. We used three Landsat images from 1985, 2002 and 2019. The results show that forest cover areas declined from 64,872 ha in 1985 to 53,805 ha in the year 2019. The study area lost about 11,067 ha (7.7%) of forest over the past 34 years. In contrast, the farmland was increased from 38,801 ha (27.06%) in 1985 to 54,917 ha (38.3%) in 2019. The increasing trend of cultivated land is associated with the increment of human population. Forest cover has been declined in the study area for a variety of reasons, including fire wood collection, charcoal and timber extraction, semi-forest and khat investments, and settlements. Loss of forest cover can have significant implications for environmental sustainability, as forests have played an important role in ecosystem services, such as climate regulation, clean air, flood control, carbon sequestration, soil protection against soil erosion, and increased environmental resilience to the impacts of climate change. The existence of forest resources can contribute to sustainable development of local communities, as the majority of agricultural communities are directly or indirectly dependent on forest products. The findings of this study can be used to improve forest conservation and protection at different scales.

1. Introduction

Forests are valuable natural resource that supports human beings by providing ecosystem services (Zhang and Li, 2016). It is obvious that humans associated land use land cover (LULC) change brings significant impact on the environment. The increasing demand for firewood and timber production worsened the problem of forest degradation in third world countries (Iqbal and Khan, 2014; Kidane et al., 2019; Mengist et al., 2021; Yeshineh et al., 2022). A study by Odawa and Seo (2019) in Kenya found that there is an inverse relationship between human population growth and forest cover change. This anticorrelation is common in agriculture based economic activities like African and Asian countries.

Forest is the most vulnerable human-driven agricultural expansions. People and forest have an inextricable relationship. Similarly, many people directly or indirectly dependent on the forest to generate incomes and livelihood. For example, people depend on forest to build a house, make household items, cook food, and produce honey. Due to man's overuse of forest products, the impact on forests has been increasing recently. The relationship between the forest and the environment is very strong. Environmental disturbance such as forest cover loss have resulted to degradation of ecosystem services (Cudlín et al., 2013). As forest ecosystem services in tropics have declined, it is one of the international policy and political agendas to be solved to increase environmental resilience. Previous studies (Nayak and Mandal, 2019; Gemeda et al., 2021, 2022; Merga et al., 2022; Moisa et al., 2022; Zaman, 2022) stressed that LULC change significantly contribute to the changes in minimum and maximum temperatures, leading to environmental problems. Good air can only exist if there is a natural or man-made forest in an area. The presence of forests plays an important role in mitigating climate change. It is well understood that the existence of vegetation enables us to live in a climate-friendly environment.

It is easy for everyone to imagine that if the current situation continues, it could have a major impact on the environment. Forests not

* Corresponding author. Jimma University College of Agriculture and Veterinary Medicine, Department of Natural Resource Management, Jimma, Ethiopia.
E-mail address: nigustselassie@gmail.com (N.T. Tsegaye).

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only meet the daily needs of humans, but also play a crucial role in climate change mitigation. Forest can sequester carbon dioxide from the atmosphere and contributes towards climate change mitigation at global level. Recently, substantial studies have clearly documented the role of forest in climate change mitigation (Brown et al., 2020; Moomaw et al., 2020; Hou et al., 2020; van Kooten, 2020; Poudel et al., 2020; Calama et al., 2021; Dhyani et al., 2021; Huang et al., 2021; Njana et al., 2020).

Research data from various countries have confirmed that forest development is declining as the number of people using forests has increased. Depletion and shrinking forests are posing a serious threat to the delivery of ecosystem services. The main reason for this may be the increasing population and the fact that people are less aware of the benefits of forests. The provision of ecosystem services from the forest sector is expected to decline as a result of changing spatiotemporal forest cover (Hansen et al., 2010; Appiah et al., 2021; Calama et al., 2021). Besides ecosystem services, forest also plays a crucial role in protecting the environment from natural disasters. Forest conservation can prevent the occurrence of drought in one hand and plays an important role in increasing water resources on the other hand.

Since forests are used in small and large factories, if the relevant authorities do not take care of them, the forests may be significantly declined in the near future. The share of forest resources in industry is very high throughout the world. However, the overall use of forest resources for industry in Africa is limited, due to less investment in commercial agro-industrial business development (Hansen et al., 2010). Despite lower investment in the forest industry, the forest cover in the tropical region is experienced a declining trend as reported by Brown et al. (2020), which requires robust scientific evidence to influence the stakeholders to design appropriate management planning. Forest loss has significant impact both on the economy and environmental sustainability conditions.

Forest degradation is one of the key environmental challenges in developing countries whose livelihood is heavily depend on agriculture. Moreover, the multi-purpose provisions of forest resources in one hand and weak policy implementation on forest protection and conservation, results to forest cover loss. According to the Food and Agriculture Organization (FAO) global forest assessment report, the global forest cover declines overtime due to the increasing demand of forest products and need for more land for agricultural production. The global forestland cover was about 4128 million hectares (ha) in the year 1990, which dramatically declined to 3999 million ha in 2015, showing a decrease of 129 million ha in 25 years (FAO, 2016). The total forest cover in Africa continent was about 5,635,000 km^2 (17%) in the year 2000, and it declined by 115,000 km^2 (2%) in the year 2005 (Hansen et al., 2010).

It is not difficult to imagine that forest resources could decrease in the future as the number of populations is increasing across the globe. With this in mind, we wanted to do this research to see what the forests in this area look like and how they are now shrinking. Research conducted in Ethiopia shows that the area covered by forests is decreasing from time to time (Gebreselassie, 2014; Daye and Healey, 2015; Byg et al., 2017; Solomon et al., 2018; Alemneh et al., 2019; Berihun et al., 2019; Betru et al., 2019; Negassa et al., 2020; Abera et al., 2021). The global forest assessment report indicates that; the forest cover in Ethiopia in 2000 was about 3651935 ha, which was decreased to 3337988, 12295847 and 11527356 ha in 2005, 2010 and 2015, respectively (Food and Agriculture Organization, 2015).

The government of Ethiopia is documenting the increasing of forest cover over the last few years a result of mass green legacy. Knowing the rate of forest cover loss can support decision makers to take actions. Monitoring and detecting forest change has become an important element for forest policy development (Rotich and Ojwang, 2021). The government of Ethiopia initiated afforestation and reforestation programme to increase the forest coverage, particularly after Ethiopian Millennium (2008). In spite of government efforts to enhance forest resources, the forest cover in different regions shows a declining trend.

The main factor that leads to the change in forest cover in Dedo district was agricultural expansion leading to environmental problems. Over the past decades, the district was covered with a wide variety of natural and indigenous vegetation. Due to constant pressure from the local communities for the sake of poverty alleviation forest cover in Dedo district was substantially declined over the past decades. Forest resources are being depleted due to legally or illegally timber exploitation and use of forest products for income generation. Although forest surveys have been reported the declining of forest cover in various parts of the country, forest cover loss has not been studied in this area, especially in Dedo district. There is lack of up-to-date information on spatiotemporal forest cover in Dedo district. It is believed that forest cover in the study area was substantially declined for the purpose of agricultural land expansions and over-exploitation of forest products. However, there are no records that provide the necessary quantitative information, including extent, and trends of forest cover change. Most notably, this study is unique from previous studies by analyzing the negative implication of forest cover loss on economic and environmental sustainability. To conduct this study, we used geospatial techniques to understand how much forest cover changed in the study area between 1985 and 2019.

2. Materials and methods

2.1. Study site

Dedo district is one of the 23 districts of Jimma zone in southwestern parts of Ethiopia (Fig. 1). The study district is located between 7°10′-7°40′N latitude and 36°45′-37°10′E longitude, and has a total area of 143,400 ha. The elevation of the study area ranges from 898 to 3041 m above sea level. About 49.1% of the district is cultivated or agricultural land, while 23.9%, 13.9%, and 13.1% are forest, woodland and grassland, respectively. Barely, wheat, teff, maize, sorghum, bean, potatoes and coffee are the major agricultural crops in the study area. The district has a total population of 288,457, out of which 143,935 and 144,522 were males and females, respectively (Central Statistical Agency, 2007).

The study area experienced a long rainy season, occurring from June to September, with moderate rains in autumn (October and November) and spring (March to May). The study area received annual rainfall between 913.3 mm and 2935.58 mm. The temperature of the study area varied between 12 °C and 29 °C, with the average temperature of 19.5 °C.

2.2. Data type and source

2.2.1. Satellite image acquisition and processing

The Landsat data were downloaded from the USGS website (https://www.usgs.gov/) during the dry season (January to February). In this study, Landsat 5 (1985), Landsat 7 (2002), and Landsat 8 (2019) were taken (Table 1). The year 1985 was chosen as the starting point, due to a drought occurred in the country, which forced the Ethiopia government to relocate the drought and famine victims from the north to the southwestern parts of Ethiopia. In the present study, the supervised maximum likelihood classification method (Richards, 1995) was used for LULC classification. Finally, Landsat images of 1985, 2002, and 2019 are classified into forestland, shrubland, farmland, built-up, and bare land cover classes.

2.2.2. Accuracy assessment

An accuracy assessment was performed by comparing the assigned land cover class to each sample size with the actual land cover investigated using remotely sensed data. A comparison between the interpreted land cover map and a map containing the results of a ground truth was made using an error matrix to perform an accuracy assessment of the study area.

The overall accuracy and kappa statistics (Jensen, 2015) calculated by using Eq. (1).

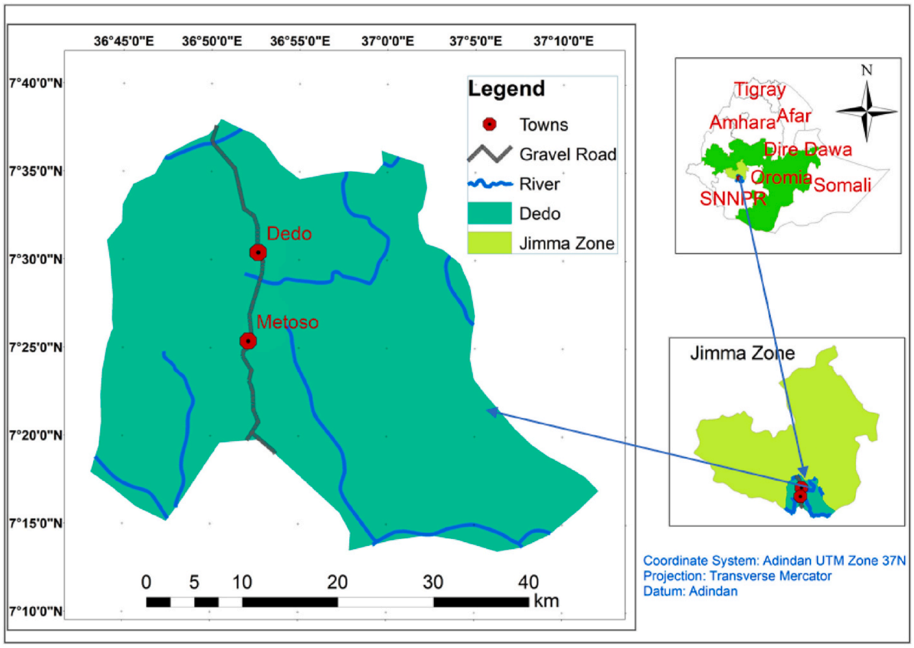

Fig. 1. Map of the study area.

Table 1
Data types and sources.

Data types	Path-row	Spatial resolution	Acquisitions date	Source of data
Landsat 5	169–055	30 m	23/02/1985	http://www.earthexplorer.
Landsat 7	169–055	30 m	01/01/2002	http://www.earthexplorer.
Landsat 8	169–055	30 m	23/01/2019	http://www.earthexplorer.
DEM Topo-map		12.5 m	2019	ASF Ethiopian Mapping Agency

$$OA = \frac{\text{Number of pixels correctly classified}}{\text{Total number of pixels}} \quad \text{Eq.1}$$

where, OA = overall accuracy; diagonals in the error matrixes table represent sites classified correctly according to reference data while off-diagonals are miss classified.

2.2.3. *Analysis of land use and land cover change*

Three methods were used to calculate LULCC statistics.

1) The total LULCC in hectares was determined using:

$$Total\ LULCC = A_f - A_i \quad \text{Eq.2}$$

where, A_f is Area of the final year, A_i is Area of the initial year. While negative numbers signify a reduction in extent, positive ones indicate an increase.

2) The following equation is used to compute the percentage of LULCC:

$$LULCC\ \% = \left(\frac{A_f - A_i}{A_i}\right)100 \quad \text{Eq.3}$$

where, A_f is Area of the final year, A_i is Area of the initial year. Positive values suggest an increase whereas negative values imply a decrease in extent.

3. Rate of LULCC

The rate of forest cover change between the year 1985, and 2019 was calculated by cross tabulation on pixel-by-pixel (Garai and Narayana, 2018; Munsi et al., 2009; Kumi et al., 2021). The rate of forest cover change is computed using Eq. (3).

$$R = \frac{Q2 - Q1}{T} \quad \text{Eq.4}$$

where R is rate of change, Q2 is final year (2019) of forest cover in ha, Q1 is initial year (1985) forest cover in ha and T is interval year between the initial year and final recent year.

4. Implication of forest cover loss on environmental sustainability

To understand the impact of forest cover loss on socioeconomic and environmental sustainability, we conducted a literature review from similar previous studies. In addition to literature reviews, we investigated the opinion of key informants on the implication of forest cover loss on socioeconomic and environmental sustainability in the study area.

5. Results and discussions

5.1. *LULC classification*

Five major LULC classes specifically; forest land, shrubland, farmland, built-up and bare land were categorized in the study area. In this study, both plantation forests and natural forests were classified as forest land; since they share similar spectral nature, and it is difficult to differentiate. The other reason is the Landsat image resolution (30 m) we used in the present study isn't good enough to distinguish different land cover with similar reflectance like plantation forest and natural forest. Thus, we recommend high resolution satellite image like SPOT 5, which can easily distinguish plantation forest from natural forest.

The results show that forest cover area is the highest followed by farmland in the year 1985 (Table 2). The forest cover comprises about 64,872 ha (45.24%) of the study area in 1985, and has reduced to

Table 2
Summary statistics of LULC (1985–2019).

Class Name	Year					
	1985		2002		2019	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest land	64,872	45.24	59,633	41.58	53,805	37.52
Shrub land	17,883	12.47	15,081	10.52	12,385	8.64
Farm land	38,801	27.06	45,172	31.5	54,917	38.3
Built-Up	15,594	10.87	18,346	12.79	20,648	14.4
Bare land	6250	4.36	5168	3.6	1645	1.15
Total	143,400	100	143,400	100	143,400	100

59,633 ha (41.58%) in the year 2002, then decreased to 53,805 ha (37.52%) by the year 2019. It is well known that the decline of forest cover can cause significant damage on the natural environment. Our findings are in agreement with the work of (Negassa et al., 2020) who confirmed that forest cover is converted to farm land to address the demand for more open space for agriculture. Therefore, it is possible to correlate the loss of forest cover with rapid population growth in developing countries. Kogo et al. (2019) and Rotich and Ojwang (2021) highlight that deforestation affects ecosystem services. Deforestation also poses a significant impact on socio-economic development. As compared to the socio-economic development, the impact of deforestation on the environment may be apparent in the short term as forest loss may significantly affect fresh air, clean water, soil moisture, wind, temperature, precipitation and climate in general.

The forest cover is substantially declined overtime in the study area as the result of semi-coffee forest and khat plantation and intensification of cereal crops. In contrast, farmland, shrubland, built-up and bare land accounted for 38,801 ha (27.06%), 17,883 ha (12.47%), 15,594 ha (10.87%) and 6250 ha (4.36%), respectively. Better understanding of LULC change is important for effective land use planning and ecosystem management (Kogo et al., 2019). This study clearly indicates significant declining of forest cover over the study period. In contrast, farmland, and built-up up area registered gains over the last thirty-four years. The increasing trend of farmland and the declining of forest cover area is attributed to population growth in the study area.

The results of LULC classification of 2002 indicates that the forest cover in the study area is relatively higher than the other land cover classes. It occupied an area of 59,633 ha (41.58%), followed by farmland, built-up, shrubland and bare land accounted for 45,172 ha (31.5%), 18,346 ha (12.79%), 15,081 ha (10.52%) and 5168 ha (3.6%), respectively. About 54,917 ha (38.3%), 20,648 ha (14.4%), 12,385 ha (8.64%) and 1645 ha (1.15%) were covered to farmland, built-up, shrubland and bare land, respectively in 2019. A study by Odawa and Seo (2019) in Kenya found that there is an inverse relationship between the change in forest cover and the rapid population growth. Furtado and Martins (2018) conclude that land use intensification due to rapid population growth and demand for more food supply leads to irreversible environmental changes. Therefore, any environmental management should consider the potential impacts of population growth on forest cover change. The share of each LULC in 1985, 2002, and 2019 is presented in (Fig. 2).

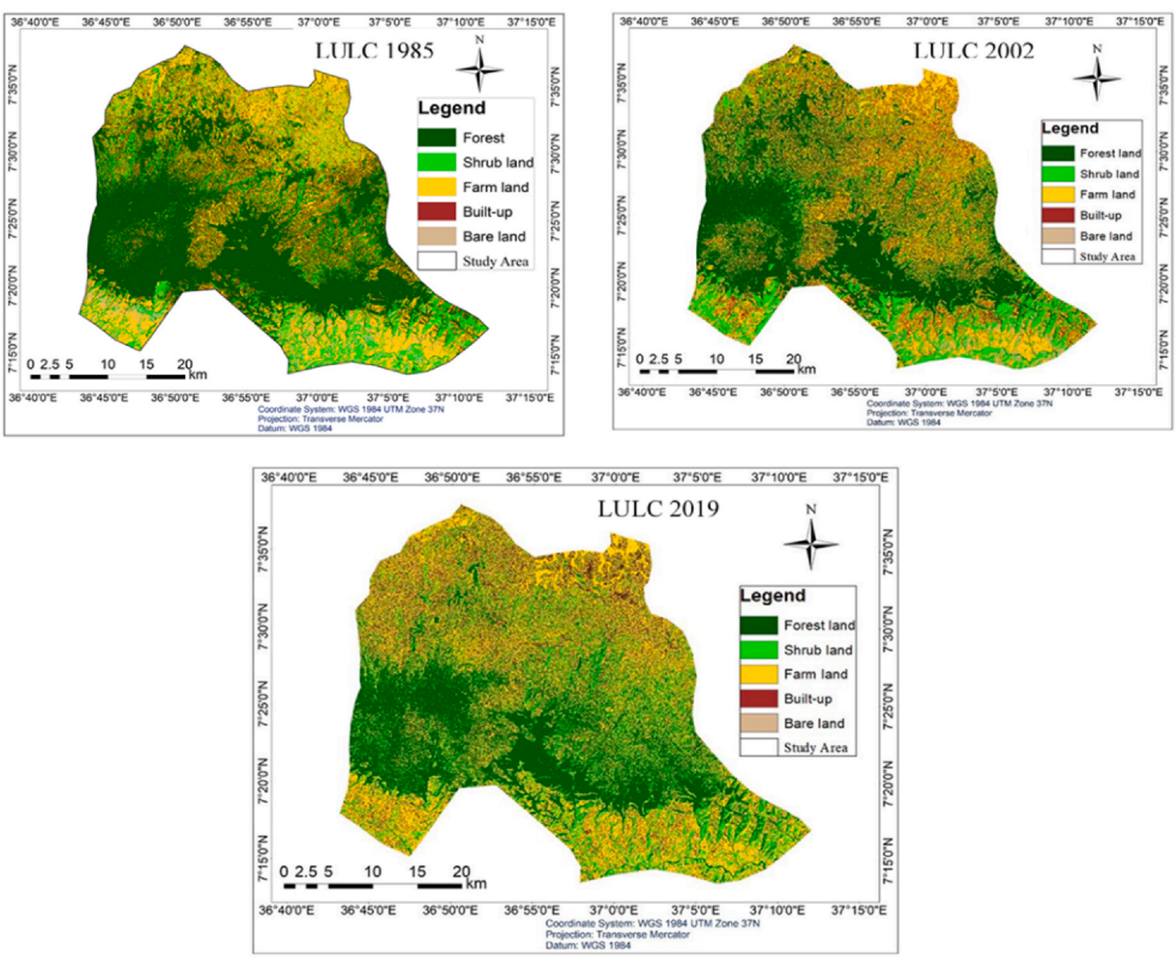

Fig. 2. LULC map of Dedo district in 1985, 2002, and 2019.

5.2. Accuracy assessment

An accuracy assessment using confusion matrix (Story and Congalton, 1986; Garai and Narayana, 2018; Thakur et al., 2020), and Kappa co-efficient (Lea and Curtis, 2010; Islam et al., 2018; Hossain and Moniruzzaman, 2021) are performed. The accuracy assessment result of 2019 classified image is presented in (Table 3). The obtained Kappa coefficient for the present study is 0.8905, and the computed overall accuracy is 91.7%.

5.3. Change detection analysis

In the present study, the rate, and pattern of forest cover change are presented and discussed. Results show that there is a significant change in the pattern of LULC in the Dedo district from 1985 to 2019. The results revealed that the forest cover area of 64,872 ha (45.24%) in 1985 declined to 53,805 ha (37.52%) in 2019. The declining of forest resources remains a key challenge in tropical countries (Venegas-Cubillos, 2022). Deforestation is one of the key challenges in tropical countries that negatively affects the provisions of ecosystem services (Allen and Vasquez, 2017). The farmland and built-up area land cover classes have also experienced a significant change with time. These results are in agreement with that by Negassa et al. (2020) in western parts of Ethiopia, and Rotich and Ojwang (2021) in western Kenya found that substantial changes in LULC indicates high demands of land use by the local communities.

There are different factors that contributes for the declining of forest cover. Among these factors, population growth is the most dominant, which demand more open space for agricultural activities. The land less households are forced to encroach the forest and covert to agricultural land and settlement areas. In addition to agricultural farming, forest is served as a major source of livelihoods, local communities exploit fuel wood and timber production. These results are in agreement with that by Iqbal and Khan (2014), who reported that forest cover was declined due to ever grown human population that extract timber and fuel wood.

Shrubland has also declined from 17,883 ha (12.47%) by 1985, to 15,081 ha (10.52%) in 2002, then reduced to 12,385 ha (8.64%) in 2019. This finding is comparable with the finding of Kidane et al. (2019) in West Shewa zone in Ethiopia who found that the shrubland cover classes declined from 12.3% in 1995 to 8.54% in 2015. Bare land in another land cover classes which experienced a declining trend. However, the rate of declining is not comparable with that of forest resources. There was a slight decline in the bare land cover classes over the past three decades in the study area. Accordingly, the share of bare land cover classes was 6250 ha (4.36%) in 1985, and slightly declined to 5168 ha (3.6%), and 1645 ha (1.15%) in the year 2002, 2019, respectively. The rate of change over bare land class is relatively low due to less demand from the local communities.

The farmland was 38,801 ha in the year 1985 (27.06%), which rapidly increased to 45,172 ha (31.5%) and 54,917 ha (38.3%) in the year 2002 and 2019, respectively (Table 4). Farm land expansion is one of the most important drivers of deforestation in the study area. Our results are consistent with Rotich and Ojwang (2021), who found that expansion of farmland is the main cause of deforestation. The built-up area was another land-use class that showed continuous increment over the study period. The area under the built-up area increased from 15,594 ha (10.87%) in 1985 to 18,346 ha (12.79%), and 20,648 ha (14.4%) in the year 2002 and 2019, respectively.

The calculated LULC conversions in this study is presented in (Table 5). The diagonal of the table shows the LULC proportions that remain unchanged from 1985 to 2002. The total area of unchanged LULC proportion during the study period was estimated to be 74,959 ha, representing 52.3% of the study area. Results show that the forest land cover made the highest conversion, as an area of 10,788 ha (16.63%) were converted to farmland. This is mainly due to heavy dependence of the local community on agriculture. People are converting forest land to agricultural land since the existing cultivated land is not sufficient to support the farming communities.

About 5841 ha of shrub land was changed to farmland, representing 4.1%. The conversion of forest land to other LULC classes such as shrub land, built-up and bare land are 3476 ha (2.4%), 4244 ha (3%) and 136 ha (0.1%), respectively. In the study area about 7602 ha (19.59%) of farm land was converted to settlement area as the number of populations is increasing. Our results also revealed that substantial areas of bare land were transformed to farm land, which accounts about 2307 ha (36.91%). Rapid change in LULC has a significant impact on the environment. LULC change may alter the hydrological cycle which in turn to environmental deterioration.

Between the year 2002 and 2019, a total area of 4379 ha (3.1%), 3509 ha (2.4%) and 110 ha (0.01%) were converted from forest cover to shrub land, built-up area, and bare land, respectively (Table 6). The forest land made the highest conversion of 12,658 ha to farm land representing 8.8%, followed by farm land converted to built-up 9783 ha representing 6.8% of the area. This conversion causes the reduction of soil organic matter that results in degradation of physical soil properties (Tolimir et al., 2020). To ensure the sustainability of soil organic matter and agricultural yield sustainable environmental management is needed. The forest cover decreased from 64,872 ha in 1985 to 53,805 ha (11,067) by the year 2019, representing 7.7% loss over the study period (Table 7). The conversion of forest land to other LULC classes such as shrub land, built-up and bare land are 4919 ha (3.4%), 4144 ha (2.9%) and 152 ha (0.1%), respectively. Other LULC conversions are shrub land to farm land 7800 ha (43.62%) and farm land to built-up 9419 ha (24.28%).

5.4. Change detection analysis

The forest cover class accounts about 64,872 ha (45.24%) in the year 1985, and later decreased to 59,633 ha (41.58%), and 53,805 ha (37.52%) in the year 2002 and 2019, respectively. Deforestation during the 1985–2002 period might be due to immigration from northern and north-central parts of Ethiopia, in response to the deadly famines of the 1980s. Human resettlement, large-scale agricultural investment, and charcoal production contribute to the reduction of forest cover

Table 3
Confusion matrix of the year 2019.

	Class name	Ground truth data							
		Forest	Shrub land	Farm land	Built-up	Bare land	Row Total	User accuracy	KC for each Category
Classified Image	Forest land	38	0	1	0	0	39	97.44%	0.965
	Shrub land	0	13	1	0	0	14	92.86%	0.920
	Farm land	1	2	42	3	1	49	85.71%	0.789
	Built-up	0	0	3	28	0	31	90.32%	0.877
	Bare land	0	0	0	0	11	11	100.00%	1.00
	Column Total	39	15	47	31	12	144		
	Producers Accuracy	97.44%	86.67%	89.36%	90.32%	91.67%			

Overall Accuracy = (132/144) 91.7% Users accuracy = number correct/classified total.
Overall Kappa Coefficient = 0.8905 Producers accuracy = number correct/reference total.

Table 4
LULC change in Dedo district in 1985, 2002, and 2019.

LULC class	Year						Net-Change 1985–2002 (ha)	Net-Change (1985–2002) %	Net-Change 2002–2019 (ha)	Net-Change (2002–2019) %	Net-Change 1985–2019 (ha)	Net-Change (1985–2019) %
	1985		2002		2019							
	Area (ha)	%	Area (ha)	%	Area (ha)	%						
Forest land	64,872	45.24	59,633	41.58	53,805	37.52	−5239	−8.08	−5828	−9.77	−11,067	−17.06
Shrub land	17,883	12.47	15,081	10.52	12,385	8.64	−2802	−15.67	−2696	−17.88	−5498	−30.74
Farm land	38,801	27.06	45,172	31.5	54,917	38.3	6371	16.42	9745	21.57	16,116	41.54
Built-Up	15,594	10.87	18,346	12.79	20,648	14.4	2752	17.65	2302	12.55	5054	32.41
Bare land	6250	4.36	5168	3.6	1645	1.15	−1082	−17.31	−3523	−68.17	−4605	−73.68
Total	143,400		143,400		143,400	100						

Table 5
LULC changes matrix of Dedo district from 2002 to 2019 in ha.

	LULC of 2019												
	LULC Class	Forest land		Shrub land		Farm land		Built-Up		Bare land		Class Total	
		Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
LULC of 2002	Forest land	38,977	65.36	4379	7.34	12,658	21.23	3509	5.88	110	0.18	59,633	100
	Shrub land	3703	24.56	3293	21.83	6106	40.49	157	10.41	409	2.71	15,081	100
	Farm land	8057	17.84	3128	6.92	23,642	52.34	9783	21.66	562	1.24	45,172	100
	Built-Up	2886	15.73	1036	5.65	9382	51.14	4881	26.6	161	0.88	18,346	100
	Bare land	182	3.52	549	10.62	3129	60.55	905	17.51	403	7.8	5168	100
	Class Total	53,805	37.52	12,385	8.63	54,917	38.3	20,648	14.4	1645	1.15	143,400	100

Table 6
LULC changes matrix of Dedo district from 1985 to 2019 in ha.

	LULC of 2019												
	LULC Class	Forest land		Shrub land		Farm land		Built-Up		Bare land		Class Total	
		Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
LULC of 1985	Forest land	40,937	63.1	4919	7.58	14,720	22.69	4144	6.39	152	0.23	64,872	100
	Shrub land	3826	21.39	3039	16.99	7800	43.62	2762	15.44	456	2.55	17,883	100
	Farm land	4981	12.84	2584	6.66	21,169	54.56	9419	24.28	648	1.67	38,801	100
	Built-Up	3655	23.44	1028	6.6	7589	48.66	3235	20.74	87	0.56	15,594	100
	Bare land	406	6.5	815	13.04	3639	58.23	1088	17.41	302	4.82	6250	100
	Class Total	53,805	37.52	12,385	8.63	54,917	38.3	20,648	14.4	1645	1.15	143,400	100

Table 7
Pattern of forest cover change into other LULC classes.

Forest cover change	B/N 1985 & 2002		B/N 2002 & 2019	
	Area (ha)	%	Area (ha)	%
Forest to shrub land	3476	18.64	4379	21.19
Forest to farm land	10,788	57.86	12,658	61.28
Forest to built-Up	4244	22.76	3509	16.98
Forest to bare land	136	0.72	110	0.53
Total change	18,644	100	20,656	100

(Yeshineh et al., 2022). Mengist et al. (2021) also highlight that cultivated land and settlement areas gain much from the forested areas around Kaffa biosphere reserve in southwestern part of Ethiopia. Between the years 2002 and 2019, coal mining and construction of a road to access the mining sites were another factor that aggravated the loss of forest cover in the area. The spatial distribution of forest cover in 1985, 2002, and 2019 is presented in (Fig. 3).

5.5. *Areal extent and rate of forest cover change*

Forest extent declined by 45.24% in 1985 to 41.58% and 37.52% in 2002, and 2019, respectively. Between 1985, and 2002, about 8% of the total forest deforested in the area, while between 2002 and 2019 about 9% of the forest land cover are lost. Between 1985 and 2002, about 5239 ha of forest were deforested, which indicates there is a loss of 308 ha per year. Between 2002 and 2019, about 6, 828 ha of forest were deforested with an average loss of 343 ha per year. In the past three decades a total of 11,039 ha of forest deforested with an average loss of 326 ha per year.

5.6. *Patterns of forest cover change*

The pattern of forest cover change between the years 1985 and 2019 is presented in (Table 7). About 18,644 ha of forest was converted into other LULC units between 1985 and 2002. Based on the result, it was evident that 57.86% and 22.7% of forest cover was converted into farm land and built-up areas, respectively between 1985 and 2002 in the study area. The remaining 18.64% and 0.72% of the forest cover was converted into shrubland and bare land, respectively.

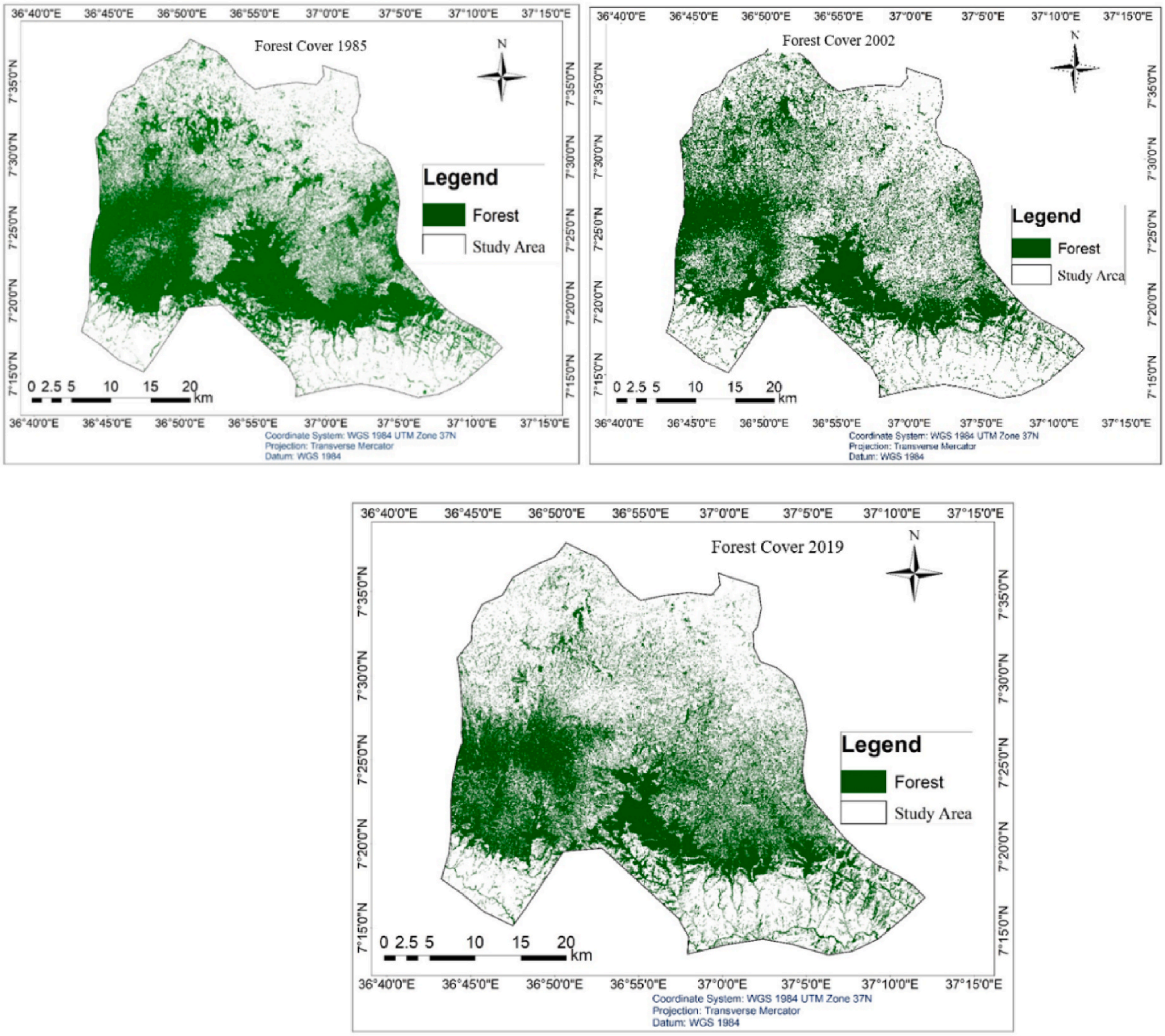

Fig. 3. Forest cover map of Dedo district in 1985, 2002, and 2019.

Between 2002 and 2019, a total of 20,656 ha of forest cover was changed into other land cover units. The conversion of forest land to farm land was about 61.28%. The increasing demands for fuel wood and timber, agricultural investments, charcoal production and human settlement are some of the major contributing factors for the declining of forest cover in the study area. This result is consistent with the work reported by Yeshineh et al. (2022), who found that forest cover was declined as the results of re-settlement, agricultural expansion, and charcoal production in the northwestern part of Ethiopia. Semi-forest coffee and khat investment also threatened the forest cover in the study area.

5.7. Implication of forest cover loss on environmental sustainability

It is unequivocally that forest cover loss in developing countries led to significant impact on biodiversity and environmental sustainability. The increasing demand for agricultural products is the major driving factors for the loss of forest ecosystems in tropical regions (Gibbas et al., 2010; Miyamoto et al., 2014; Pawar and Rothkar, 2015; Twongyirwe et al., 2018). Forest protects communities' livelihoods and contribute to sustainable development and well-being of rural communities. The agricultural expansion and wood extraction on the one hand and weak policy implementation on the other hand contribute to the declining of forest cover in the study area. The key informants clearly indicates that the forest sector in the study area is under serious threats that can affect forest ecosystem services, including climate regulation, water supply and regulation, energy and bioproducts and habitat for wild animals. Zhang et al. (2022) reported that forest ecosystems are important to human sustainable development and survival. Forest loss can setback sustainable development. Zaman (2022) showed that forest degradation exacerbates the problem of climate change by increasing the concentration of greenhouse gases in the atmosphere, hindering achievement of the global environmental sustainability agenda. Forest protection is essential for the sustainable survival of people on this planet. Without forests, life on this planet would be a problem. Therefore, forest protection and conservation benefit and ensure the sustainability of future generations on this planet.

6. Conclusion

Agricultural expansion, fuel wood and timer exploitation, charcoal production, and human settlement at the forest edges contribute to the reduction of forest cover in the study area. Semi-forest coffee and khat farming inside and along the margin of forest are another driving forces for the declining of forest cover. From all factors, agricultural expansions played a key role in forest degradation. Forest cover land is declining and is expected to decline in the future due to rapidly growing population of the region. The declining of forest cover significantly affects water and soil conservation, biodiversity conservation and climate change. Forest loss due to agricultural expansions and overexploitation of forest products has negative impacts on socio-economic and environmental sustainability. It is too difficult to sustain the environment in the absence of forest resources. Thus, investing on tree planting is important as a key strategy to sustain environmental health. The problem of forest degradation is very complex and requires the involvement of various stakeholders. Thus, an integrated forest conservation plans and participatory forest management practices are urgently required to maintain environmental sustainability. Particular attention should be given to afforestation and reforestation programs to increase the resilience of the environmental to the impacts of climate change. Moreover, high-resolution satellite imagery should be used to conduct detailed scientific research that can influence policy makers at national, regional and global level on forest conservation.

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Data availability

The data that has been used is confidential.

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