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Effect of forest cover change on ecosystem services in central highlands of Ethiopia: A case of Wof-Washa forest

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ABSTRACT

Forest provides a wide range of ecosystem services and is considered as one of the major sources of livelihood for the local people. In recent years, forest cover in developing countries has been declining due to expansion of agricultural land and increasing human demand for forest products.

The declining of forest cover significantly reduces forest ecosystem services, impacting environmental health and community well-being. Although many studies have shown declining of forest cover, the impact of declining forest cover on ecosystem services is not getting much attention in Ethiopia. Therefore, this study aimed to assess the impact of forest cover change on ecosystem service values in the Wof-Washa forest over the past 47 years. This study combined geospatial techniques and socioeconomic survey methods to assess the impact of land use and land cover (LULC) change on the value of ecosystem services. Ecosystem services were estimated using the benefit transfer method and socioeconomic assessment. A total of 184 households were surveyed with structured and semi-structured questionnaires. The results revealed that the provisioning services increased, while the regulating, supportive, and cultural services decreased. We find that about US$ 2 million were reduced due to LULC change, especially due to forest cover change. As forest cover decreased, the monetary value of ecosystem services and their benefits to local people declined significantly. The results reveal that deforestation is a major challenge that can reduce the value of ecosystem services. The results of this study are vital for developing effective forest conservation strategies before irreversible damage to ecosystem services.

1. Introduction

Forests provide a variety of ecosystem services that play a major role in the livelihoods of local people. People depend on forests for ecosystem services such as house construction, firewood, honey production, wild edible fruits and spices. Ecosystem services is defined as the benefits people obtain from nature, directly and indirectly [1–3]. Ecosystem services consists of flows of materials, energy, and information from natural capital stocks which combine with manufactured and human capital services to produce human welfare [1]. History tells us that people used to eat things they found in the forest before they started agricultural practices. Agricultural practices primarily focused on shifting herding, but crop domestication developed thousands of years later in the southern Sahara, including Ethiopia [4].

Foraging and agriculture began competing with each other after humans began growing crops approximately 12,000 years ago [5].

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As such, people have had huge impacts on forests since the evolution of agriculture, the forest cover declined significantly in several regions. In the future, especially in developing countries like Ethiopia, the number of people using forest resources is expected to double as the population grows. Significant number of people in Ethiopia depend on forest for energy, construction, non-timber forest products such as fruits, vegetables, medicinal plants, fibers, and honey, as their ancestors have for generations.

Increasing agricultural land in tropical regions at the expense of forests has significant impacts on the environment [6–8]. Land use and land cover (LULC) conversion is another threat to forest ecosystems. The LULC change is literally defined as the study of land surface change over the given period. These changes can lead to biodiversity loss and have significant impacts on ecosystem services. The LULC change disrupts the actual flow of ecosystem services [9–11]. A study by Ref. [12] in Upper Blue Nile found that tremendous LULC changes are causing great damage to ecosystem services. Expanding agricultural land to meet the growing demand for food, fuel and fiber has received research attention recently as forest encroachments negatively affect global public goods and biodiversity [6,13].

Forests offer a number of ecosystem services [14,15]. Forests can be considered multiuse natural resources due to their capacity to provide various ecosystem services. Among forest ecosystem services, food supply, fodder for livestock, pharmaceuticals, firewood and timber, filtered water supply, erosion and flood mitigation, biodiversity conservation, climate regulation, and recreational values are the most prominent. Although forest ecosystem services are very important, people are converting forest to agricultural land in several countries [16–21]. The expansion of agricultural land may be due to increasing demands for agriculture caused by population growth.

The results of LULC change analysis based on geographic information system (GIS) and remote sensing showed that global forest cover has declined significantly in recent decades [22–24]. Some regions experienced a declining trend, while others experienced an increasing trend. For instance, the FAO Global Forest Resources Assessment 2015 reported that temperate forest has increased, while tropical forest cover declines [25]. A study by Ref. [26] found that forest cover increased in the Global North but sharply declined in the Global South.

The pressure on forest cover is expected to continue as the population grows exponentially [27]. The increasing trend in the human population will increase the demand for forest products [2]. These declines are reported to have significant impacts on ecosystem services [28–31]. Conflicting results on forest cover changes have been reported in Ethiopia. Some authors reported reductions in forest cover [19,32–37], while others have found increased forest cover due to afforestation [38,39].

Whether forests are shrinking or increasing is debatable, but it is hard to imagine that rapid population growth and increased human demand for forest products are putting forest under enormous pressure in many places. The decline in forest cover has a considerable impact on the capacity of ecosystem services. A study by Ref. [34] in the Kaffa Biosphere Reserve found that LULC conversion significantly affects ecosystem services. The ecosystem services approach was originally developed to understand the importance of ecological processes that support human well-being and to integrate those values into decision making [40–42]. More specifically, study by Ref. [1] reported that ecosystem services are very important to human welfare. Valuation of ecosystem services is not an easy task for researchers. Some argue that valuation of ecosystem services is either impossible or unwise, that we cannot place a value on ecological benefits [1,43]. Others argued that economic valuation can lead to "selling out on nature'' [44].

Assessing changes in LULC and estimating the value of ecosystem services using the ecosystem service value coefficient is critical for quantifying the overall ecosystem service value [34,45,46]. Other studies highlight the importance of ecosystem services assessment for policy makers to identify benefits and trade-offs in environmental management [42,47–49]. Monetary quantification of the value of ecosystem services is critical to raising user awareness of the need to integrate the conservation of natural resources into prosperity, well-being and sustainability [50]. Valuing ecosystem services provides important information that can support the design of institutions that guide resource monitoring, management and policy formulation [41]. Well-established institutions can provide incentives so that the decision made by different sectors promote shared values. The Ethiopian government is giving high attention to realize the contribution of forests and woodlands as demonstrated by designation and safeguarding of a protected area system.

Previous studies have documented the importance of ecosystem services assessment in communicating the importance of environmental conservation [3,51,52]. The connection between human and forest is very high in Ethiopia. People are using forest on daily bases a source of economic and environmental services like timber, honey, gums, fodder, charcoal, fruits, spices, beeswax, and indigenous medicines [49,53]. Thus, it is possible to say forests are sources of environmental goods and services, and makes it difficult to live in this country without a forest product. However, the ecosystem services of forests are declined due to over-exploitation of forest resources.

Study conducted in the northern parts of Ethiopia [48,54], and in central parts of Ethiopia [55,56] reported the reduction of forest ecosystem services due to the declining of forest cover caused by over-exploitation. Similarly, studies conducted in southwestern parts of Ethiopia [45,57,58] documented significant declining of the values of climate regulation, erosion control, nutrient cycling, genetic resources, which can aggravate the problem of surface runoff and soil erosion.

It is essential to periodically assess the values of ecosystem services of a given area, which can support spatial planning, land management, and decision making on the wise use of natural resource. In addition, empirical data for local ecosystem services are limited. Thus, there is a need for further research at local level, that are most in need of additional study [1]. Ecosystem services become more stressed and 'scarce' in the future due to rapid conversion of LULC [1]. Although ecological and economic valuation methods for ecosystem services are widely applied, some studies have used the survey method [18,32,59,60] to estimate the value of ecosystem services. Other scholars used geospatial technologies [61–63] to calculate the ecosystem service values. A study by Ref. [43] highlight that there are no universally accepted techniques to assess ecosystem services. Moreover, there is full of uncertainty on monetary value of ecosystem services [64,65]. This study is more inclusive to evaluate the forest ecosystem services by integrating the results of satellite imagery and socioeconomic surveys. Understanding the extent of ecosystem services values will provides insight into what conservation strategies can be applied to minimize forest loss and maintain the wise use of forest resources. Assessing the impact of LULC changes on ecosystem services is important for raising public awareness and designing policies on ecosystem services. Furthermore, changes in forest cover are closely related to individual ecosystem services and change over time and space, requiring continuous research under changing environment. To this end, we have attempted to integrated geospatial technologies, survey methods, and the benefit transfer method to estimate the effect Wof-Washa forest cover change on ecosystem services.

2. Materials and methods

2.1. Study area

The Wof-Washa forest is located in the northern Shewa Zone of Ethiopia and is characterized as a dry mountain mixed broad-leaved/conifer forest. This forest is located between 9°38′ 00″ and 9°54′ 00″ latitude and 39°41′00″ and 39°51′ 30″ longitude and situated about 162 km northeast of Addis Ababa, the national capital. The Wof-Washa forests are located in the districts of Tarmaber, Bassona-werana, and Ankober (Fig. 1). The Wof-Washa forest lies in the eastern Afromontane Hotspot, an area of high biodiversity that extends across the Ethiopian highlands.

The topography of the study area varies between 1700 and 3700 m above sea level. The agroecological composition of the forest consists of cool subhumid, cold and humid and cold and moist climates. The study area receives maximum rainfall during the summer season (June to September) with a mean annual rainfall of approximately 1400 mm. Ethiopia has a diverse climate and landscape that ranges from equatorial rainforest to desert-like climate [66].

2.2. Data sources

Landsat1 Multispectral Sensor (MSS) 1973, Landsat 5 Thematic Mapper ™ 1988, Landsat7 Enhanced Thematic Mapper Plus (ETM+) 2003, and Landsat8 Operational Land Imager (OLI)/Thermal Infrared Scanner (TIRS) 2020 were downloaded from the U.S. Geological Survey (USGS) website (https://www.usgs.gov/). Descriptions and spatial resolutions of Landsat images are presented in Table 1.

2.3. Training data points

Ground control points were collected using the Global Positioning System (GPS) 72H Garmin, while inaccessible areas were collected using Google Earth. Training data for 1973, 1988, and 2003 were collected from Google Earth Pro and World images. Ground control points (GCPs) were collected using a GPS device (50 points from each LULC types). Such kind of data collection methods help to classify image and produce LULC map and perform accuracy assessment, which is important to minimizing potential classification errors in interpretation of spectral signatures.

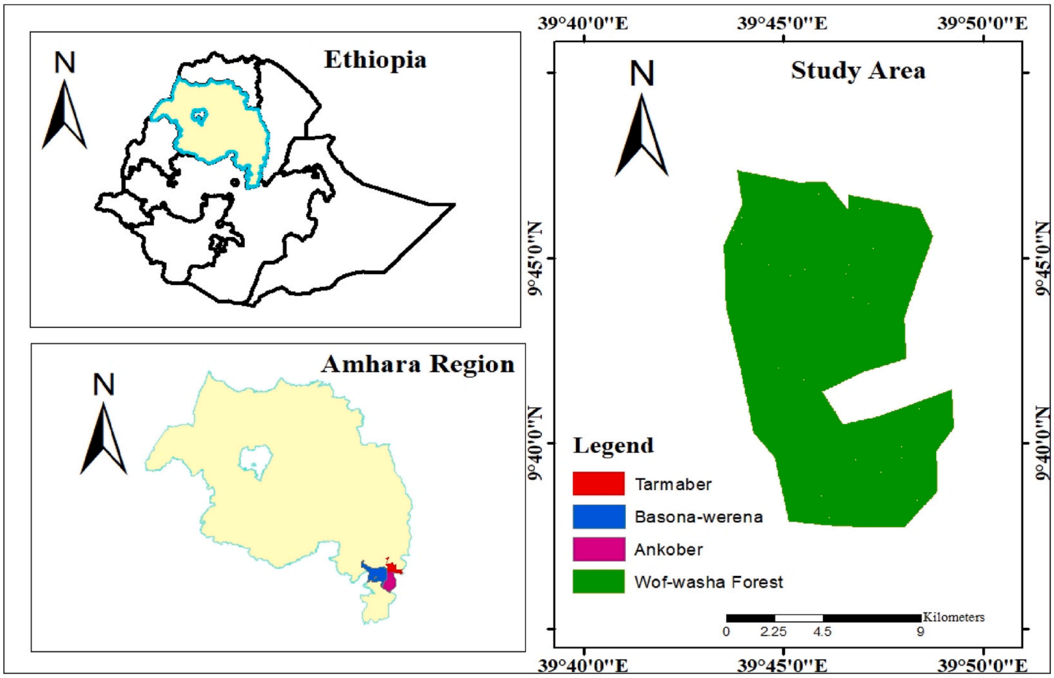

Fig. 1. Map of the study area.

Table 1
Descriptions of Landsat images.

Acquisition date	Images	Path/Row	Resolution (in meter)	Source
01/30/1973	Landsat MSS	180/53	60 m (resample to 30 m)	USGS
03/15/1988	Landsat TM	168/53	30 m	USGS
01/12/2003	Landsat ETM$^+$	168/53	30 m	USGS
01/19/2020	Landsat LOI-TIRS	168/53	30 m	USGS

In this study, field observation was conducted to observe and capture information on socio-economic activities about the respondent, LULC types in the study area. During field survey, interview with key informants such as community leaders, elders, and professionals were conducted to obtained firsthand information on forest ecosystem services and values.

2.4. Image preprocessing

The area of interest was designed from the original Landsat using ERDAS Imagine 2015 and connected to Google Earth Pro. Landsat MSS stacked bands 1–4, Landsat TM, Landsat ETM+, and Landsat OLI/TIRS are stacks of blue, green, red, near-infrared, and near-infrared bands. In the present study, both geometric correction [67] and geometric registration [68] were used to indicate the geometric correlation between each point in the images. False color composite was applied to Landsat MSS image for 1973 using Near Infrared (3), Red (2), and Landsat TM and ETM + using 4 (Red), 3 (Green) and 2 (Blue) and OLI-TIRS using 5 (Red), 4 (Green) and 3 (Blue).

2.5. Image classification

Each Landsat image was classified into forest, grassland, agriculture, settlement, and bare land. After image classification, forest change detection analysis was performed. First, resampling was applied to Landsat MSS classified images with a resolution of 30-m resolution. Second, LULC classification for 1973, 1988, 2003, and 2020 was performed. Third, the rate of change from 1973 to 2020 was determined using matrix union with the support of ERDAS IMAGINE. Finally, the net value of gain, loss, net change, and no change in forest cover were produced using ArcGIS. In the present study, forest cover change is calculated using Eq. (1)).

$$r = b - a \tag{1}$$

where r is forst cover change, a is recent year forest cover in hectare.
b is the initial forest cover in hectare.

2.6. Accuracy assessment

Accuracy assessment for 1973, 1988, 2003, and 2020 was performed to produce an error matrix and accuracy measures for final classification following [69]. All accuracy assessment techniques, namely, User's [70], producer's, overall accuracy and Kappa coefficients [71], were computed in the present study.

To identify the types of ecosystem services that forests provide to communities, we interviewed 184 people from different groups (elders, forestry department heads, rural and agricultural development employers, and Wof-Washa forest project managers). During the interviews, the types of ecosystem services that were provided to local people were listed (Supplementary Materials (SM) Table 1).

After stakeholders identified ecosystem services, we conducted direct interviews with household heads of a total of 184 households in the three districts covering the Wof-Washa forest. After identifying ecosystem services, structured and semi structured household questionnaires were developed to identify forest ecosystem services. Five classes of Likert scales from very low importance to very high importance were used following [72] to identify the scale of ecosystem services provided by the forests.

2.7. Estimation of ecosystem service values

The assessment of ecosystem services for each LULC class was calculated using the benefit transfer method [73,74]. Benefit transfer method is a technique to estimate the economic benefits collected from one site and applying to them to another [73]. This method is one of the most widely used technique to estimate economic values of ecosystem services. In the present study, the corresponding

Table 2
Sample size for each village.

District	Villages	Total household	Sample taken
Tarmaber	Wof-Washa	1311	78
Ankober	Mescha	742	44
Basona Worrena	Keyit	1042	6
	Total	3095	184

valuation coefficients of ecosystem services were assigned for all LULC classes (SM Table 2). Ecosystem services value [75] and ecosystem services value of function [76] were calculated for each LULC class (SM Table 3). The valuation coefficients and annual value coefficients for ecosystem services function for each LULC class was calculated using Eq. 2, and 3), respectively.

$$ESV = (A_k * VC_k) \tag{2}$$

$$ESV_f = \left(A_k * VC_{fk}\right) \tag{3}$$

where ESV is the estimated ecosystem services value.

ESV_f is ecosystem services value function, Ak is the area in hectare.

VC_k is the value coefficient $(US\$ha^{-1}yr^{-1})$.

VC_{fk} is the value of coefficient of function f $(US\$ha^{-1}yr^{-1})$ for LULC class.

The value of ecosystem services change (gain and/or loss) was measured as the difference between the estimates for each reference year following previous studies [76,77]. The coefficient of sensitivity was calculated using Eq. (4)).

$$CS = \frac{(EVa - \mathrm{EVi})/\mathrm{EVi}}{(VCa_k - VCi_k)/VCi_k} \tag{4}$$

where CS = coefficient of sensitivity, EV = the estimated service value, VC = the value coefficient, "a" and "i" refer to the "adjusted" and "initial" values, respectively, and "k" is the land use class.

2.8. Sampling size and sampling techniques for household survey

In the present study, a multi stage sampling techniques was employed to select sample villages and household. In the first stage three districts (Tarmaber, Ankober and Basona Worrena) were selected purposively due to geographically location of the Wof- Washa forest. In the second stage, three villages from the total of 11 villages were purposively selected based on household dependency on forest ecosystem services. Thirdly, simple random sampling technique was used to selected 184 households from the selected sampled villages namely Wof-washa, Mescha, and Keyit were selected purposively (Table, 2). To determine representative sample size [78] at 95% confidence level, degree of variability(p) = 0.5 and level of precision(e) = 7% (0.07) by using Eq. (5).

$$\mathrm{n} = \frac{N * Z^2 * p * q}{e^2(N-1) + Z^2 * p * q} = \frac{3095 * 1.96^2 * 0.5 * 0.5}{0.07^2(3095-1) + 1.96^2 * 0.5 * 0.5} = \frac{2972.44}{16.121} = 184.38 \sim 184 \tag{5}$$

To calculate the distribution of sample of household of the three villages Eq. (6) was used.

$$n_o = \frac{N_1}{N} * n \tag{6}$$

where, N_1 is the total population size of households in each village, N is total population size of households in three villages, n is total sample size and n_0 is sample taken from each village.

After sample size identification, both a structured closed-ended and open-ended questionnaire were developed for household interviews in the study area. In the present study, face-to-face interviews with a total of 184 households were conducted to examine the relationship between estimated ecosystem service and local people's perceptions of ecosystem services.

3. Results and discussion

3.1. Land use and land cover change from 1973 to 2020

In the present study, accuracy assessment was conducted by using high resolution Google Earth imagery from Google Earth Pro. The classified image accuracy assessment: user's accuracy, producer's accuracy, overall accuracy, was 82.05%, 84.09%, 88.61% and 87.1%, in 1973, 1988, 2003, and 2020, respectively. The Kappa coefficient was 77.2 (1973), 78.88 (1988), 84.64 (2003) and 83.62 in 2020 (SM Table 4). Accuracy assessment results greater than 80% indicates strong agreement between the reference data and

Table 3
Area coverage and percentage of LULC classes.

LULC	1973		1988		2003		2020	
	ha	%	ha	%	ha	%	ha	%
Forest	7974.49	62.62	6929.55	54.42	6627.96	52.05	5676.04	44.57
Grassland	3841.20	30.16	3122.28	24.52	2022.27	15.88	2000.19	15.71
Agricultural land	638.64	5.02	2226.49	17.48	3154.84	24.77	4236.06	33.27
Bare land	137.32	1.08	264.67	2.08	725.67	5.70	453.22	3.56
Settlement	142.32	1.12	190.98	1.50	203.23	1.60	368.46	2.89
Total	12,733.79	100	12,733.79	100	12,733.79	100	12,733.79	100

classification data [79]. The Kappa coefficient value between 0.40 and 0.85 represents the good correspondence [71]. In 1973, dense forest of Wof-Washa cover significant areas in the study area (Fig. 2). The dense forest has declined intensely in the study area due to agricultural encroachments.

In 1973, the forest cover was 62.62%, which declined to 54.42%, 52.05%, and 44.57% in 1988, 2003, and 2020, respectively, which indicates a decline in forest cover by 18.2% in 47 years. We need forest for building houses, house furniture, climate change regulation, erosion and flood risk mitigation, medicines, honey production, recreational purposes and many other services. Quantifying the dynamics of LULC change is crucial for addressing global challenges such as biodiversity loss and climate change [26]. This is primarily because policies can be formulated based on the analysis of temporal and spatial LULC changes. The percentage of forest cover loss sharply increased in the late 20th century due to rapid population growth in Ethiopia [19,34–36,80]. Forest loss has a significant impact on ecosystem services. Assessing the impact of LULC changes on ecosystem services is important for raising public awareness and designing policies on ecosystem services [11]. In the same year, agricultural land, settlements, and bare land classes covered approximately 638.64 ha (5.02%), 142.04 ha (1.12%), and 137.32 ha (1.08%, respectively. Intuitively, it is clear that strengthening agricultural land to increase production is the best way to protect the loss natural ecosystems due to agricultural encroachment [6].

Initially, the area covered by forest and grasslands accounted for approximately 92.78%, while agriculture, settlement and bare land accounted for only approximately 7.22%. After 47 years, the proportion of forests and grasslands decreased from 92.78% to 60.28%. This is a loss of 32.5% and could have a significant impact on the values of ecosystem services in the study area.

In 15 years (1973–1988), the most changed land cover after forests was agricultural land. Agricultural land increased from 5.02% in 1973 to 17.48%, with an increase rate of 12.46%. This increase in agricultural land has caused serious problems with forest cover. Due to increasing human population and high demand for food supply, forest cover is transformed to agricultural lands. Forest is continuously degraded and transformed into other agricultural landscapes in Ethiopia [32,56,80]. Significant forest cover has been lost over the past decades due to direct causes (agricultural expansions, timber exploitation, charcoal production) and underlying causes such as rapid population growth in different parts of Ethiopia [19,81].

The impact of land cover change on the forest sector is particularly pronounced compared to other land cover classes. Previous research has confirmed that much of the forest in northern Ethiopia has been destroyed for agricultural activities [7]. Recently, study by Ref. [82] concludes that the tendency to increase agricultural land at the expense of forests lead to land degradation problems in northern Ethiopia. Land cover has changed significantly in the study area over the last 47 years. Agricultural land increased from 17.48% in 1988 to 24.77% in 2003 (Table 3), an increase of 7.29% within one decades and half.

Changes in land cover significantly affects natural ecosystem services [50]. The analysis of LULC map of the study area indicates a significant increase in agricultural land since 1988. Fig. 3 shows the spatial distribution of LULC of the study area in 1988. Forest cover loss associated with agricultural encroachment remains a challenge for sustainable development, particularly for developing countries whose economies depend heavily on agriculture. Agricultural expansion could result in deforestation if it is applied in forest regions without strengthen conservation actions.

Of all LULC forest and grassland areas were significantly decreased in the year between 1973 and 2020. Forests play an important role in ecosystem services, and abrupt changes in forest cover lead to diminished ecosystem services [76]. In contrast, agricultural land, settlement and bare land were experienced an increasing trend. Study by Ref. [83] in the northwestern part of Ethiopia found a decline of forest cover and grassland, while an increase in bare land and settlement/built-up area in the northwestern part of Ethiopia. The forest and grassland cover declined by 2298.45 ha and 1841.01 ha, respectively, while the agricultural land and bare land classes increased by 3597.42 and 226.14 ha, respectively, between 1973 and 2020 (Table 4). Grassland is another land cover experiencing a declining trend. The area of agricultural land increased by 1587.85 ha between 1973 and 1988, 928.35 ha between 1988 and 2003, and 1081.22 ha between 2003 and 2020. The LULC map of the study area in 2003 is presented in Fig. 4.

Settlement land cover also experienced an increasing trend over the study period. A study by Ref. [35] found that both agricultural land and settlement increased, while forest and grassland areas substantially declined in the northeastern part of Ethiopia. Other study in the Kaffa Biosphere Reserve in Ethiopia also reported increasing tendency in agricultural land and settlement areas and decreases in forest and grassland cover [34].

The results show that significant forest areas were transformed into different LULC classes as the demand for more food and open space increased, reflecting rapid population growth. Approximately 1289.87 ha, 919.87 ha, 57.33 ha, and 32.13 ha of forest cover was converted into agricultural land, grassland, bare land and settlement, respectively. Previous study by Ref. [56] in central Ethiopia found a decreasing trend of forest and grassland to satisfy the demand of the growing population to address the concern of food security. The results show that approximately 2298.45 ha of forest area is changed to other LULC classes (Table 5).

Table 4
Change in LULC types.

LULC	1973–1988		1988–2003		2003–2020		1973–2020	
	ha	%	ha	%	ha	%	ha	%
Forest	−1044.94	−13.10	−301.59	−4.35	−951.92	−14.36	−2298.45	−28.82
Grassland	−718.92	−18.72	−1100.01	−35.23	−22.08	−1.09	−1841.01	−47.93
Agricultural land	1587.85	248.63	928.35	41.70	1081.22	34.27	3597.42	563.29
Bare land	127.35	92.74	461	174.18	−272.45	−37.54	315.9	230.05
Settlement	48.66	34.19	12.25	6.41	165.23	81.30	226.14	158.90

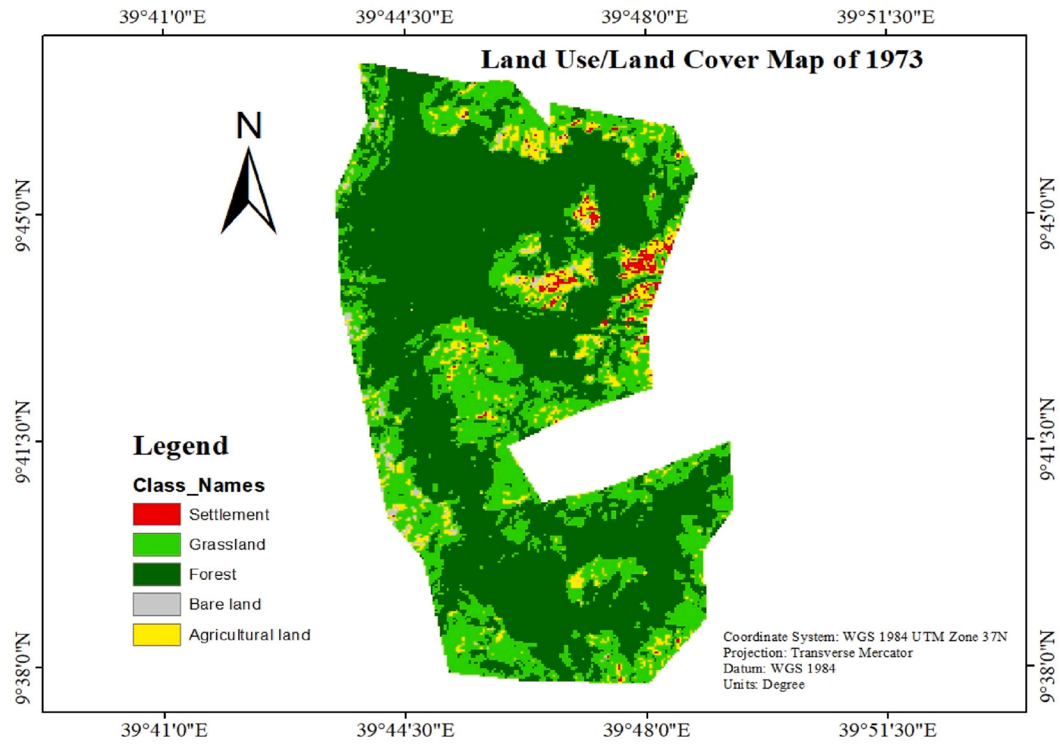

Fig. 2. LULC map of 1973.

As the population increases, the demand for humans to cultivate the land for consumption increases dramatically, playing a major role in causing deforestation. Changing human consumption patterns and rapid population growth negatively affect biodiversity [20, 38]. As compared to the previous decades, the coverage of forest dramatically declined in 2020 (Fig. 5).

3.2. Ecosystem services value from 1973 to 2020

The value of ecosystem services in the Wof-Washa forest was calculated using the value of coefficients and the benefit transfer method. Results reveled that there is considerable variation in ecosystem services provided by different LULC in the study area. The overall value of ecosystem services in the Wof-Washa forest decreased from US$9.151*$10^6$ in 1973 to US$8.266*$10^6$, US$7.854*10^6, and US$7.151*$10^6$ in 1988, 2003, and 2020, respectively. These results showed that there has been an overall decline of US$2.001*$10^6$ over the past 47 years. As reported by Refs. [20,30] found that LULC change resulted in changes in ecosystem service values.

Forest plays a major role in ecosystem service value [84]. The ecosystem services value from the forestland cover class was approximately US$7.877*$10^6$, US$6.845*10^6, US$6.547*$10^6$ and US$5.607*$10^6$ in 1973, 1988, 2003, and 2020, respectively (Table 6).

Forests provide many services to local communities in various aspects, such as energy use, house construction, timber, medicinal value, climate change mitigation, flood and erosion control and more. Although the ecosystem services value of forest is declining, it contributes the highest ecosystem services. For instance, timber and non-timber forest products significantly support the annual household incomes in Ethiopia [53,77]. Change in forest cover can significantly affects biodiversity and ecosystem services [20]. A study by Ref. (14) indicated that biodiversity loss is likely to have one the major impacts on sustainability of earth's ecosystem services. Grasslands and agricultural lands ranked second and third after forests in providing ecosystem services over the study period. Grasslands played a key role in providing regulatory services, including climate regulation, erosion control, soil formation, and pollination services [85]. Recently, Ethiopian government have become increasingly aware of the role of forests on ecosystem services and environmental wellbeing. The Ethiopian government is committed to overcome environmental challenges by promoting the Green Legacy. The objective of the Green Legacy Initiative is to minimize the problem of land degradation on the one hand, and to combat the impacts of climate change and environmental sustainability on the other hand.

Grassland accounted for US$1.130 *$10^6$ in 1973, US$0.919 *$10^6$ in 1988, US$0.595*$10^6$ in 2003 and US$0.589*$10^6$ in 2020. Therefore, the value of ecosystem services obtained from grassland ecosystems is important and greatly supports the livelihoods of people in the study area. Agricultural land contributed US$0.144*$10^6$ in 1973, 0.530US$*$10^6$ in 1988, US$0.712*$10^6$ in 2003 and US$ 0.955*10^6 in 2020. Agricultural land provides different services, including food, fiber and energy from biomass [86]. Of all LULC classes, only agricultural land shows an increasing trend in ecosystem services. This is consistent with [45], who reported the increasing of ecosystem services of arable land. The overall ecosystem services value of forest and grassland decreased by US

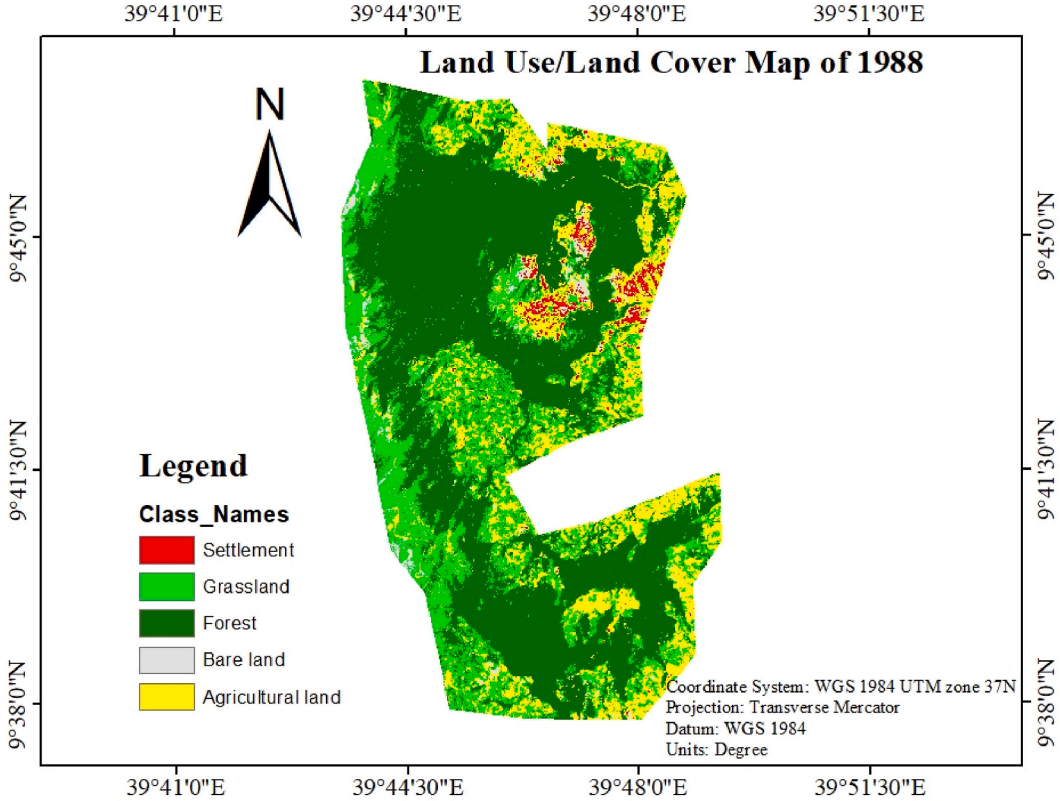

Fig. 3. LULC map of 1988.

$2.270*10^6 and US$0.542*10^6, respectively, whereas the value of agricultural land ecosystem services increased by US$0.811*10^6.

3.3. Ecosystem services categories

The ecosystem service value of food production was higher than that of water supply, raw material, genetic resources, and medicine between 1973 and 2020. The results show that food production and biological control services increased between 1973 and 2020. This is consistent with the results of [11] who reported an increasing trend of food production by US$ 2.80 million between 2000 and 2020 in the Upper Blue Nile Basin due to the expansion of cultivated land.

Regulating services lost high ecosystem service values because of significant changes observed in erosion control (US$-0.616*10^6), climate regulation (US$-0.512*10^6), waste treatment (US$-0.473*10^6), and nutrient cycling (US$-0.423*10^6) relative to other services. Cultural and supportive services decreased by US$0.017*10^6 and US$0.04*10^6, respectively, between 1973 and 2020. With the loss of forests and grasslands over the past 47 years, the value of ecosystem services has decreased by US$2.001*10^6. A study Ref. [77] found comparable results, found a decline in ecosystem services by approximately US$ 3.7 million between 1986 and 2000 in central Ethiopia. Another study in Chillimo forest by Ref. [29] found that there was a loss of US$ 3.69*10^6 between 1973 and 2015.

3.4. Change in forest ecosystem services

The total loss of forest ecosystem services values accounted for US$2.2704*10^6. Due to the conversion of forest to agricultural land and grassland, the loss of ecosystem services was US$1.2734*10^6 and US$0.9086*10^6, respectively. Forest conversion contributed significantly to the loss of regulatory services (US$1.9085*10^6), followed by provisioning (US$0.3065*10^6), supportive (US $0.0398*10^6) and cultural services (US$0.0156*10^6) between 1973 and 2020 (Table 7). Currently, forests in the study area contribute US$5.3477*10^6. Converting forests to another LULC class can significantly reduce ecosystem services [45,56,87].

3.5. Coefficient of sensitivity

The coefficient of the sensitivity value of grassland was 0.12 in 1973, 0.11 in 1988, 0.08 in 2003, and 0.08 in 2020 (Table 8). The coefficient of the sensitivity value of agricultural land increased from 0.02 in 1973 to 0.13 in 2020 due to the gradual increase in agricultural land. Our results therefore support [88] finding that forest-dependent species show higher sensitivity to fragmentation.

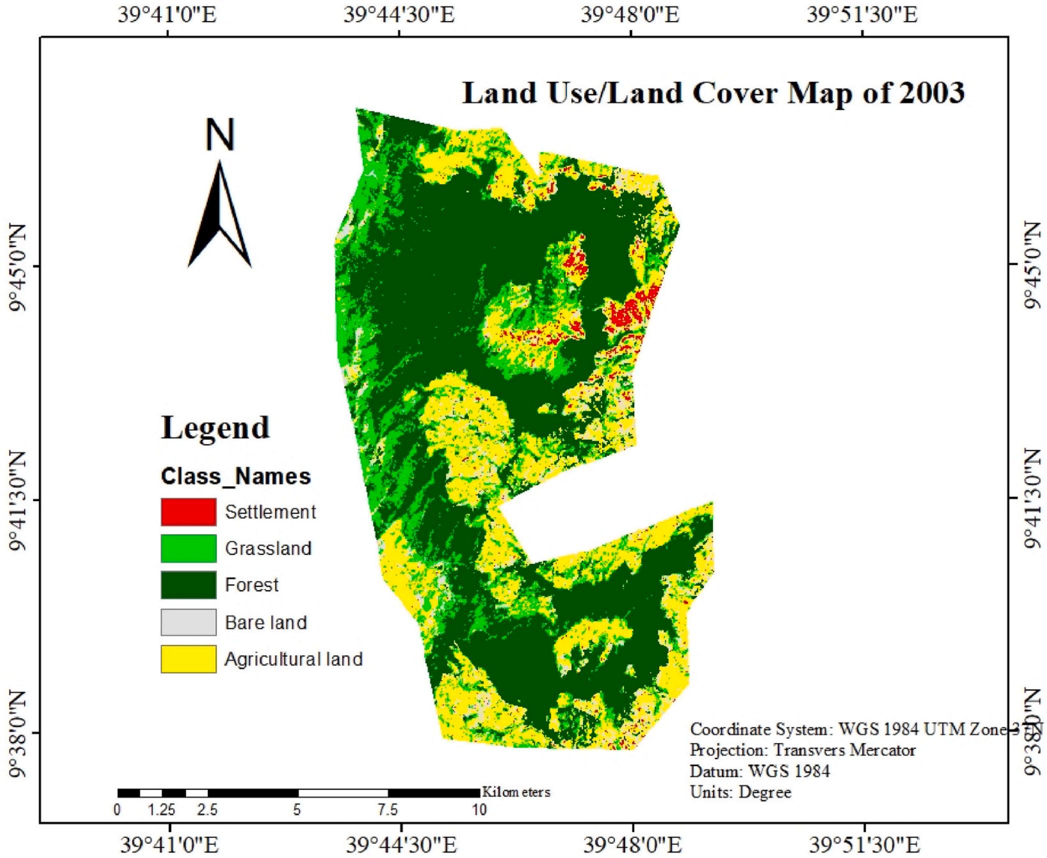

Fig. 4. LULC map of 2003.

Table 5
Forest conversion in hectares (ha).

Change type	1973–1988	1988–2003	2003–2020	1973–2020
	ha	ha	ha	ha
Forest to grassland	653.71	115.32	702.02	919.87
Forest to agricultural land	355.14	161.19	215.01	1289.12
Forest to settlement	8.55	0.9	8.19	32.13
Forest to bare land	27.54	24.18	26.71	57.33
Total	1044.94	301.59	951.93	2298.45

The coefficient of sensitivity is highest for forestland because of species composition and richness, which significantly influence the biomes of the ecosystem [89].

3.6. *Relative importance value of forest ecosystem services*

From the local people's point of view, the overall change in the relative importance of provisioning services was reduced from 9.66 (before 1988) to 4.66 by 2020 (SM Table 5). The raw material significantly decreased from very high importance (0.9) to very low importance (0.21). Overexploitation of forest resources, illegal logging, and overgrazing contributes to forest degradation. Changes in LULC will inevitably affect ecosystem structure and function [89]. The quality and quantity of various ecosystem services have decreased significantly, which adversely affects livelihoods [29,90,91]. The results of the study show that the regulatory services of forest ecosystems decline over time. Disturbance regulation (protection of flood, drought, fire, and landslide), soil erosion control, climate regulation, and pollination are the key regulatory services of forests identified by the key informants. The decline of forest ecosystems has a negative impact on the environment. The decline of forest ecosystems will likely aggravate climate extremes mainly drought and floods [91].

Changes in the relative importance of regulatory services such as flood, drought, fire, and landslide protection, soil erosion control,

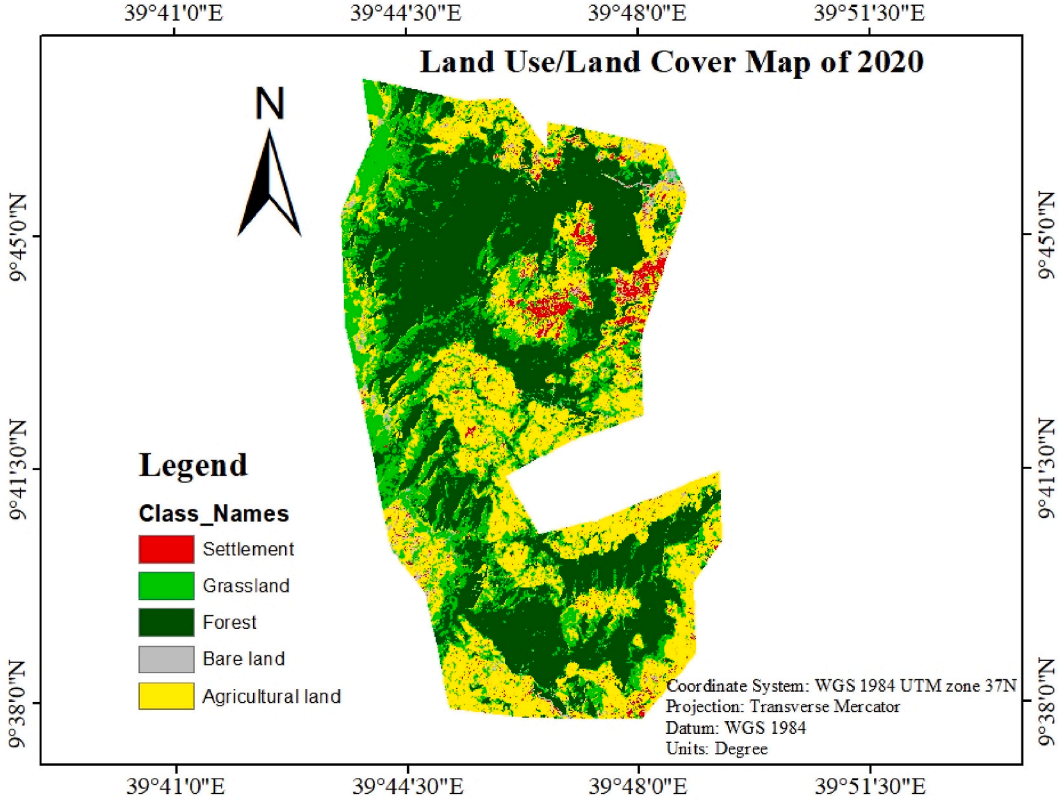

Fig. 5. LULC map of 2020.

Table 6
Values and changes in ecosystem services in different LULC classes.

LULC classes	ESV (US$*10^6)				Change ESV (US$*10^6)			
	1973	1988	2003	2020	1973–1988	1988–2003	2003–2020	1973–2020
Forest	7.877	6.845	6.547	5.607	−1.032	−0.298	−0.940	−2.270
Grassland	1.130	0.919	0.595	0.589	−0.212	−0.324	−0.006	−0.542
Agricultural land	0.144	0.502	0.712	0.955	0.358	0.209	0.244	0.811
Bare land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Settlement	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sum	9.151	8.266	7.854	7.151	−0.886	−0.412	−0.703	−2.001

Table 7
Impacts of forest cover change on ecosystem services values.

Change type	ESVs (US$*10^6) between 1973 and 2020				Total
	Provisioning	Regulating	Cultural	Supportive	
Forest to grassland	0.1227	0.7638	0.0063	0.0159	0.9086
Forest to agricultural land	0.1719	1.0704	0.0088	0.0223	1.2734
Forest to settlement	0.0043	0.0267	0.0002	0.0006	0.0317
Forest to bare land	0.0076	0.0476	0.0004	0.0010	0.0566
Net change	0.3065	1.9085	0.0156	0.0398	2.2704
No change	0.7219	4.4953	0.0368	0.0937	5.3477

climate regulation, and pollination decreased by 43.01%, 39.36%, 38.14%, and 15.07%, respectively, due to the decline in forest cover. Forests also provide cultural services. The relative importance values of forests for cultural services such as recreation and education were increased by 104.27% and 100%, respectively. The ecosystem services value of the Wof-Washa forest declined from US $9.151*10^6 in 1973 to US$7.151*10^6 in 2020, with an overall decline of US$2.001*10^6 over the past 47 years (SM Table 6). Forest degradation reduces the quality and quantity of ecosystem services [92]. The ecosystem services values were calculated based on the

Table 8
Estimated ecosystem service value and coefficient of sensitivity (CS) results from a 50% adjustment in the ecosystem value of coefficients.

Change in value of coefficients	The effect of changing value of coefficients from the original value							
	1973		1988		2003		2020	
	%	CS	%	CS	%	CS	%	CS
Forest ± 50%	±43.04	0.86	±41.40	0.83	±41.68	0.83	±39.20	0.78
Grass land ± 50%	±6.17	0.12	±5.56	0.11	±3.79	0.08	±4.12	0.08
Agricultural land ± 50%	±0.79	0.02	±3.04	0.06	±4.53	0.09	±6.68	0.13

household questionnaire survey designed for this study (SM Table 7).

4. Conclusions

Our empirical results confirmed that changes in forest cover significantly reduced the value of forest ecosystem services. The LULC change has been significantly affecting the provisions of ecosystem services. These results have practical implications for both policymakers and land administrations. Continuous modification of LULC have a negative impact on the value of ecosystem services. The increasing number of human population and high demand for agricultural land increases the rate of LULC conversion. The benefit transfer method estimates economic values by transferring existing benefits estimates conducted somewhere, which is the limitation of this method. To increase the accuracy of the benefit transfer techniques, we used key informant interviews to estimates values of forest ecosystem services from a study conducted in another region. We also use geospatial technologies to understand the extent of LULC change over that have a potential impact on ecosystem services.

The results show that agricultural land experiences an increasing tendency in terms of ecosystem service value. Specifically, food production, and biological control were increased, while other ecosystem services decreased. Due to forest degradation, local people do not get enough ecosystem services and receive less than expected. In terms of ecosystem service provision, grasslands and agricultural lands rank second and third after forests. A decline in the provision of ecosystem services indicates that there is environmental deterioration, which requires stakeholders' intervention for conservation actions. Thus, the findings of this study are important for designing intervention policies for land management, which can promote the conservation of forest ecosystems and other land cover classes.

Declarations

Author contribution statement

Mekdes Shiferaw: Conceived and designed the experiments; Perform the experiments; Analyzed and interpreted the data and contributed reagents, materials, analysis tools.

Zerihun Kebebew Conceived and designed the experiments; Perform the experiments; Analyzed and interpreted the data and contributed reagents, materials, analysis tools.

Dessalegn Obsi Gemeda Conceived and designed the experiments; Perform the experiments; Analyzed and interpreted the data and contributed reagents, materials, analysis tools and wrote the paper.

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e18173.

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