IMPACT OF LAND USE LAND COVER CHANGES ON ECOSYSTEM SERVICE VALUES: IMPLICATION FOR LANDSCAPE MANAGEMENT

ENGDAYE MERSHA[*1], SILESHI DEGEFA[1], MEKURIA ARGAW[1], WONDIMAGEGN MENGIST[2]

[1]*Center for Environmental Science, Addis Ababa University, P.O. Box 1176, Addis Ababa, Ethiopia, email: sileshi.degefa@aau.edu.et, mekuria.argaw@aau.edu.et*
[2]*Debre Berhan University, P.O.Box 445, Debre Berhan, Ethiopia, email: wondime2007@gmail.com*
**Corresponding author email: engd98@gmail.com, engdaye.mersha-w@aau.edu.et*

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ABSTRACT

Globally growing human activity has had an enormous effect on natural ecosystems and the services they provide. Estimating the effects of land use and land cover (LULC) on ecosystem service values (ESVs) is crucial for determining how land use changes affect human well-being. To ensure long-term sustainability of the ecosystems, considering the trade-offs and synergies between ecosystem services, tracking changes in ecosystem services, and implementing effective land use planning and conservation strategies, we can ensure the long-term sustainability. This study aimed to find out how ESV in the Borkena watershed of the Awash basin was impacted by LULC changes during the last three decades (1993–2023). The study quantifies the spatiotemporal variation of ESV of the Borkena watershed in relation with LULC changes. Six LULC types were identified using supervised image classification following maximum likelihood method in ArcGIS 10.8 environment. The ESV was estimated following benefit transfer methods based on the coefficients published by Costanza and his team in 2014. The results demonstrated that between 1993 and 2023, there was a continuous increase in the amount of land under cultivation and built-up area, as well as a decrease in the amount of forest and shrub land. The study shown that the significant expansion of cultivated land and built-up area and decreasing of forest and shrub land cover during 1993-2023 periods, has reduced the total ESV from US$ 640.74 in 1993 to US $603.52 in 2003 and US $607.05 in 2013 and US $625.45 in 2023. It is urgently necessary to take action to improve the sustainability of ecosystem service value at the landscape level with proper land management methods in light of the decline in both the total and individual ESV in the study area and period. The results of this study could be useful to raise public awareness of the state of ESV, landscape management and support policy-making processes.

Keywords: Ecosystem services, Land use/land cover change, ESV, Remote sensing and GIS; Borkena.

INTRODUCTION

All living things on Earth depend entirely on the ecosystems and services they offer, including food, water, protection against sickness, temperature control, spirituality, and aesthetic enjoyment (Millennium Ecosystem Assessment *et al*., 2005). Ecosystems have been continuously altered by humans in several ways. The principal cause of ecosystem deterioration in many locations is the conversion of natural regions into farms and urban areas (Wassie, 2020). These changes harm climate patterns, biodiversity resources, and socioeconomic dynamics resulting in biodiversity loss, global warming, and increased natural disasters such as flooding and drought (Shivanna, 2022). Ecosystems provide a variety of services that are of crucial to human well-being, health, livelihoods, and survival (Harrison *et al*., 2010). Science and policy fields have experienced an enormous rise in interest in ecosystem services in recent years (Arowolo *et al*., 2018; Mengist *et al*., 2022).

LULC have observed significant changes over the past several decades throughout the world due to the growing human population, economic growth, and urban sprawl. Natural landscapes like woodland and savanna lands are changed to different LULC types like cultivated land, pasture lands, and built-up areas (Chen *et al*., 2014). For example, global level estimation of changing forest lands to cultivation was about 13 million hectares per year and approximately 40 % of the terrestrial land surface is being used for crop production (Kubiszewski *et al*., 2017; Mengist *et al*., 2022). However, in the globe there is contradictory report in the forest coverage. According to (Pretzsch *et al*., 2023), in the Northern Europe, forest showed higher coverage in 2016 than the year in 1878, and in some areas, natural habitats such as forest and woodland recently showed expansion for instance in Italy (Ghaderpour *et al*., 2024).

The functions and activities of natural ecosystems and the species that inhabit them that support human well-being and sustainable development are referred to as ecosystem services (ES), or the benefits that humans gain from ecosystems either directly or indirectly, such as services of provisioning, regulatory, cultural, and supporting (Costanza *et al*., 1997; Bennett *et al*., 2009; Fisher *et al*., 2009). Ecosystem service value (ESV) is a technique of assigning monetary value to the services and goods of an ecosystem. The rapid change in land-use land cover (LULC) is a major factor in the change in the capacity of ES. Understanding LULC change and its impact on ESV is vital for decision-making processes (Biratu *et al*., 2022; Kuma *et al*., 2022; Mengist *et al.*, 2022).

Numerous approaches have been used to quantify the influence of LULC change from the perspective of characterizing the ESV. Researchers like (Turner *et al*., 2007) estimated the value of 17 ES for 16 biomes using the value transfer approach, the unpredictability of value coefficients, however, has been the subject of concerns. Estimation of global ESV was carried out by (Costanza *et al*., 2014) and (Groot *et al.*, 2012); however, their estimates were criticized due to the overestimates of some ES. As a result, various researchers like (Kindu *et al*., 2016) developed their own modified ES coefficient. LULC change detection based on remote sensing data is an important source of information for various decision support systems (Tewabe & Fentahun, 2020). Nowadays, the land use and land cover change and its impacts are revealing on different natural resource and man-made systems (Tessema *et al*., 2020).

Researchers began to pay more attention to the concept of ecosystem services when the "Ecosystem Service Valuation Model" was published by (Costanza *et al*., 1997) and (Arge *et al.*, 1997) and the 'Millennium Ecosystem Assessment (MEA), reported by the United Nations in 2005. The report titled 'The Economics of Ecosystems and Biodiversity (TEEB), published by the UN Environment Program in 2010 further aroused interest in this issue among mass audiences (Costanza *et al.*, 2014). Despite criticism of Costanza's model for its limits in terms of local application and the uncertainty of its coefficients, several researchers have used them in areas where data are scarce and improved upon initial values (Dammag *et al*., 2024), and, these efforts are considered fruitful and valuable for understanding various benefits arising from ecosystem functions necessary to estimate the value of ES (Groot *et al.*, 2012). Another study in Small Sanjiang Plain in China, which is becoming more concerned about the contradiction between economic development and the loss of ecosystem services as a result of the rapid increase of agricultural operations during the last 30 years, and they examined changes in land use and the resulting value loss of ecosystem services (Chen *et al.*, 2014).

A major contributing factor to the current biodiversity extinction issue is habitat degradation, which compromises the fundamental functions that healthy ecosystems provide to humanity (Kubiszewski *et al*., 2017). Securing both species and ecosystem services might be accomplished with common solutions. Ecosystems through their functioning provide a multitude of services, which are essential for human survival, livelihoods, and well-being (Turner *et al*., 2007). These are provisioning (e.g. food, water, and fuel), regulating (e.g. climate regulation and water purification), and cultural services (e.g. recreation and aesthetic values) that directly affect people and supporting services (e.g. soil formation and erosion control) with a relatively indirect impact on people (Costanza *et al*., 2012; Groot *et al*., 2012). The results from (Harrison *et al*., 2010) show that intensively managed ecosystems contribute mostly to vital provisioning services (e.g. agro-ecosystems provide food via crops and livestock, and forests provide wood), while semi-natural ecosystems (e.g. grasslands and mountains) are key contributors of genetic resources and cultural services (e.g. aesthetic values and sense of place) However, the provision of these services has been greatly altered by LULC dynamics. The total ecosystem services values of Eastern Afromontane Biodiversity Hotspots has been estimated by researchers in response to terrain dynamics, and have found the causes for the decline in ESV of the biosphere reserve were the change of forestland, grassland, and wetland to settlement and agricultural areas. From the land-use types, the contribution of wetland, forest, and agriculture was the most leading land use in ESV. The largest inputs to the overall ESV were genetic resources, climate regulation, water regulation, and recreation (Mengist *et al*., 2022). The study's findings suggest that land-use changes that resulted in ecosystem degradation are to blame for ESV's degradation (Mengist *et al*., 2022).

The study assessing changes in the value of ecosystem services in response to LULC dynamics in Nigeria the findings showed that changes in land use, or Nigeria's ever-increasing agricultural expansion, may seem economically advantageous because to the rise in the country's overall ESV and the enormous increase in ecosystem services brought about by the extension of cultivated land. However, persistent losses in ecosystem-dependent services like water and climate management can cause enormous economic losses that may outweigh the apparent benefits of developing farmed land (Arowolo *et al*., 2018).

Many interrelated causes, including population pressure, agricultural development, migration, rapidly urbanization, resettlement, climate change, and environmental pollution, have an impact on Ethiopia's natural resources (Gashaw *et al*., 2019; Wassie, 2020). Its enormous population has been severely affecting the sustainability of practically all natural resource kinds. Thus, there is a severe deterioration of the resources related to land, water, forests, rangelands, and animals that seems to be mutually reinforcing (Wassie, 2020). This leads to a vicious cycle of increased resource degradation due to significant soil erosion, low vegetative cover, unsustainable farming practices, overgrazing, ongoing use of dung and crop leftovers as fuel, and wildlife movement or destruction (Wassie, 2020). (Aneseyee *et al*., 2020), has investigated on the effect of land use/land cover changes on ecosystem services valuation of Winike watershed, and ArcGIS 10.8 was used to estimate ESVs and their changes using LULC datasets from 1988 to 2018 and the global ESV coefficient. The total ESV decreased from US$481.85 million in 1988 to US$445.5 million in 2018, with a decreasing rate of US$1.21 million per year. Within this period, the largest ESV increment was observed in cultivated land with an increasing of US$33.47 million, and the largest decreasing was observed in grazing land with a decreasing of US$47.35 million (Aneseyee *et al*., 2020).

In recent decades, researchers worldwide have been paying closer attention to biodiversity in terms of the economic valuation of ecosystem services. The study examined changes in LULC and their effects on ESVs in the Eastern Himalayan Region in 1992, 2002, 2012, and 2020 (Rasool *et al*., 2021), hence, the results reveal an increase in urban areas, wetlands, forest cover, croplands, and barren lands; with urban areas experiencing the most significant expansion (265.81 %). Conversely, grasslands and water bodies decreased, indicating growing anthropogenic influences (Ghafoor *et al*., 2022).

The Borkena watershed is rich in biodiversity resources including different forest biome classes, which have ecological and economic importance (Mersha *et al*., 2024). However, forests and shrub lands in the watershed have been converted to croplands at unprecedented rates due to increased human strain (Mersha *et al*., 2024). Between 1993 and 2023, forest, and shrub land decreased by 12 %, and 132 %, respectively. The loss of these ecosystems came at the expense of increased farmland (78 %) and built-up areas (24 %) (Mersha *et al*., 2024). It is necessary to gain a better understanding of how these LULC alterations affect ESVs in order to raise awareness of the consequences and facilitate improved decision-making.

In this study, for 1993 and 2003 the Landsat 5 (TM) data and for 2013 and 2023, the Landsat 8 (OLI/TIRS) data were downloaded. The accuracy of the classified images was checked and 6 representatives LULC were used as a proxy for each LU/LC category. The ESV and ESV_f were analyzed using ArcGIS 10.8 to quantify the ESV for years 1993, 2003, 2013, and 2023. Therefore, the main contributions of this study are to:

a) Quantify LULC changes and assess the changes in ESVs in association with LULC dynamics in the Borkena watershed using time series Landsat images for the period between 1993 and 2023.
b) Raise public awareness on the impacts in LULC on the ESV of the watershed, which can support the policy-making processes in the area.
c) After estimating the ESVs for 1993, 2003, 2013 and 2023 reference years, we map their spatial distribution and computing the changes between study periods.

The rest of this study is structured as follows. Section 2 describes the study area, data collection and image processing steps and methods used to quantify ESV at landscape level. Section 3 demonstrates the study results, including LULC changes and their trend maps, and land cover maps and their trend analyses. This section also presents the estimated ESVs with change in individual and grouped ecosystem services. The relationships between the ecosyatem services with LULC change, and estimation of the ES value at individual and group level, and the study limitations are discussed in light of other similar studies in Section 4. Section 5 concludes the main study findings.

MATERIALS AND METHODS

Description of the study area

The Borkena River starts in Kutaber Woreda, where it marks the boundary between two river basins, Abay and Awash. It flows from the chain of mountains and escarpments, in the plateau, to the Afar Rift. The river then heads southeast. Eventually meets the Jara River near the Cheffa swamp before joining the Awash River. On the other hand, the Berberie River originates from northeast of Kombolcha town. After winding its way through the town it merges with the Borkena River in Kombolcha town (Makwinja *et al*., 2021). Geographically, the study area is bounded by 10°40′0″–11°20′0″ N latitude and 39°27′0″–39°58′30″ E longitudes and the total area of the sub-basin was estimated to be 126,243 km^2 (Fig. 1). The total distance of the flow path towards the outlet of Borkena River is 85 km. The elevation of Borkena varies between 1412 and 3463 m.a.s.l (Fig. 2). The climate of the study area varies between Dega and Weyna Dega. The mean annual rainfall of the catchments was 1028 mm. The mean monthly temperature of the area varies between 16.1 and 22.1°C which correspond to December and June, respectively.

Fig. 1: Study area location map. Source: Author

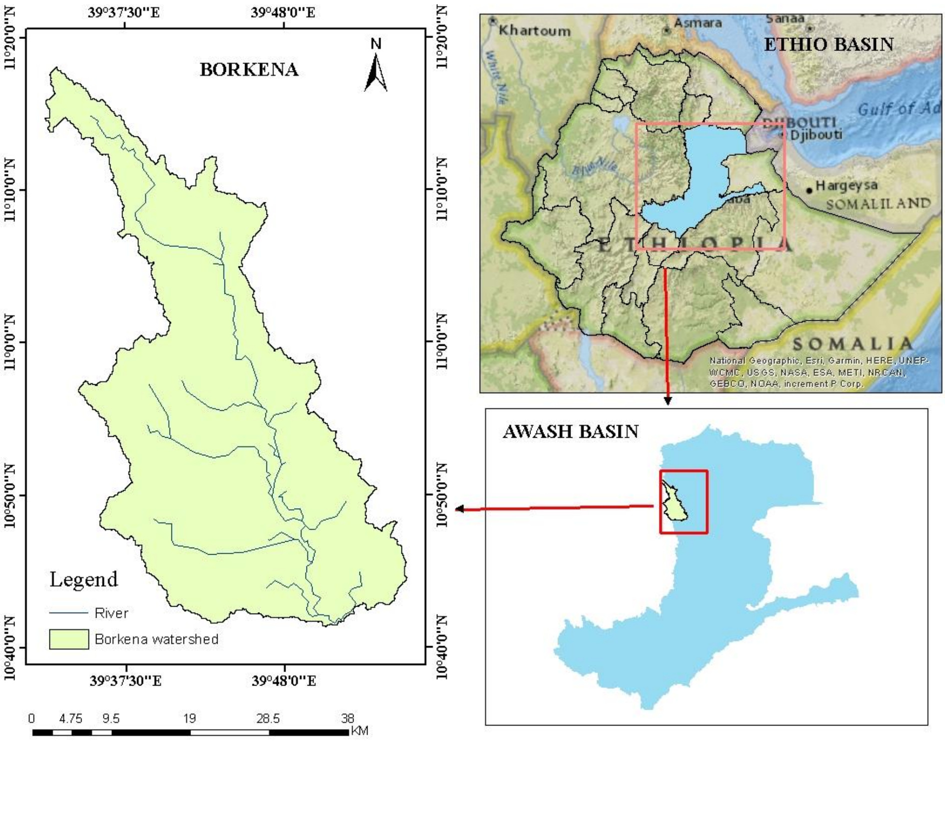
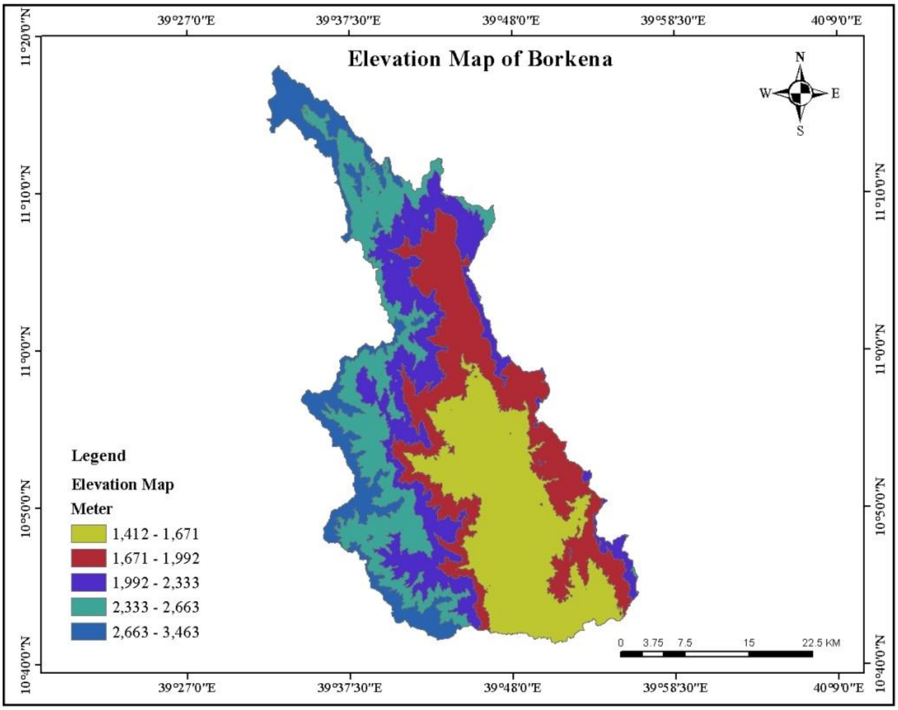


Fig. 2: Digital Elevation Model map of the study area



Methods

Data collection and Image processing

The images with 30 m resolution and cloudfree were collected from the US Geological Survey (USGS) Earth Explorer (https://earthexplorer.usgs.gov). For 1993 and 2003 the Landsat 5 (TM) while for 2013 and 2023, the Landsat 8 (OLI/TIRS) data were downloaded for the same season for each study year,i.e. March or April months (Mersha *et al*., 2024).

Table 1: Details of the satellite data used and their average could coverage

No	Satellite	Sensor	Spectral Bands	Month/year of Acquisition	Av. Cloud cover
1	Landsat 5	TM	7	Mar-Apr 1993	3%
2	Landsat 5	TM	7	Mar-Apr 2003	5%
3	Landsat 7	OLI/TIRS	7	Mar-Apr 2013	7%
4	Landsat 8	OLI/TIRS	7	Mar-Apr 2023	7%

To achieve classification of image in multi-temporal approach and for mapping purposes, ArcGIS 10.8 software was used. A combined procedure was developed to analyze, map, quantify and interpret the collected data.

LULC classification

The accuracy of the classified images was checked against reference data collected from the field sites and other images (Bekele *et al*., 2019; Mersha *et al*., 2024; Naikoo *et al*., 2020). The total accuracy was calculated by dividing the number of correctly classified elements (i.e., the sum of the diagonal elements in an error matrix) by the total number of pixels included in the evaluation process (Table 3). The Kappa statistic is an alternative measure of classification accuracy that subtracts the effect of random accuracy and quantifies magnitude of correct classification compared to another (Mersha *et al*., 2024). According to the LULC change analysis, during the last 30 years, cultivated land in the studied watershed has significantly expanded at the expense of forest land and other land uses (Table 2).

Table 2: The LULC types of the Borkena Wateshed (1993–2023) (Mersha *et al*., 2024)

Class name	1993		2003		2013		2023	
	Ha	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**
Forest	8,336	7%	6,336	5%	6,566	5%	7,610	6%
Crop land	72,666	57%	77,716	61%	80,142	63%	82,486	65%
Shrub land	29,214	23%	27,214	21%	11,869	9%	11,709	9%
Water body	1,950	2%	1,899	2%	698	1%	932	1%
Built-up	2,533	2%	3,534	3%	8,319	7%	11,106	9%
Bare land	11,544	9%	9,544	8%	18,649	15%	12,364	10%
Total	126,243	100%	126,243	100%	126,243	100%	126,243	100%

Table 3: The confusion matrix of the LULC classification accuracies (Mersha *et al*., 2024)

Class Value	FL	CL	SL	WB	BU	BL	Total	User accuracy (%)
Forest	**5**	0	0	0	0	0	5	1
Crop land	0	**58**	7	0	0	2	67	0.87
Shrub land	0	1	**10**	0	0	0	11	0.91
Water body	0	0	0	**3**	0	0	3	1
Built-up	0	1	1	0	**5**	0	7	0.71
Bare land	0	1	0	0	0	**6**	7	0.86
Total	5	61	18	3	5	8	**100**	Overall Accuracy 87%
Producer Accuracy (%) Kappa	1	0.95	0.56	1	1	0.75	0	Kappa Coefficient 0.77

Quantifying landscape level ecosystem services values.

Following the methodology used by (Kreuter *et al*., 2001), the total value of ecosystem services in the study landscape for years 1993, 2003, 2013 and 2023, were quantified using the following equation (eq.1):

$$ESV = \sum(A_k \times VC_k)\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(eq.1)}$$

Where the ESV is the estimated Ecosystem value, A_k is the area (ha) and VC_k is the value coefficient (US$ha^{-1} yr^{-1} for LULC category k. The changes of ESV were calculated using the difference of the estimated values in each reference year.

The percentage change of ESV (1993–2003, 2003–2013, and 2013–2023) can be calculated using eq. 2 and the values were presented in currency (US$) and percentages.

$$Percentage\ of\ ESV\ change = \frac{(ESV\ final\ year) - (ESV\ initial\ year)}{ESV\ initial\ year} 100 \ldots\ldots\ldots\ldots \text{(eq.2)}$$

Where ESV = total estimated ecosystem service value and positive value suggest an increase and negative values imply a decrease in the amount. It is also estimated the effect of this changes on 17 individual ecosystem services in the study landscape (Table 4). Individual ecosystem services were multiplied with each ESV identified for each LULC classes because there is direct relationship between each ESV and the biomes (Costanza *et al*., 2014).

To estimate the ecosystem service values for 17 ecosystem services provided by LULC at the landscapes level; the following equation (eq.3) was used, which is recommended by (Hu *et al.*, 2008).

$$\text{ESVf} = \sum(A_k) \times (VC_{fk})) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(eq. 3)}$$

Where ESV_f is the estimated ecosystem service of function f, Ak is the area (ha) and VCfk the value coefficient of function f (US$ $ha^{-1}yr^{-1}$) for LULC category k.

The biomes used as proxy for the LULC categories identified at the landscape level were similar. Specifically, bare land differed from biomes of desert (Costanza *et al*., 1998). Bare lands are the result of the removal of vegetation and subsequent exposure of land to erosion and sometimes the use of land for obtaining quarries. In terms of the provision of ecosystem services the provision of such raw material for construction could be underestimated by the proxies used. Furthermore, the environmental conditions within which each biome exists are also quite different and there is a possibility of rehabilitation of bare land as compared to deserts. We also used temperate forests as a proxy to estimate the ecosystem service values of plantation forests identified in our case because plantation forests are those woodlots grown by farmers on their plot of land to meet the demand for wood and cash income, and hence, this monoculture plantation species could be approximated with temperate forests. These plantations are monocultural with short rotation period. Similarly, shrub land is not identical to grass lands/range lands where shrub land is having a better canopy cover than grass lands/range lands but, shrub land provides ecosystem services fairly similar to grass land/range lands described in (Mengist *et al*., 2022) as these land uses are extensively used for grazing and forest product collection in addition to other ecosystem services identified. Furthermore, tropical forests are used as proxies for natural forest land. The natural forest in our study is one of the last biodiversity hotspots found on the mountainous escarpments of the central highland of Ethiopia.

Table 4: Annual values of ecosystem services (ESV_f in US $ million per year) for each identified biomass

Group	Indicators	Cropland	Shrub land	Forest	Urban	Bare land	Water body
Provisioning Services	Food production	2323.00	1192.00	200		0	106
	Water supply	400.00	60	27		0	1808
	Raw materials	219.00	54	84.00		0	
	Genetic resources	1042.00	1214	1517		0	
	subtotal						
Regulating services	Water regulation		3.00	8.00	16.00	0	7514
	Waste treatment	397	75	120		0	918
	Erosion control	107	44	337		0	
	Climate regulation	411	40	2044	905	0	
	Biological control	33	31	11		0	
	Gas regulation		9	12		0	
	Disturbance regulation			66		0	
	subtotal						
Supporting Services	Nutrient cycling			3.00		0	
	Pollination	22.00	35.00	30.00		0	
	Soil formation	532.00	2.00	14.00		0	
	Habitat/refuge		1214	39.00		0	
	subtotal						
Cultural services	Recreation	82.00	26.00	867	5740	0	2166
	Cultural		167.00	2.00		0	
	subtotal						
	Total	5568.00	4166.00	5381	6661		12512

Table 5: Biomass equivalence for land use categories and corresponding ecosystem services values according to (Costanza *et al*., 2014)

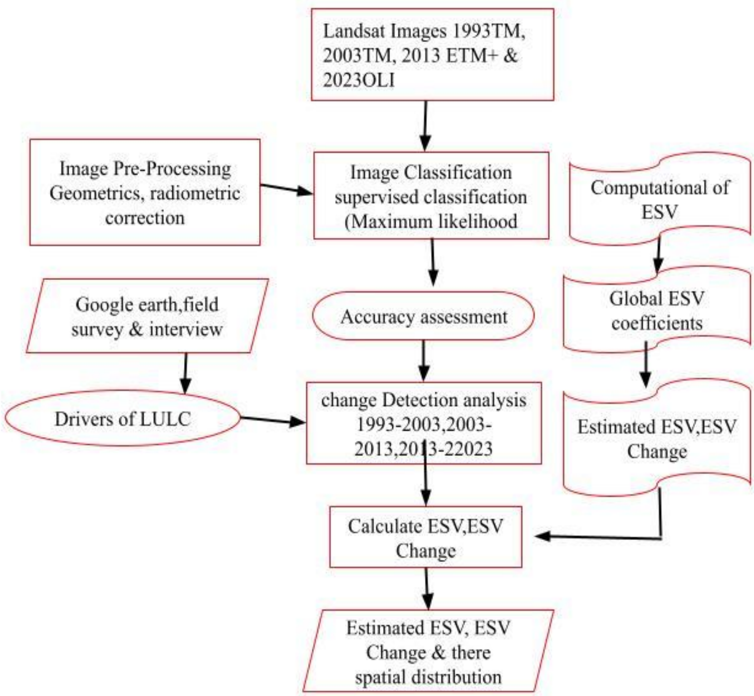
LULC	Equivalent biome	Ecosystem service coefficient (million US $ $ha^{-1}yr^{-1}$)
Cropland	Cropland	5568
Shrub land	Grasslands	4166
Forest	Tropical forest	5238
Settlement	Urban	6661
Grassland	Grassland	4166
Bare land	Desert	0
Water body	River/lakes	12,512

Global ESV coefficients

The total ESV Global ESV coefficients in the watershed during the study period were calculated using ESVs coefficients of the respective LULC types. The ESVs coefficients were used as a proxy for each LULC type in the global coefficients (Costanza *et al*., 2014). Thus, the total ESVs in Borkena watersheds were estimated using Global ESV coefficients (Table 5).

The accessibility of global datasets on LULC based on remote sensing and regional datasets coupled with value transfer of the global data equivalence by Costanza allowed to conduct this study (Woldeyohannes *et al*., 2020). Hence, the method was used to evaluate ecosystem services for Borekena watershed. The value transfer method help to calculate ESV associated with different types of LULC changes, comparison between the LULC classifications obtained from the Landsat TM/ETM dataset (Costanza *et al.*, 2014). The most relevant biome for each category was apportioned as the proxy for that LULC type (Table 5). LULC types, equivalent biome, and corresponding value coefficient over periodical years 1993, 2003, 2013, and 2023 for the study area are presented in (Table 5). Therefore, the overall study methodology is shown in Figure 3.

Fig. 3: The flowchart of this work each parallelogram represents an image



RESULTS

LULC changes in Borkena watershed (1993–2023)

Spatial analysis of the 1993, 2003, 2013, and 2023 classified image maps (Mersha *et al.*, 2024) showed that various major changes had occurred in the watershed (Table 6). In each period, the land category with the largest proportion of land use and cover was cultivated land. The built-up areas was land use and cover category which was increased rapidly between 1993 and 2023. Areas of shrub land, forest, and water decreased by 150, 101, and 10 percent, respectively, whereas intensive cultivation, built-up, and bare land increased by 12, 77, and 7 percent, respectively (Table 6). LULC varied significantly during the study period. The tendency is diminishing for both shrub land and forests. According to the LULC change analysis, during the last 30 years, cultivated land has significantly expanded at the expense of forest land and other land uses (Table 6).

Table 6: LULC types of the Borkena Watershed (1993–2023) (Mersha *et al.*, 2024)

Class name	1993		2003		2013		2023	
	Ha	%	Ha	%	Ha	%	Ha	%
Forest	8,336	7%	6,336	5%	6,566	5%	7,610	6%
Crop Land	72,666	57%	77,716	61%	80,142	63%	82,486	65%
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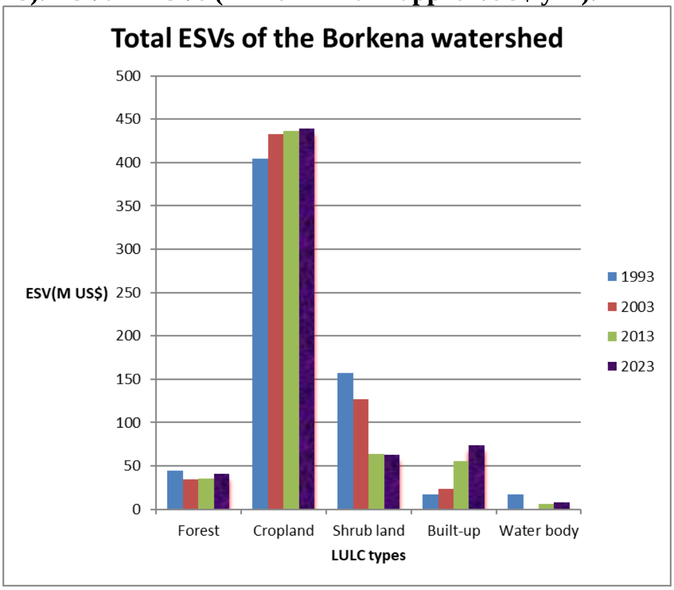
Bare Land	11,544	9%	9,544	8%	18,649	15%	12,364	10%
Total	126,243	100%	126,243	100%	126,243	100%	126,243	100%

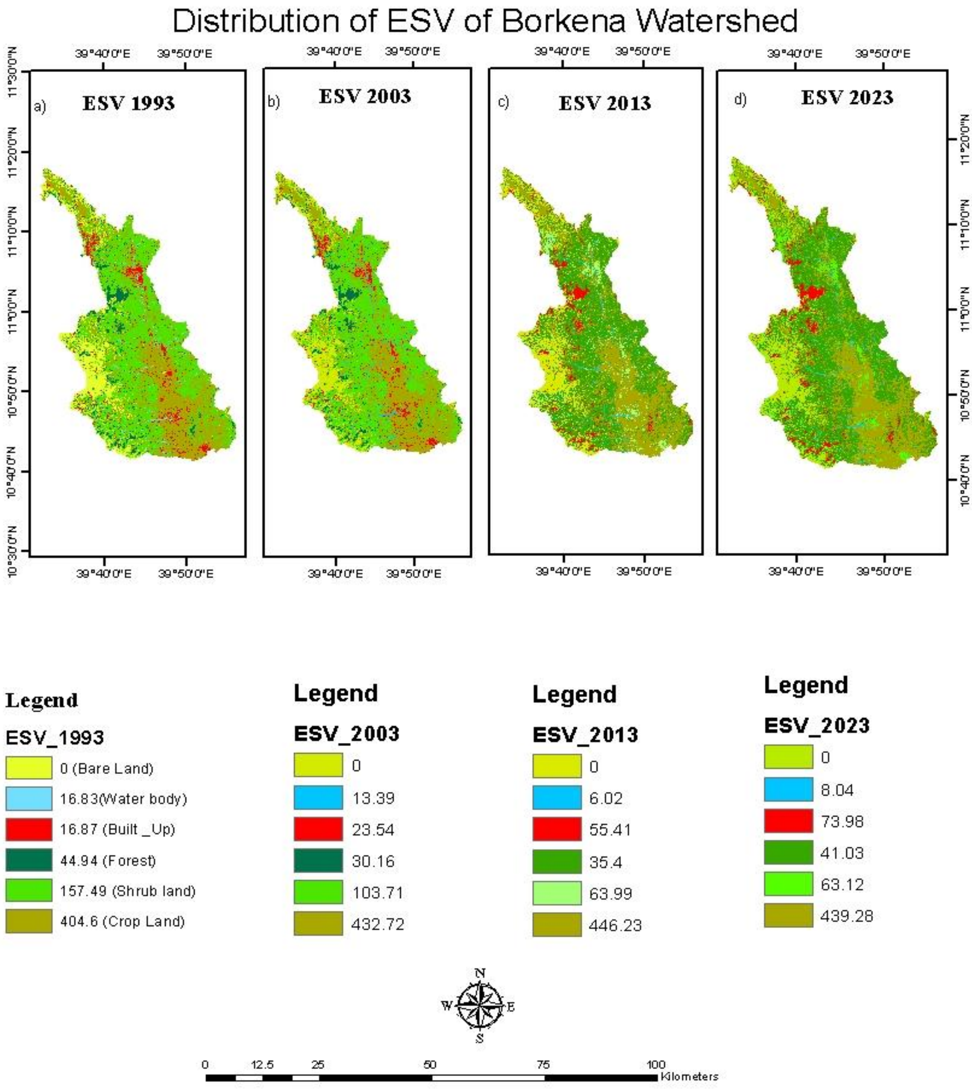
Fig. 4: Estimates of ESVs of Borkena watershed in million approx. US$ for each LULC type (1993–2023). ESVa = ESVs (million in 2022 approx.US$ yr^{-1}).



Estimated ESVs (1993–2023).

Between 1993 and 2013, global estimates of ESV coefficients show a dramatic decrease in ESVs. Based on the global ESV estimates, total ESVs in the Borkena watershed have decreased from approximately US$ 8 million in 2003 to 2023 (Fig. 4). This is because of the significant decline in forest and shrub land.

Fig. 5: Distribution of ESV of Borkena watershed a: 1993, b: 2003, c: 2013, d: 2023



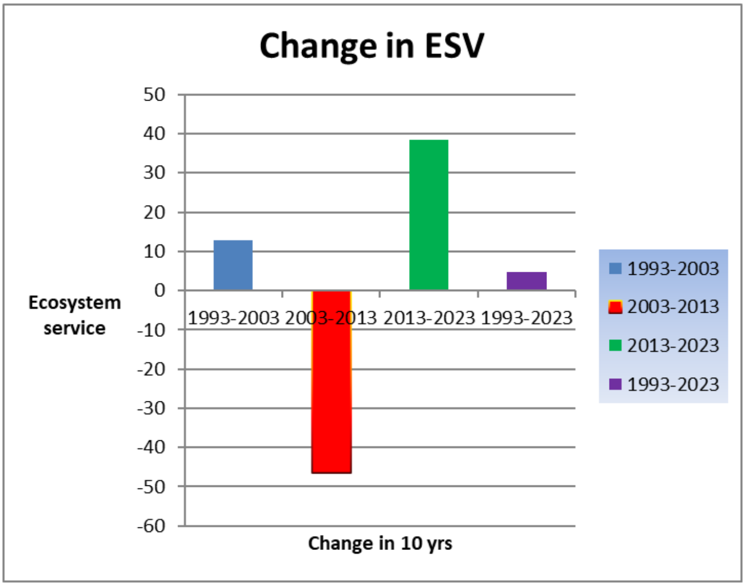
Change in individual and grouped ecosystem services

The overall results of the individual ESV functions (*ESVf*) for each study period showed slight improvement trends. From the 17 listed ES indicators, genetic resource, climate regulation, water regulation, and recreation were among the dominant ES function. These ES accounted for 56.5 and 55 % of the total ESV in the landscape in 1993 and 2023, respectively (Table 8).

The highest ecosystem service value for the study site was USD$ 176.39 million and USD$ 195.52 million in food production and USD$ 133.07million and USD$ 115.46 million in genetic resources during 1993 and 2023, respectively (Table 8). However, climate regulation and genetic resources were declined by 29.8 % and 16.5 %, respectively. From the listed ES indicators, the lowest ES value was recorded from gas regulation in 1993 and 2023. In addition, all ES except water supply, raw material, and soil formation, had declining trends from 1993 to 2023 due to anthropogenic effects that have caused a disturbance in the watershed (Figure 5). With the presence of natural habitats rich in wildlife, the watershed has the potential for tourism/recreation ES. Provisioning ecosystem service was the highest in 2003 estimated at US$ 375.40 million. The increment in the provisioning service from crop land since 1993 was associated with an increase in the land size of agricultural areas and the higher ecosystem service value assigned for it (Fig. 6).

Regulating, supporting, and cultural ES had US$180.35, 47.78, and 87.36 million, which were the highest for the years 1993, 2013, & 2023, respectively (Table 9). It is important to maintain the integrity and area share of natural habitats in the landscape to maintain diverse ecosystem benefits and services, and their long-term flow of ES.

Fig. 6: The change in ecosystem service value of Borkena Watershed in the studied years



The changes in ecosystem services valuation.

The watershed has an assemblage of provision, regulating, supporting, and cultural ES. In all land use periods, the highest value was estimated of US$375.39 million in the 2013 for provisioning ES, followed by US$ 180.36 million for regulating ES in 1993. The cultural ES was estimated US$ 87 million and for supporting ES was US$47 million for the year 2023. During the study period of 1993 to 2023, the regulating ESV covers the largest losses which accounted US$52.36million. On the contrary, the lowest ES loss was estimated for provisioning services, with a value of US$3.41million (Table 8). The food production was increased from US$176.39million in 1993 to US$195.52 million in 2023 due to increasing of cultivated land. In the regulating category, the highest loss of ES function was climate regulation- carbon sequestration with a loss of US$25.54million, related to the loss of forest. In the cultural ES category, recreation service was increased by US$33.68million. However, from regulating ES; the highest lost were seen in pollination and habitat/ refugia by US$0.33 and US$0.77 million, respectively. Soil formation and nutrient cycling were declined by US$0.05 and US$0.33 million, respectively (Table 9).

Table 8: Total ecosystem service values estimated for each land use and land cover category, and changes from 1993 to 2023 (this value is based on 2014 US$ million ha^{-1} yr^{-1})

	Estimated ESVmillion US $)				ESV Change between periods			
LULC	1993	2003	2013	2023	2003-1993	2013-2003	2023-2013	2023-1993
Forest	44.94	30.16	35.40	41.03	-10.78	1.24	5.63	-3.91
Cropland	404.60	432.72	446.23	439.28	28.12	13.51	13.05	54.68
Shrub land	157.49	103.71	63.99	63.12	-10.78	-82.72	-0.86	-94.37
Water body	16.83	13.39	6.02	8.04	-0.44	-10.36	2.02	-8.78
Built up	16.87	23.54	55.41	73.98	6.67	31.87	18.56	57.10
Bare land	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00
	640.74	603.52	607.05	625.45	12.78	-46.47	18.40	-15.29

Table 9: The estimated net change in individual ecosystem service value of Borkena Watershed (ESV_f in US$ million yr^{-1})

Ecosystem service	ESVf 1993	ESVf 2003	ESVf 2013	ESVf 2023	ESVf 1993–2003	ESVf 2003-2013	ESVf 2013-2023	ESVf 1993–2023
Provisioning Services	362.74	375.39	354.68	366.15			3.41	3.41
Food production	176.39	187.32	189.89	195.52	10.93	2.56	5.63	19.12
Water supply	34.21	36.01	34.03	35.49	1.80	-1.98	1.46	1.28
Raw materials	19.07	19.84	19.10	19.69	0.77	-0.74	0.59	0.62
Genetic resources	133.07	132.23	111.66	115.46	-0.85	-20.56	3.79	-17.61

Regulating services	180.36	175.38	135.68	144.16	0.00	0.00	-52.36	-36.21
Water regulation	10.96	10.66	4.08	5.41	-0.29	-6.58	1.33	-5.55
Waste treatment	34.20	35.70	34.33	35.47	1.50	-1.37	1.14	1.27
Erosion control	20.43	19.62	14.79	15.34	-0.81	-4.83	0.55	-5.09
Climate regulation	109.04	103.84	78.19	83.50	-5.20	-25.65	5.31	-25.54
Biological control	2.81	2.93	2.85	2.93	0.12	-0.09	0.09	0.12
Gas regulation	0.45	0.40	0.22	0.23	-0.05	-0.18	0.01	-0.22
Disturbance regulation	2.48	2.21	1.22	1.28	-0.26	-1.00	0.06	-1.20
Supporting Services	43.49	45.94	45.98	47.36	0.00	0.00	3.87	3.87
Nutrient cycling	0.11	0.10	0.06	0.06	-0.01	-0.05	0.00	-0.05
Pollination	2.73	2.72	2.32	2.39	-0.01	-0.40	0.08	-0.33
Soil formation	39.18	41.81	42.89	44.15	2.63	1.08	1.26	4.97
Habitat/refuge	1.46	1.31	0.72	0.75	-0.16	-0.59	0.03	-0.71
Cultural services	54.14	56.80	70.71	87.78	0.00	0.00	33.64	33.64
Recreation	54.07	56.73	70.67	87.75	2.67	13.94	17.08	33.68
Cultural	0.08	0.07	0.04	0.04	-0.01	-0.03	0.00	-0.04
Sum	640.74	603.52	607.05	625.45	12.78	-46.47	18.40	-15.29

DISCUSSION

In Ethiopia, loss of the natural vegetation into cultivated land has been the most intermittent LULC change as evident from previous studies (Gashaw *et al*., 2014; Tesfaye et al., 2014). Other studies showed that there have been substantial changes in LULC in the watershed and its adjacent agro ecosystem (Abera *et al*., 2021; Anteneh, 2022; Legesse *et al.*, 2024). In Ethiopia, the rapid variations of LULC observed in the last decades are mainly due to population pressure, resettlement programs, climate change, and other human- and nature-induced driving forces (Anteneh, 2022; Regasa *et al*., 2021). Nearly 44 % of Ethiopia's overall landmass is made up of the highlands (height > 1500 m.a.s.l). As a result, these highland ecosystems have been under a great deal of stress, which has resulted in a concerning trend in LULC modification (Hurni, 2024).

The major changes were expansions of crop land and built up and a decline in grazing, dense forest, and light vegetation land use/cover categories (Anteneh, 2022). In the study watershed, the total ES value showed a declining trend in the last 30 years. Particularly, from the correspond LULC dynamic over time, the ESV of forests, shrub lands, and the water body continuously declined with various proportions from 1993 to 2003 and 2013 to 2023.

Total ESVs changes

The results of numerous studies conducted in Ethiopia and other are remarkably similar to the loss of ESV in the study watershed, which is mostly caused by the loss of forest and shrub land. For example, the predominant contributor for the reduction of ESV in Andassa watershed in the Upper Blue Nile basin of Ethiopia (Gashaw *et al*., 2014) and in the Central

Highlands of Ethiopia, (Tolessa *et al*., 2018; Gashaw *et al*., 2021; Merhsa *et al*., 2024) during 1970-2023 periods, were reductions in natural forests and woodlands, forest land and shrub/ bush land, respectively. Moreover, the loss of ESV during 2000–2010 periods in Nigeria was due to the loss of forest and shrub land (Arowolo *et al*., 2018). The decrease in the average ESV of the land in China and Mozambique during each of the study periods were due to the expansion of the non-vegetation LULC and a decline in the vegetation types of land covers. (Niquisse & Cabral, 2018; Wang *et al*., 2017).

The LULC dynamics were attributed to the reductions of ES values. Changing forests and shrub land into cultivated lands were common practice. Thus, the study suggested that the decreasing of ESVs were mainly connected with the change of shrub land and forestland into cultivated land. The major declined of ESV were in the shrub land and forest land by US$94.37million and US$3.91 million, respectively. Cultivated land is the dominant LULC, which covers 50–60 % of the watershed and its ESV has increased by US$54.68 million within the study periods.

Changes in individual ESV function

The growth of cultivated land during this period is likely accountable for the sustained rise in food production and biological control over the duration of the study periods. Related to this finding, a reduction in grasslands, forest and grassland between 1985 and 2015 periods in the Upper Blue Nile basin of Ethiopia has resulted in a decrease in the value of climate regulation, gas regulation and various types of ecosystem services (Gashaw *et al*., 2014).

Most individual ecosystem functions valuation have been changed and declined due to LULC changes for all the study years (Tesfay *et al*., 2023). In this study, the individual ecosystem function valuations for regulating category of ES were declined whereas food production increased due to the fact that the agricultural land has increased by 4.77 thousand hectares (23.01 %) in the last 30 years in the Borkena watershed. According to a focused group discussion, the government's promotion of local farmers through training and inputs has resulted in an increase in crop land, which has improved farm productivity but this agricultural expansion caused degrading the forest, grazing, shrub land, and water body.

Planning for ecosystem services has not yet been approached with rigor and systematically, despite the fact that the human aspect of conservation initiatives is receiving more attention. In the central coast ecoregion of California, the United States, the researchers (Chan *et al*., 2006) examined the opportunities and trade-offs between conservation goals for biodiversity and six ecosystem services (carbon storage, flood control, forage production, outdoor recreation, crop pollination, and water provision) using a spatially explicit conservation planning framework.

Limitations of the study

The evaluation of LULC changes in ESV for the period 1993– 2023 incorporates various sources of uncertainty. The primary limitation of this study was associated with the accuracy of the land use/land cover classification. The LULC classification of 1993, 2003,2013 and 2023 were achieved with a total accuracy of 86.3, 85.5, 86.6 and 87.8 %, and a Kappa coefficient of 0.81,0.84, 0.88 and 0.83, respectively (Mersha *et al*., 2024). Another limitation is that a major error in generalizing the unit values derived from one area for a specific good as average unit values in all other areas, the approach assumes homogeneity of ecosystems services value within the entire biome/LULC types (Kindu *et al*., 2016).

CONCLUSIONS

Land use/land cover change analysis and ESV provided firsthand information about the changes in the availability of ecosystem services. This study indicated the reductions in the total and individual ecosystem services in response to LULC changes. It was found that the significant expansion of cultivated land and built-up area and lessening of forest, shrub land and grassland cover during 1993– 2023 periods, has reduced the total ESV from US$ 640.74 in 1993 to US $603.52 in 2003 and US $607.05in 2013 and US $625.45 in 2023.

The degradation of biodiversity-ecosystem services could have important implications for the sustainable development agenda in the tropics. Despite the invaluable contribution of ecosystem services to the functioning of nature and sustainable livelihoods, the value of ecosystem services has been significantly reduced over time and space due to changes in land-use/cover. The expansion of planting of exotic species at the expense of cultivated land affects ecosystem service values and has not received much attention. The results indicated that the expansion of cropland at the expense of natural forests and shrubs increased the service value of food production while reducing the total value of ecosystem services due to reduced service value of erosion control, climate regulation, nutrient cycling, and waste disposal. The expansion of plantations forests and shrub land have led to an increase in the total value of ecosystem services mainly due to an increase in the value of erosion control, climate change, waste treatment, and nutrients bicycle. Therefore, more attention should be paid to preventing deforestation of natural forests and shrubs to enhance the value of ecosystem services. Effective community management of natural forests is needed to enhance the value of ecosystem services, as the total value of ecosystem services of natural forests is higher than that of plantations.

In general, in spite of the ecological, cultural and economic importance of these services, ecosystems and the biodiversity that underpins them are still being degraded and lost at an unprecedented scale. One major reason for this is that the value (importance) of ecosystem to human’s welfare is still underestimated and not fully recognized in every day planning and decision making. In other words, the benefits of their services are not or only captured in conventional market economics. The costs of externalities of economic development (e.g. pollution, deforestation) are usually not accounted for, while inappropriate tax and subsidy (incentive) systems. They indirectly encourage the over-exploitation and unsustainable use of natural resource and other ecosystem services at the expense of the poor and future generations.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest

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APPENDIX

Table A: Summary of characteristics of some of the studies on ecosystem service values

S/N	Author with Year	Topic of the research	Method	Results	Conclusion	Recommendation
1	Mengist *et al.*, 2022	Estimating the total ESV	Eight LULC types were identified following a supervised classification using a maximum likelihood technique in ArcGIS 10.5. The ES coefficients published by Costanza and others in 2014 were used to estimate the monetary value through the benefit transfer method.	The results showed declining of ESV from US$ 5818 million to US$ 5536.9 million from 1986 to 2019 and are expected to Decline to US$ 5222.8 million in 2049. The change in ESV revealed a total loss of 4.8 %.	The reasons for the decline in ESV were the conversion of forestland, grassland, and wetland to settlement and agricultural areas. They conclude that the cause for the decline of ESV is a land-use change that caused ecosystem degradation.	Reversing the LULC trends of change towards increasing the areal size of natural habitats like the forest, grassland, and wetland is crucial to avoid the expected ESV loss. The local administrator should work to develop ecotourism activities like nature tourism and rural tourism with cultural tourism to increase off farming income sources of the local communities.
2	Tolessa *et al.*, 2018	Changes in Ecosystem Service Values in Response to Changes in	first analysed LU/LC Changes over four decades by the use of GIS. LU/LC values were used	A total of $ 43.7 million/ ha/yr ESV declined in the period 1973–2017. In terms of individual ecosystem	The decrease in total and individual ESV in the study area and period calls for urgent action to	Making trade-offs between the synergies and Complementarity of each ES and LU is vital. Managing land uses at the landscape level

		Landscape Composition in the Central Highlands of Ethiopia	along with global data sets developed for biomes to estimate the amount of total and individual ESV change for the Study landscape and period.	services, the regulating services were substantially reduced, with climate regulation (3.15 %) and water regulation (1.79 %) contributing the highest value, while food production (3.03 %) and soil formation (0.77 %) increased.	be made to enhance the sustainability of ecosystem service provision at the landscape level with appropriate land management practices.	help to optimize the overall ecosystem services values obtained. Expressing ES in quantitative terms could help decision making processes about the amount, management and benefit/cost sharing mechanisms that need to be devised to mitigate resource degradation and its consequences on ecosystem service flow
3	Kindu *et al*., 2016	Changes of ecosystem service values in response to land use/land cover dynamics in Munessa–Shashemene landscape of the Ethiopian highlands	Estimation and change analyses of ESVs were conducted, mainly, by employing GIS using LULC datasets of the year 1973, 1986, 2000 and 2012 with their corresponding global value coefficients developed earlier and our own modified conservative value	A decrease of total ESVs from US$ 130.5 million in 1973, to US$ 118.5, 114.8 and 111.1 million in 1986, 2000 and 2012, respectively. While using global value coefficients, the total ESVs declined from US$ 164.6 million In 1973, to US$ 135.8, 127.2 and 118.7 million in 1986, 2000 and 2012,	conclude that the decline of ESVs reflected the effects of ecological degradation in the studied landscape	Suggest further studies to explore future options and formulate intervention strategies.

			coefficients for the studied landscape.	respectively. The results revealed a total loss of ESVs ranging from US$ 19.3 million when using our own modified value coefficients to US$ 45.9 million when employing global value coefficients. Changes have also occurred in values of individual ecosystem service functions, such as erosion control, nutrient cycling, climate regulation and water treatment, which were among the highest contributors of the total ESVs. However, the value of food production service function consistently increased during the study periods		
4	Costanza *et al*., 2014	Changes in the global value of	Updated estimate based on updated unit ESV and land	In 1997, the global value of ecosystem services was	Our estimates show that global land use changes	it is a necessary precursor to practical application of the

		ecosystem services	use change estimates between 1997 and 2011. They also address some of the critiques of the 1997 paper. Using the same methods as in the 1997 paper but with updated data,	estimated to average $33 trillion/yr. ($46 trillion/yr in 2007 $US). The estimate for the total global ecosystem services in 2011 is $125 trillion/yr. (assuming updated unit values and changes to biome areas) and $145 trillion/yr. (assuming only unit values changed), both in 2007 $US.	between 1997 and 2011 have resulted in a loss of ecosystem services of between $4.3 and $20.2 trillion/yr, and we believe that these estimates are conservative.	concept using changes in the flows of services for decision making at multiple scales. It allows us to build a more comprehensive and balanced picture of the assets that support human well-being and human's interdependence with the wellbeing of all life on the planet.
5	Gashaw *et al*., 2018	Estimating the impacts of land use/land cover changes on Ecosystem Service Values: The case of the Andassa watershed in the Upper Blue Nile basin of Ethiopia	The hybrid land use classification technique for classifying Landsat images, the Cellular-Automata Markov (CA-Markov) model for LULC prediction, and the modified ecosystem service value Coefficients for estimating ESV were employed.	Their findings revealed that there was a continues expansions of cultivated land and built-up area, and withdrawing of forest, shrubland and grassland during the 1985–2015 periods, which are expected to continue for the next three decades Consequently, the total ESV of the watershed has	The loss of ESV in the study watershed mainly due to the loss of shrubland and forest land use categories is very similar to the findings of various studies in Ethiopia and elsewhere	Wide range of changing the widely implemented cereal production with fruits is imperative to improve vegetation cover of the study watershed, and then to increase ESV. Furthermore, the government should facilitate Payment for Ecosystem Services (PES) at microlevel as a conservation strategy and the other hand designing ecotourism

				declined from US$26.83 106 in 1985 to US$22.58 106 in 2000 and to US$21.00 106 in 2015 and is expected to further reduce to US$17.94 106 in 2030 and to US$15.25 106 in 2045. The impacts of LULC changes on the specific ecosystem services are also tremendous.		in the Andassa watershed will help to improve the income of local communities for conservation. Acknowledgements