ERJSSH 10(2), December 2023

ORIGINAL ARTICLE

The impacts of land use/cover changes on values of ecosystem service in Tul watershed, Northwest Ethiopia

Zemenu Awoke[1] & Ermias Debie [2]*

Abstract

There has been a rise in interest in the relationship between ecosystem service values and land cover change resulting from sustainable land management. Changes in land use/cover caused by soil and water conservation practices combined with plantation practices can have an impact on the values systems of ecosystem service. The study aims to address the issue of how changes in land use/ cover influence ecosystem values in Ethiopia's Tul watershed. To estimate ecosystem service values in the study watershed, the benefits transfer method of the modified value coefficient was used. The total ESV decreased by US$4.2 million between 1990 and 2010 while increasing by US$4.3 million between 2010 and 2021. The expansion of plantation practices in the watershed contributes to the improvement of the values of ecosystem service. The major ecosystem functions that influence changes in the ecosystem service values are climate regulation, erosion control, waste treatment, and the nutrient cycle. It is concluded that there needs to be scaled up the controlled management of natural forests and shrublands in steep slope areas, and sustainable plantation practices enhance the values of ecosystem service.

Keywords: LULCs dynamics, Watershed management practices, Values of ecosystem service

1. Introduction

Ecosystem services are advantages that humans derive for their survival, way of life, and general well-being from ecosystems, as well as all the ecological resources that allow human existence to continue in the biosphere (Costanza et al., 2017). The four main elements of ecosystem services are provisioning, controlling, cultural, and supporting services (Shen et al., 2021). Primary production, soil formation, and nutrient cycling are a few examples of supporting services. Food, fiber, fresh water, and other goods that ecosystems provide for human consumption are examples of provisioning services. Climate, pests, and ecosystem processes like soil erosion and air quality are all impacted by regulatory actions. Last but not least, cultural services are non-material benefits that have positive effects on the pleasure and aesthetic qualities of the landscape. Benefits range from the provision of fundamental human needs, such as food, water, health, security, and livelihoods, to the acquisition of cultural and spiritual meaning and identity through interactions with ecosystems (Rasmussen *et al.*, 2016). While provisional, regulatory, and

---

[1] *Geography and Environmental Studies Department, Bahir Dar University, Bahir Dar, Ethiopia, Email: zemenuawoke@yahoo.com*

[2] *Geography and Environmental Studies departments, Bahir Dar University, Bahir Dar, Ethiopia * Corresponding author- Email: ermi272004@gmail.com*

DOI*:* https://dx.doi.org/10.4314/erjssh.v10i2.1

cultural services have an immediate impact on human well-being, supportive services have a long-term indirect impact on human well-being by allowing other services to be produced (Costanza *et al.,* 2014). Changes in land use and cover caused by socioeconomic forces, on the other hand, have a direct impact on these ecosystem services and benefits (Gao et al., 2021). As a result of human-caused climate change and land-use change, economic and environmental trends, and ecosystem functions are changing at an alarming rate (Shaw et al., 2011). As a result of long-term land uses and land cover change, the global value of ecosystem services has been significantly reduced over time and space (Costanza et al., 2014). Food-related ecosystem services have increased, while other ecosystem services have decreased due to the potential for connected agricultural systems to permanently reduce local biodiversity (Reader et al., 2022).

A low land-to-person ratio, a large livestock population, and poor land management all contribute to land degradation making achieving various ecosystem service values difficult. Changes in land use and land cover (LULC) impact the availability and value of ecosystem services, as well as human welfare (Kindu et al., 2016; Temesgen, 2018). The total ecosystem service values (ESVs) decreased as cultivated land increased at the expense of natural woods, bushes, and grasslands (Debie& & Anteneh, 2022).

The dynamics of land use/cover are important in soil degradation, which affects ecosystem services in general. Deforestation, overgrazing, conventional tillage, and poor farmland management all contribute to increased biodiversity loss, and the loss of other ecosystem services (Borrelli et al., 2021). Soil degradation-induced land cover changes have several onsite effects on regulating ecosystem services, a decrease in biodiversity, and the depletion of ecosystem carbon pools (Lal, 2014; Wassie, 2020; Borrelli et al., 2021).

To prevent soil deterioration caused by land use/cover dynamics, sustainable land management strategies that include soil, water, and vegetation management should be implemented. Sustainable watershed management is critical for the sake of the ecosystem and to reduce soil erosion. In Ethiopia's highlands, the most effective substitute for a variety of ecosystem services is the use of a land management technique that incorporates compost, a rotation of legume and cereal crops, and vegetation-maintained terraces (Debie, 2022). To improve ecosystem functions and services and achieve land degradation neutrality, sustainable soil management strategies based on changes in land use and cover are required (Abera et al., 2020). It is critical to understand the benefits of land management techniques for gaining ecological benefits from preserved watersheds to enable targeting and scaling. Management of perennial plant cover and moisture management strategies resulted in the augmentation of other ecosystem service values (Desta et al., 2021). Watershed management has the potential to increase biodiversity by allowing for synergies between various ecosystem functions. Despite the vital contribution they make to the functioning of nature and sustainable livelihoods, the values of ecosystem service have decreased dramatically over time and space due to changes in land use/cover. More emphasis should be placed on attempting to prevent the loss of natural forests and shrubs to enhance the value of ecosystem services. Because natural forests provide more ecosystem services than plantations (Paudyal et al., 2020; Thammanu et al., 2021), effective community management of these areas is required to increase their value. To enhance the many advantages of ecosystem services, a mosaic agricultural space composed of plantations, natural forests, agroforestry, and wetlands must be developed (Debie & Anteneh, 2022).

In the last three decades, the value of ecosystem services has progressively decreased as the cost of wetlands, forests, bushes, and grasslands has increased due to farming and barren land (Kindu et al., 2013; Temesgen et al., 2018; Godebo et al., 2018; Assefa et al.,2021; Nigussie et al., 2021; Anley et al.,2022; Debie& & Anteneh, 2022). For instance, according to Anley et al. (2022), the Rib watershed's total value of ecosystem service decreased from US$ 68.6 million in 2000 to US$ 59.3 million in 2020 due to environmental degradation. The decline in the combined ecosystem service values of wetlands, forests, and bushlands over the previous 26 years, according to Msofe et al. (2020), has resulted in a loss of US$ 811.5 million. According to Assefa et al. (2021), the total ESV has decreased from US$ 29.73 million to US$ 20.84 million in 35 years.

The prudent management of ecosystem services necessitates taking into account changes over time (Felipe-Lucia et al., 2021). There has been an increase in interest in the relationship between ecosystem services and land cover change as a result of sustainable land management over time (Wu et al., 2022). Effective soil and water conservation remedies must be developed to effectively enhance other ecosystem service values (Hu et al., 2014). Although little attention has been paid to this issue, changes in land use/cover as a result of soil and water conservation practices combined with plantation practices can have an impact on the values of ecosystem services. In Ethiopia's Tul watershed, this study attempts to respond to how can changes in land use/cover influence the values of ecosystem service.

2. Materials and Methods

2.1. Study area description

2.1.1. Location

The study was conducted in the Tul watershed in Ethiopia's northwest highlands. Tul watershed contains a 591 km2 area and is located at 11°1′0" N–11°28′30"N latitude and 37°20′30"E–37°42′30"E longitude (Figure 1).

2.1.2. Landforms and topography

The study watershed is situated between 3528 and 1570 meters above sea level (Figure 1). Higher elevation ranges are found in the watershed's southwest and eastern parts. Alluvium, Ashangi basalts, basalts associated with volcanic centers, and Termaber basalts characterize the geology. Basalts associated with volcanic centers account for more than 85% of the watershed's geological composition. The watershed has a diverse topography, with moderate, gentle, steep, and extremely steep slopes. Plantations and degraded bushlands are found on steep to extremely steep hills. The main river that drains the watershed is the Tul River, one of the tributaries of the Blue Nile River in the upper basin. The watershed is characterized by unimodal rainfall patterns. Because of its dissected topography and landmass slopes down from Mount Adama toward the watershed's outlet, the study watershed is prone to soil erosion, gully formation, and floods.

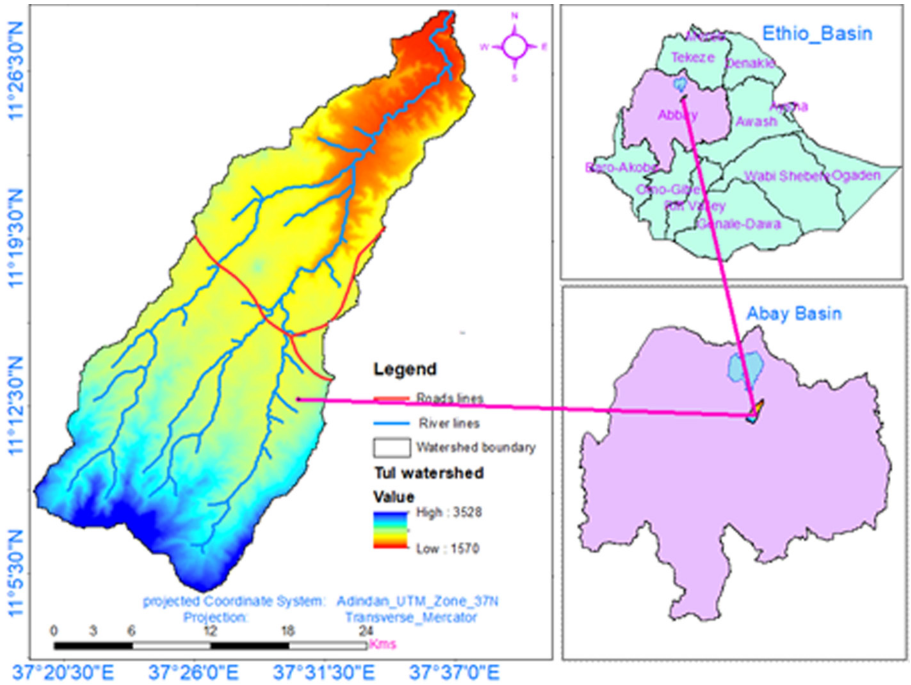

Figure: 1. Locational Map of the study watershed

2.1.3. Climate

The watershed contains a wide range of ecosystems and resource types, as well as climates ranging from Wurch to Woina-dega. According to Hurni's (1985) Ethiopian agro-climatic classification, the majority of the study watershed falls within the Woina-dega agro-climatic zone (traditional climate classification), which is equivalent to sub-humid. The average annual rainfall in the study area was 1270mm, and the average annual low and high temperatures were 8.8°C and 25.2°C, respectively (Figure- 2).

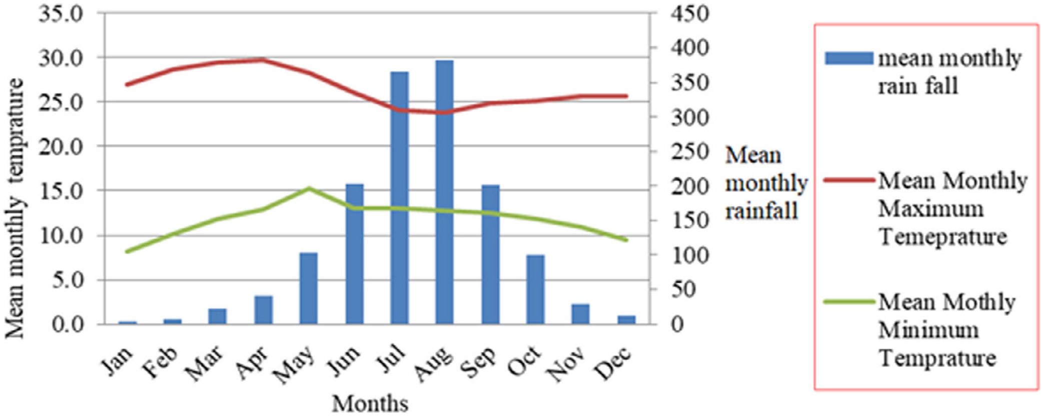

Figure: 2. The average monthly temperature and rainfall distribution of the study watershed from 1980 to 2020.

The month with the highest mean monthly temperatures was March, while the months with the lowest mean monthly temperatures were December and January. The main rainy season in the study area lasts from June to mid-October. The main rainy season accounts for approximately 83.3% of annual rainfall. The remaining 16.7% was distributed over the rest of the year inconsistently.

2.1.4. Soil

The major soil types in the watershed are nitosols, vertisols, lithosols, luvisols, and cambisols. Vertisols are the most common soil type on relatively gentle slopes and in very deep soils. This soil type is characterized by heavy black clay and is frequently waterlogged during the rainy season. It has a high cation exchange capacity and base saturation content in both the surface and subsurface horizons. The watershed's upslope areas are characterized by shallow soil profiles. The bottom soils, on the other hand, are very deep and have nearly uniform profiles.

2.1.5. Vegetation Cover

The most common land uses/covers in the watershed are settlements, grazing land, cultivated land, plantations, shrublands, grassland, and forests. Significant natural vegetation resources include Afro-Alpine and sub-AfroAlpine forests, dry evergreen montane forest and evergreen scrub, combretum Terminalia woodland, Acacia Commiphora woodland, bamboo forests, and plantations. As a result, the vegetation supply in the study area consists of evergreen and semi-evergreen bushes, small trees, and larger trees on rare occasions. The study watershed headwater is also covered by Juniperus pocera, Olea europaea, Hagenia abyssinnica, Erica arborea, Carissa spinarum, Dovyalis abyssinica, Justicia schimperiana, Dombeya torrida, Eucalyptus tree, Accaica Abyssinica, Cordia Africana, Olivera Africana, and Erica arborea. Various indigenous plant species exist in the area, depending on the terrain and topography of the watershed. Furthermore, residual indigenous biomasses found along ridges and rivers, as well as in a few protected areas, are reliable indicators of degeneration over time.

2.1.6. Agricultural Practices

The primary economic activity in the study area is mixed crop and livestock production. The most common crops grown in the area are barley (Hordeum vulgare), wheat (Triticum Vulgare), teff (Eragrostis teff), potato (Solanum tuberosum), maize (Zea mays), and legumes such as beans (Vicia faba), pea (Pisum sativum), and sorghum. Domestic animals raised in traditional farming include cattle, goats, sheep, donkeys, horses, mules, and chickens. The primary source of food for cattle production is grazing land, both communal and private. Zero-grazing methods, in which grass is mechanically mowed and fed to cattle, have grown in popularity in recent years as a way to mitigate the effects of climate change.

2.2. Methods of the Study

2.2.1. Data Sources and Types

A digital elevation model (30*30) and four years set of satellite images from the USGS Earth Explorer (Landsat TM-1990, Landsat ETM-2000, Landsat ETM-2010, and OLI IRS-2021, all with a spatial resolution of 30m) were obtained. To detect changes over three decades, the years were selected based on the availability of cloud-free satellite images from the earliest possible time (1990) to the most recent time (2021). For ground verification, raster DEM data (30*30), GPS, and topographic maps at a resolution of 1:50,000 were employed.

2.2.2. Sattelite Image Processing and Analysis

Software ERDAS Imagine 14 and ArcGIS 10.4.1 were used for image processing, analysis, and LULC mapping. Image processing techniques, such as layer stack, image enhancement, and a subset were undertaken. Land uses and covers were classified using a supervised classification process using the maximum likelihood classifier algorithm across the study periods. The maximum likelihood classifier is recommended for many LULC change studies for producing accurate LULC categorization. Using the training site sample found in each of the Landsat images of the Tul watershed, LULC maps for 1990, 2000, 2010, and 2021 were produced.

2.2.3. Valuation of the modified ecosystem service value coefficients

The effects of changing land use/ cover on the dynamics of ecosystem service value were evaluated using an integrated valuation of updated ecosystem service value coefficients. The change in ecosystem service values in the study watershed was investigated using Landsat categorized land use and land cover classes from 1990, 2000, 2010, and 2021. Costanza et al. (2014) developed an ecosystem service valuation model for 16 biomes to determine the values of ecosystem services for various land use and land cover categories. Other academics, on the other hand, argue that the model is problematic because of its ambiguities and limited application at the local level (Wang et al., 2017). Kindu et al. (2016) developed more conservative estimating coefficients for Ethiopia based on an in-depth understanding of the study landscape conditions and additional research, primarily from the Economics of Ecosystems and Biodiversity (TEEB) valuation database. The benefit transfer method was used to estimate the ecosystem service value of other comparable areas where there is no site-specific valuation method available, using current values and other data from the original study site. The modified ecosystem service valuation model was used to estimate the ecosystem service values for five different land use/ covers within the research watershed. The appropriate sample biomes were then designated based on the study watershed’s land use and land cover types (Table 1).

Table 1. LULC classifications, matching biomes, and ecosystem services coefficients for the research watershed based on updated estimations (Kindu et al., 2016)

LULC	Equivalent biome	Ecosystem services coefficient (US$ ha-)
Built-up area	Urban	0
Cultivated land	Cropland	225.56
Forest	Tropical Forest	986.69
Grassland	Grass/range land	293.25
Plantation	Tropical Forest	986.69
Shrub land	Tropical Forest	986.69

Grassland/rangeland is used to represent grassland, tropical forest is used to represent the forest, plantation forest, and shrubland, and urban is used to represent the built-up region. Some land use/cover categories do not exactly correspond to the biomes depicted. For example, shrubland was used to represent the tropical forest biome. However, in the study area, shrubland is less dense than forest and consists primarily of small trees, bushes, and shrubs, with grasses sprouting on occasion. As a result, while the represented forest and shrubland categories differ in composition and structure from the tropical forest biome, they provide comparable ecosystem services. Cultivated fields are defined in this study as areas used for both perennial and annual crops, as well as irrigated areas and dispersed rural settlements. Despite their dispersion, including rural settlements in this category may understate the environmental benefits associated with the farming biome.

Grassland, forest, and plantation forests, on the other hand, are all closely related biomes. As a result, even though all of the represented biomes have different traits and roles, the land usage and land cover in this context are the same. Using them as proxies, the ecosystem service values of the various land use and land cover categories in the study region can be estimated. In studies of the ecosystem service value, such proxies for land use, land cover types, and associated biomes are frequently used (Kindu et al., 2016; Temesegen et al., 2018).

Equations 1 and 2 can be used to estimate the ecosystem service values and determine the percent change in ecosystem service value over time, respectively (Caberal et al., 2016; Kindu et al., 2016; Shiferaw et al., 2019). The overall ecosystem services value for each LULC type was determined by multiplying the area of each type in hectares by the relevant value coefficients. To estimate the total ecosystem service values of the landscape of each reference year in the study region, the values for the LULC types in each reference year were calculated.

$$ESV_k = \sum A_K * VC_k \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq.1)}$$

Where: $ESV_{k\ is}$ the Ecosystem service value of the land use land cover type K, A_K is the area (ha) of LULC type K and VC_K is the value coefficient of LULC type 'K' $_($the US \$ $ha^{-1}y^{r-1}$).

Table: 2. Coefficients (US$ $ha^{-1}yr^{-1}$) of the Modified ecosystem service functions of each LULC type (Kindu et al., 2016) for the four represented biomes.

Ecosystem services	Natural forests	Plantation forest	Croplands	Grasslands
Provisioning services				
Water supply	8	8		
Food production	32	32	187.56	117.45
Raw material	51.24	51.24		
Genetic resources	41	41		
Regulating services				
Water regulation	6	6		3
Water treatment	136	136		87
Erosion control	245	245		29
Climate regulation	223	223		
Biological control			24	23
Gas regulation	13.68	13.68		7
Disturbance regulation	5	5		
Supporting services				
Nutrient cycling	184.4	184.4		
Pollination	7.27	7.27	14	25
Soil formation	10	10		1
Habitat/Refuge	17.3	17.3		
Cultural services				
Recreation	4.8	4.8		0.8
Cultural	2	2		
Total	986.69	986.69	225.56	293.25

The percent change of ecosystem service value across different periods could be computed by using equation two (eq 20.) (kindu et al., 2016; Caberal et al., 2016; Temsegen et al., 2018). The percentage of ecosystem service value change was calculated using the following equation.

$$\text{Percent of ESV change} = \frac{(\mathbf{ESV}\ \mathit{recent}\text{-}\mathbf{ESV}\ \mathit{previous})}{\mathbf{ESV}\ \mathit{previous}} * 100 \qquad \text{............. (eq.2)}$$

Where:- ESV_k is of ESV of land use land cover type K, AK is the area (ha) of LULC type K; VC_K is the value coefficient of LULC type 'K' (the US \$ $ha^{-1}yr^{-1}$). Positive values suggest an increase whereas negative values imply a decrease in amount.

In addition, the following equation was used to evaluate the value of services given by individual ecological functions within the study watershed:

$$ESVf-\sum AK*VCfk \ldots\ldots\ldots\ldots\ldots\ldots \text{eq. 3}$$

Where ESVf = calculate ecosystem service value of functions (f), AK= the area (ha), and VCfk= value coefficient of function (f) (us\$ ha^{-1} $year^{-1}$) for LULC type (^{k}). The contribution of individual ecosystem functions to the overall values of ecosystem services per year was ranked based on estimated values of ecosystem functions for each reference year.

2.2.4. Analysis of coefficient of sensitivity

To reflect the dependency of ecosystem service value on the ecosystem services value index over time, the elasticity of the coefficient of economics is selected to calculate the sensitivity index.

$$CS= \frac{(ESV_j-ESV_i/ESV_i}{(VC_{jk}-VC_{ik})/CV_{ik}} \ldots\ldots\ldots\ldots \text{eq.4}$$

Where ESV represents the total ecosystem services value; VC is the value coefficient i and j represent the initial and adjusted values respectively jk is the land use type j and CS is the coefficient of sensitivity. Adjust the value coefficient of each land-use type by 50% respectively and then measure the change of ecosystem services value. If CS>1, the ESV for VC is flexible, if CS<1 the ESV for VC is lack elasticity; CS= 0 indicates a complete in-elasticity. The greater the ratio is the more important it is to the accuracy of the ecosystem services function value index (Zhang et al., 2015).

3. RESULTS AND DISCUSSION

3.1. Changes in land use/covers from 1990 to 2021

Shrublands, natural forests, grasslands, cultivated land, built-up area, and plantations were identified to be the major land uses and cover in the area of study. Debie and Awoke (2023) quantified changes in these land use/covers from 1990 to 2021. For instance, the first research period (1990–2000) saw a significant rise in the area under cultivation as a result of the loss of natural grasslands, shrublands, and woodlands. In the second phase (2000-2010), plantations, natural forests, grasslands, and settled regions have been acquired at the expense of shrublands and cultivated land. The plantation was steadily extended to cultivated land and grassland at a significant cost throughout the study (1990–2021).

3.2. Coefficient of sensitivity of land use/covers to eco system service values

Results in Table 3 indicate the coefficient of sensitivity (CS) was greater than one in all land uses except forests and plantations between 1990 and 2010. However, except coefficient of sensitivity of plantation and cultivated land, CS values of all land uses are less than one in 2021. Cultivated land and shrubland had the highest CS value of relatively larger area coverage in addition to the highest ecosystem service values between 1990-2010 years.

Conversely, plantation and cultivated land have the highest CS value in 2021 due to their highest area coverage in addition to the highest ecosystem service values. Most of the ESVs calculated for the watershed between 1990 and 2010 were fairly elastic. This suggested that the estimation of the ecosystem service values is reliable since most CS value is greater than one. The reverse is also true in 2021 in the study area.

Table: 3. Coefficient Sensitivity (CS) of each land use/ cover with their respective years

LULC Categories	CS 1990	CS 2000	CS 2010	CS 2021
Cultivated land	4.2	5.9	5.84	4.92
Forest	0.93	0.031	0.22	0.15
Grassland	1.34	1.24	1.53	0.31
Plantation	0.11	0.23	0.4	1.25
Shrub land	1.85	1.54	1.1	0.91

3.3. **Changes in ecosystem service values**

Results in Table 4 disclosed the change in ecosystem service value of each land-use/cover type from 1990 to 2021. The total values of ecosystem services were US$26.6 million in 1990, US$ 22.9 million in 2000, US$ 22.4 million in 2010, and US$ 26.7 million in 2021. Shrublands, cultivated lands, and plantations were the main land use/covers making a contribution to the total values of ecosystem service between 1990 and 2000, 2010, and 2021, in that order. The total value of plantation ecosystem services continuously increased by US$ 8.7 million, while constantly declining by US$ 7.9 million for the total value of shrubland ecosystem services between 1990 and 2021.

The total ecosystem service values have decreased from US$ 26.6 million in 1990 to US$ 22.9 million in 2000 and US$ 22.42 million in 2010. Because of the loss of natural vegetation (such as forest, shrubland, and grassland) and the increase in cultivated areas, the total ecosystem service values decreased by US$3.5 million between 1990 and 2000 (Table 4). Declining in the values of shrubland ecosystem services contributed largely to the decline of the total values of the watershed ecosystem service from 1990 to 2010. The conversion of natural vegetation covers, such as forests, shrubs, and grasslands to cultivated land has contributed to a drop in the total values of ecosystem service (Anley et al., 2022; Berihun et al., 2019; Debie & Anteneh, 2022; Gashaw et al., 2018; Godebo et al., 2018; Hu et al., 2008; Kindu et al., 2016; Li et al., 2019; Shiferaw et al., 2019; Temesgen et al., 2018; Wang et al., 2017). The decreasing ecosystem service values reflected the effects of land use/cover changes on ecological degradation (Anley et al., 2022).

Table: 4. The estimated changes in total ecosystem service values in the Tul Watershed from 1990 to 2021

LULC Categories	The total ESV (US $ in millions)				ESV changes (US $ in millions)			
	1990	2000	2010	2021	1990-2000	2000-2010	2010-2021	1990-2021
Cultivated land	7.3	8.8	8.49	8.52	+1.5	-0.31	+0.03	+1.22
Forest	0.7	0.2	1.4	1.1	-0.5	+1.2	-0.3	+0.4
Grassland	3	2.4	2.9	0.7	-0.6	+0.5	-2.2	-2.3
Plantation	0.8	1.5	2.6	9.5	+0.7	+1.1	+6.9	+8.7
Shrub land	14.8	10	7	6.9	-4.8	-3	-0.1	-7.9
Total	26.6	22.9	22.4	26.7	-3.7	-0.5	+4.3	+0.1

On the contrary, the total ecosystem service values increased by US$ 4.3 million between 2010 and 2021 due to soil conservation and plantation practices that began in 2003 through community mobilization in the watershed.

3.4. **Changes in Values of Ecosystem Service Functions**

Table 5 shows the estimated change in the values of specific ecosystem services due to land use-cover dynamics between 1990 and 2021. Food production had the highest specific ecosystem service values across all study years, while cultural service had the lowest. The major contributors to watershed ecosystem services are food production from provisional ecosystem services, erosion control, climate regulation, waste treatment from regulating ecosystem services, and nutrient cycling from supporting ecosystem services. Food production increased by US$ 0.9 million between 1990 and 2000, while erosion control, climate regulation, waste treatment, and nutrient cycling decreased by US$ 1.2 million, US$ 1.1 million, US$ 0.93 million, and US$ 0.8 million, respectively. The findings show that food production functions were expanded at the expense of other major regulating and processing functions of ecosystem service. This was due to an increase in cultivated land at the expense of natural vegetation covers. Changes in the values of erosion control, climate regulation, waste treatment, and nutrient cycling functions were the most services can contributors to the loss of ecosystem service values in 2010. The loss of natural shrublands, forests, woodlands, and grasslands as cultivated land increases have reduced the value of erosion control, climate regulation, nutrient cycling, and waste treatment functions (Debie & Anteneh, 2022; Temesgen et al., 2018; Kindu et al., 2013; Msofe et al.,2021).

Table 5: Impact of land use/cover changes on the values of individual ecosystem services from 1990 to 2021.

Ecosystem services	**ESV functions across different periods (ESVf US$ in millions over all periods**			
Ecosystem services	ESV_f 1990	ESV_f 2000	ESV_f 2010	ESV_f 2021
Provisioning services				
Water supply	0.13	0.1	0.09	0.14
Food production	7.8	8.7	8.6	7.9
Raw material	0.84	0.61	0.6	0.9
Genetic resources	0.67	0.49	0.46	0.73
Regulating services				
Water regulation	0.13	0.1	0.1	0.11
Water treatment	3.1	2.3	2.4	2.6
Erosion control	4.3	3.1	3	4.4
Climate regulation	3.7	2.6	2.5	4
Biological control	1	1.1	1.1	1
Gas regulation	0.3	0.2	0.2	0.3
Disturbance regulation	0.08	0.06	0.06	0.09
Supporting services				
Nutrient cycling	3	2.2	2.1	3.3
Pollination	0.83	0.83	0.85	0.72
Soil formation	0.2	0.1	0.1	0.5
Habitat/Refuge	0.3	0.2	0.2	0.3
Cultural services				
Recreation	0.09	0.06	0.06	0.09
Cultural	0.03	0.02	0.02	0.04
Total	26.5	22.77	22.42	27.12

Food production ecosystem service declined by US$ 0.7 million between 2010 and 2021, while erosion control, climate regulation, nutrient cycling, and water treatment functions increased by US$1.4 million, US$1.5 million, US$1.2 million, and US$0.2 million, respectively. Such increases in the functions of ecosystem service were primarily attributed to an increase in the study watershed's plantation and conserved area coverage (Figure 3). Legesse et al. (2018) discovered that a community-based watershed management intervention resulted in biodiversity restoration and improved soil fertility. The expansion of acacia and eucalyptus species plantation at the expense of cultivated land contributes to the overall increase in ESV in the watershed (Debie & Anteneh, 2022).

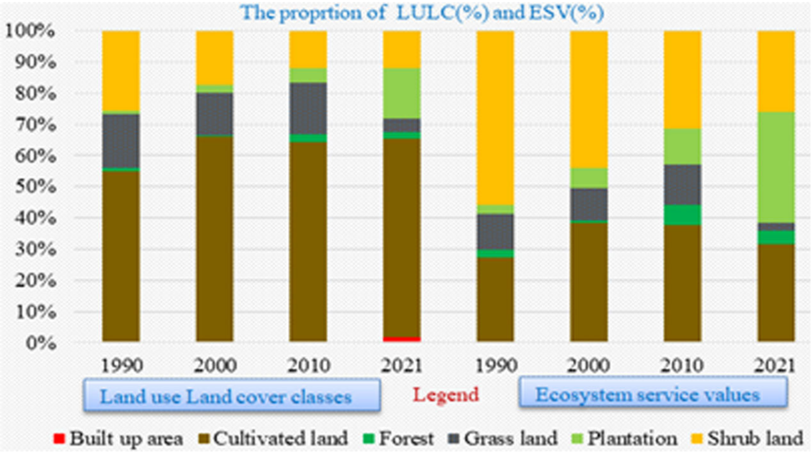

Figure 3. Proportions of LULC (%) and ESV (%) for the periods from 1990 to 2021 in the tul Watershed

4. Conclusion

The main goal of sustainable land management practices should be to improve land use/covers and ecosystem service values. The relationship between ecosystem services and land cover change caused by sustainable watershed management strategies is receiving more attention. This study aims to assess the ecosystem service values that are influenced by changes in land use and cover in Ethiopia's Tul watershed. Changes in land use and cover between 1990 and 2000 reduced the ecosystem service values of forests, shrubs, and grassland. Preliminary ecosystem services, such as food production, increased during this period while regulating and processing ecosystem services declined. Plantation methods, on the other hand, increased total ecosystem service values, as well as ecosystem functions, including climate regulation, erosion control, waste treatment, and nutrient cycling from 2010 to 2021. During the study period, it was discovered that the values of regulating and supporting ecosystem services increased at the expense of provisional ecosystem services. This resulted from the watershed management program's expansion of plantations at the expense of cultivated land. The findings suggest that cultivated land should be restricted from encroaching on steep slope areas with wild vegetation. Protecting and reforesting the natural vegetation that covers the upper watershed's steep slope will improve the overall value of ecosystem service. Maintaining a variety of degraded afforestation, agroforestry, sustainably managed farmland, and diverse agroecosystems is required to create a synergistic interaction between values of regulating, provisional, and supporting ecosystem service.

Acknowledgment: The authors are grateful to recognize the cited literature.

Conflict of Interest: The authors declare that they have no competing interests.

Ethical consideration: It is confirmed that the authors conform to research ethics principles.

References

Abera, W., Tamene, L., Tibebe, D., Adimassu, Z., Kassa, H., Hailu, H., Mekonnen, K., Desta, G., Sommer, R., &Verchot, L. (2020). Characterizing and evaluating the impacts of national land restoration initiatives on ecosystem services in Ethiopia. *Land Degradation & Development*, Vol.31, 37e52.

Anley, M. A., Minale, A.S., Haregeweyn, N., & Gashaw, T. (2022). Assessing the impacts of land use/cover changes on ecosystem service values in Rib watershed, Upper Blue Nile Basin, Ethiopia. *Trees, Forests and People,* Vol.7, 100212.

Aschonitis, V.G., Gaglio, M., Castaldelli, G., & Fano, E.A. (2016). Criticism of the elasticity-sensitivity coefficient for assessing the robustness and sensitivity of ecosystem services values. *Ecosystem Services*, Vol. 20, 66–68

Assefa, W.W., Eneyew, B. G., & Wondie, A. (2021). The impacts of land use and land-cover change on wetland ecosystem service values in the peri-urban and urban areas of Bahir Dar City, Upper Blue Nile Basin, Northwestern Ethiopia. *Ecological Processes,* 10(39).

Birhanu, L., Hailu, B. T., Bekele, T., & Demissew, S. (2019). Land use/land cover changes along elevation and slope gradient in the highlands of Ethiopia. *Remote Sensing Applications: Society and Environment*, Vol. 16, 100260.

Borrelli, P., Alewell, C., Alvarez, P., Anache, J. A. A., Baartman, J., Ballabio, C., Bezak, N., Biddoccu, M., Cerda, A., Chalise, D., Chen, S., Chen, W., de Girolamo, A. M., Gessesse, G. D., Deumlich, D., Diodato, N., Efthimiou, N., Erpul, G., Fiener, P., & Panagos, P. (2021). Soil erosion modeling: A global review and statistical analysis. *Science of The Total Environment,* Vol. 780, 146494.

Cabral, P., Feger, C., Levrel, H., Chambolle, M., & Basque, D. (2016). Assessing the impact of land-cover changes on ecosystem services: The first step toward integrative planning in Bordeaux, France. *Ecosystem Services*, Vol. 22, 318-327.

Costanza, R., deGroot, R., Sutton, P., vanderPloeg, S., Anderson, S.J., Kubiszewski, I., Farber, S., & Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change*, Vol. 26, 152–158.

Costanza, R., de Groot, R., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., Farber, S., & Grasso, M. (2017). Twenty years of ecosystem services: How far have we come and how far do we still need to go? *Ecosystem Services*, Vol.28, 1–16.

Debie, E. (2022). Stakeholder perceptions of multiple ecosystem services of soil conservation practices in Tiwa Watershed, Northwest Ethiopia. *Journal of Environmental Assessment Policy and Management,* Vol. 22 (No. 03n04).

Debie, E., & Anteneh, M. (2022). Changes in Ecosystem service values in response to the planting of Eucalyptus and Acacia Species in the Gilgel Abay Watershed, Northwest Ethiopia. Tropical Conservation Science V*olume*, Vol. 15, 1–18.

Desta, G., Tamene, L., Abera, W., Amede, T., & Whitbread, A. (2021). Effects of land management practices and land cover types on soil loss and crop productivity in Ethiopia: A review. *International Soil and Water Conservation Research,* Vol. 9, 544e554

Felipe-Lucia, M.R. (2021). Modeling dynamic ecosystem services. *Nature Sustainability,* Vol. 4, 928–929 .

Gao, J., Tang, X. G., Lin, S. Q. & Bian, H. Y. (2021). The influence of land-use change on key ecosystem services and their relationships in a mountain region from past to future (1995–2050). Forests, Vol. 12, 616.

Godebo, M., Ulsido, M.D., Jijo, T.E., & Geleto, G. M. (2018). Influence of land use and Land cover changes in ecosystem services in the Bilate Alaba Sub-watershed, Southern Ethiopia Markos. *Journal of Ecology and the Natural Environment,* 10(9), 228-238.

Hu, H., Liu, W., & Cao, M. (2008). Impact of land use and land cover changes on the Ecosystem services in Menglun, Xishuangbanna, Southwest China. *Environmental monitoring and assessment,* Vol.146, 147-156

Hu, S., Cao, M., Liu, Q., Zhang, T., Qiu, H., Liu, W., & Song, J. (2014). Comparative Study on the Soil Conservation Function of InVEST Model under Different Perspectives. *Geographical Research,* 33 (12), 2393–2406.

Kindu, M., Schneider, T., Teketay, D., & Knoke, T. (2016). Changes in ecosystem service values in response to land use/land cover dynamics in the Munessa–Shashemene landscape of the Ethiopian highlands. *Science of the Total Environment*, Vol. 547, 137-147.

Lal, R. (2014). Soil conservation and ecosystem services. *International Soil and Water Conservation Research*, 2(3), 36-47.

Legesse, A., Bogale, M., & Likisa, D. (2018). Impacts of Community-Based Watershed management on Land Use/Cover Change at Elemo Micro-Watershed, Southern Ethiopia. *American Journal of Environmental Protection*, 6(3), 59-67.

Li, J., Chen, H., Zhang, C., & Pan, T. (2019).Variations in ecosystem service value in response to land use/land cover changes in Central Asia over 1995-2035. *PeerJ,* Vol.7, e7665.

Msofe, N.K., Sheng, L., Li, Z., & Lyimo, J.(2020). Impact of Land Use/Cover Change on Ecosystem Service Values in the Kilombero Valley Floodplain, Southeastern Tanzania. *Forests,* Vol.11, 109.

Nigussie, Z., Tsunekawa, A., Haregeweyn, N., Tsubo, M., Adgo, E., Ayalew, Z., & Abele, S. 2021). The impacts of Acacia decurrens plantations on livelihoods in rural Ethiopia. *Land Use Policy*, Vol.100, 104928

Paudyal, K., Samsudin, Y.B., Baral, H., Okarda, B., Phuong, V.T., Paudel, S., & Keenan, R.J. (2020). Spatial Assessment of Ecosystem Services from Planted Forests in Central Vietnam. *Forests*, Vol.11, 822

Rasmussen, L.V., Mertz, O., Christensen, A.E., Danielsen, F., Dawson, N., & Xaydongvanh, P. (2016). A combination of methods is needed to assess the actual use of provisioning ecosystem services. *Ecosystem Services 17(24),75-86.*

Reader, M.O., Eppinga, M.B., de Boer, H.J., Damm, A., Petchey, O.L., & Santos, M.J. (2022). The relationship between ecosystem services and human modification displays decoupling across global delta systems. *Communications Earth & Environment,* Vol.3,102

Shaw, M.R., Pendleton, L., Cameron, D.R. *et al.* 2011. The impact of climate change on California's ecosystem services. *Climatic Change* Vol.109, 465–484

Shen, J., Li, S., Liu, L., Liang, Z., Wang, Y., Wang, H., &Wu, S. (2021). Uncovering the relationships between ecosystem services and social-ecological drivers at different spatial scales in the Beijing–Tianjin–Hebei region. *Journal of Cleaner Production*, Vol.290, 125193.

Shiferaw, H., Bewket, W., Alamirew, T., Zeleke, G., Teketay, D., Bekele, K., Schaffner U., & Eckert, S. (2019). Implications of land use/land cover dynamics and Prosopis invasion on ecosystem service values in the Afar region, Ethiopia. *Science of the total environment,*
Vol. 675, 354-366.

Temesgen, H., Wu, W., Shi, X., Yirsaw, E., Bekele, B., & Kindu, M. (2018).Variation in Ecosystem Service Values in an Agroforestry Dominated Landscape in Ethiopia: Implications for Land Use and Conservation Policy. *Sustainability*, 10(4), 1126.

Thammanu, S., Han, H., Ekanayake, E.M.B.P., Jung, Y., & Chung, J. (2021). The Impact on Ecosystem Services and the Satisfaction Therewith of Community Forest Management in Northern Thailand. *Sustainability*, 13(23), 1347.

Wang, X., Dong, X., Liu, H., Wei, H., Fan, W., Lu, N., Xu, Z., Ren, J., & Xing, K., (2017). Linking land use change, ecosystem services, and human well-being: A case study of the Manas River Basin of Xinjiang, China. *Ecosystem Services,* Vol. 27, 113–123.

Wassie, S.B. (2020). Natural resource degradation tendencies in Ethiopia: a review *Environmental System Research*, Vol.9, 33.

Wu, H., Sun, L., & Liu, Z. (2022). Ecosystem Service Assessment of Soil and Water Conservation Based on Scenario Analysis in a Hilly Red-Soil Catchment of Southern China. *Water,* Vol.14, 1284.

Zhang, P., He, L., Fan, X., Huo, P., Liu, Y., Zhang, T., Pan, Y., & Yu, Z. (2015). Ecosystem Service Value Assessment and Contribution Factor Analysis of Land Use Change in Miyun County, China. *Sustainability* , 7(6), 7333-7356