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Indicative of Land Use/Land Cover Change influenced Ecosystem Service Value Changes in Wayu-Tuka District, Western Ethiopia

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Abstract Land use/land cover (LULC) changes have a substantial influence on ecosystem services. The objective of this study is to estimate LULC dynamics induced ecosystem service values (ESV) changes in Western Ethiopia. Data were acquired from Landsat images of the area for four periods (1990-2020), and 221 sample households. The areas of LULC classes and the improved ESV coefficients of Costanza et al (1997) were used estimate ESV changes in 1990-2020. Forest provides diverse provisions, regulatory, supportive and cultural services. Analysis of the Landsat images showed that forest, farmland, settlement, water body and bare-land were the major LULC classes in the study area. While forest ESV had accounted 46.1% (US$ 4.95 million) of the ESV of Wayu-Tuka district in 1990, farmland ESV constituted the largest share (63.3%, US$ 5.21 million) of the ESV of the area after 30 years (2020). The ESV of forest and bare-land showed decreasing trends in three decades (1990-2020) but the farmland service value revealed an increasing trend in the same periods. Forest ecosystem exhibited the largest service value loss (US$ 3.91 million) in 1990-2020; whereas, the service value gain of farmland was only US$ 2.2 million although farmland was responsible for the conversion of the largest area size (9,766.5 ha) from other land covers in 30 years. LULC change induced net ESV loss of the district in three decades (1990-2020) was 23.4% (US$ 2.51 million). Land conversion due to expansion of farmland (by 9,766.5 ha) and settlement (by 4,061.3 ha) was the main cause for the LULC dynamics and the significant ESV loss in 1990-2020. Thus, the government and local people should cooperate so as to curb the steady degradation of forest and its ecosystem services in Wayu-Tuka district, Western Ethiopia.

Keywords: ESV; estimated; change; induced; loss; western Ethiopia

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1. INTRODUCTION

Ecosystem services are described as the mechanisms by which people engage with environment and gain advantages from it, either directly or indirectly (da Costa et al., 2017). These products and services that people receive from ecosystems are divided into four categories: cultural, regulatory, sustaining, and provisioning services (Hasan et al., 2020; Shiferaw et al., 2019; Shi et al., 2015). But in recent years, changes in LULC have impacted the ecosystems and the benefits they provide. Apparently, it is possible to comprehend the effects of LULC change on ecosystem services by estimating the value of these services and how that value changes overtime (Mekonnen, 2019; Solomon et al., 2019; Gashaw et al., 2018; Costanza et al., 2014; Brown et al., 2013). The LULC has the potential to influence the biological processes, and alter the provision of ecosystem services (Belay et al., 2022; Shrestha et al., 2022; Negassa et al., 2020). Changes in LULC are the major drivers for the decline and loss of ecosystem services around the world (Tesfay & Kibret, 2022; Mekuria et al., 2021; Wassie, 2020; Egussie et al., 2019; Feyisa et al., 2017; Joana et al., 2015; Thomas & Bekele, 2003).

The rapid socioeconomic transformation and quick rise in anthropogenic activities have altered the value of ecosystem services in the recent past (Gebo et al., 2022; Wu et al., 2013; Gantioler et al., 2009). The impacts of LULC change on ecosystem services vary across space, time and stakeholders who depend on the resources (Admasu et al., 2023;Wu et al., 2013). For example, LULC analysis, focusing on forest area showed that forest loss started thousands of years back owing to population growth and increased demand for agricultural land (Kuma et al., 2022; Zekarias et al., 2021; Deribew & Dalacho, 2019; FAO, 2016; Lambin et al., 2003). The greatest net loss of forests and net gain in farmland was common in the low-income countries (Berihun et al., 2021; FAO, 2016). Such a dynamic has continued to affect ecosystem at various level, from local to global scales (Gashaw et al., 2018; Mlotha, 2018). According to Costanza et al., (2014) global LULC changes induced declines in ecosystem service values were observed from US$ 145 trillion year−1 in 2007 to US$ 125 trillion year−1 in 2011. According to Berihun et al., (2021) and Almaw et al., (2020), the ESV loss at a global scale also ranged in about US$ 4–20 trillion year−1 in the period 1997 - 2011. That is why LULC change is often cited as the leading contributor to the decline and loss of ecosystem services worldwide (Mada, 2022; Tesfay & Kibret, 2022; Mekuria et al., 2021; Egussie et al., 2019).

Analysis of the LULC changes in Southwestern Ethiopia revealed that substantial loss and gains were observed in LULC classes and ESV in the period 1987-2002 (Tadesse et al., 2019). A recent study conducted by (Negassa et al., 2020) indicated that the LULC change dramatically increased agricultural land from (24.78%) in 1991 to (33.5%) in 2019 with annual expansion rate of 23.68% per annum, where forest cover declined by 20.1% in 1991 and 37.38% in 2019 with annual decreasing rate of 4.18% per annum. Much of the rural life, nowadays, is challenged by deforestation and degradation. Today, forest cover revealed significant decrease due to agricultural expansion, logging of trees for timber, charcoal and firewood, and other products.

In recent years, population growth and their demands have placed enormous strain on Ethiopian's land use system, including the current study region. However, much of the research on LULC dynamics to date has focused primarily on LULC change analysis, with little emphasis paid to how these dynamics may alter the values of ecosystem services in Ethiopia. Assessing LULC dynamics induced ecosystem service value changes (gains and net losses) overtime is useful to recognize the gains and losses in ecosystem services and the values of the services; besides, results of such studies are used as inputs in the decisions on policies and management options towards the conservation and sustainable management of ecosystem services, natural resources and the overall environment. This study, therefore, aims to analyze LULC dynamics induced ESV losses/gains in three decades (1990-2020) in the Wayu-tuka District of East Wallaga Zone, Western Ethiopia.

2. Study Area and Research Methods

2.1. Description of the Study Area

The study area, Wayu Tuka District, is located in the Oromia National Regional State in Western Ethiopia, about 322 km west of Addis Ababa. The district borders with Sibu Sire district in the North and East, Leka Dulacha district in the South, and Guto Gida in the West. Specifically, the study area is situated at 8^{o} 51′ 30″ – 9^{o} 10′ 30″ N latitude and 36^{o} 32′ 0″ – 36^{o} 50′ 0″E longitude (Figure 1). In the district there are mountain peaks and hill slopes like Komto, Gara-achani and Tuka which rises to elevations of about 3350, 3140 and 2350 m.a.s.l. respectively. The district possesses a total area of 54,590.4 ha and comprises 12 Kebeles (i.e., Kebele - is the smallest administrative unit in Ethiopia), 10 rural villages and 2 urban centers.

The zone had three agro-ecological divisions of which 11% is high land, 49% mid-land and 40% low lands (EWARDO, 2009).Since Wayu-tuka District is located within 8^{0}-9^{0} north which is close to the tropical rainforest region (0^{0}-6^{0} north and south), the district experiences largely a tropical climate. That is why the mean annual temperature of Wayu-Tuka District based records of 30 years (1990-2019) is about 21.4 ^{0}c (Figure 2).That is why the temperature, based on the agro-climate classes of Ethiopia, is categorized under the kola (tropical) climate. In Figure 2, the dark zigzag represents the average (mean) annual temperature of the study area for 30 years (1990-2020); and the broken arrow shows the change in the average annual temperature of the area overtime.

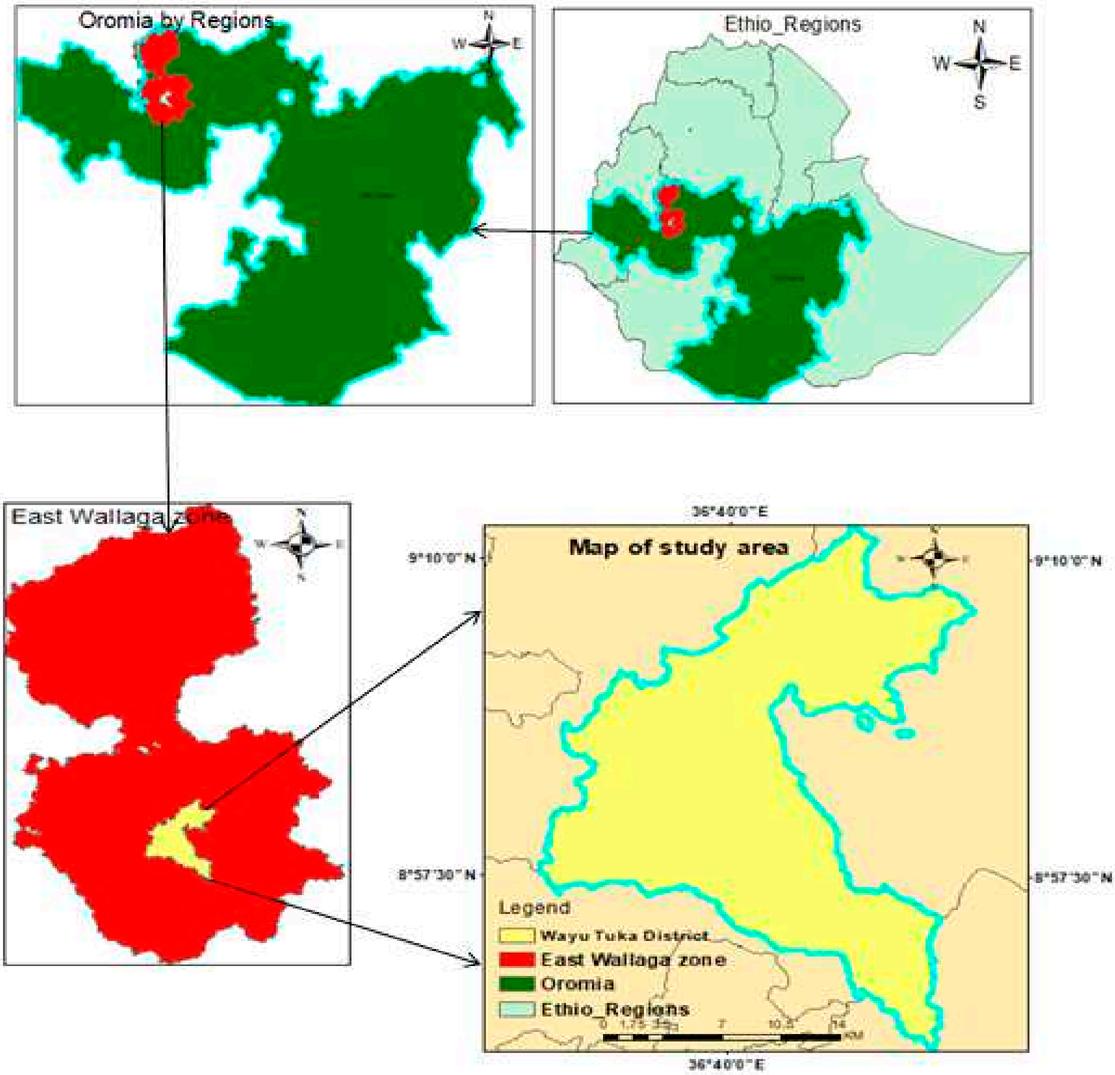

Figure 1. Location Map of Wayu-Tuka District (Source: Own Design upon Database of Ethio-GIS, 2022).

Unlike the total annual rainfall that showed a decreasing trend (Figure 3), average/mean annual temperature of Wayu-Tuka district revealed an increasing trend in 30 years (1990-2019). This is clearly observed from the positive coefficients (slopes) of 'x' in the linear equation ($y= 0.0376x +20.857$) representing the trend of temperature change overtime (Figure 2). Here, even if temperature and rainfall are directly related (or have a positive correlation), these two climatic variables showed contradicting trends within 1990-2019; and, this could be an indicator of the variability in the climate resources of the study area. Figure 2 also illustrates that the mean minimum (Mn) annual and mean maximum (Max) annual temperature of the district war about 14.6^0c and 28.3^0c, respectively.

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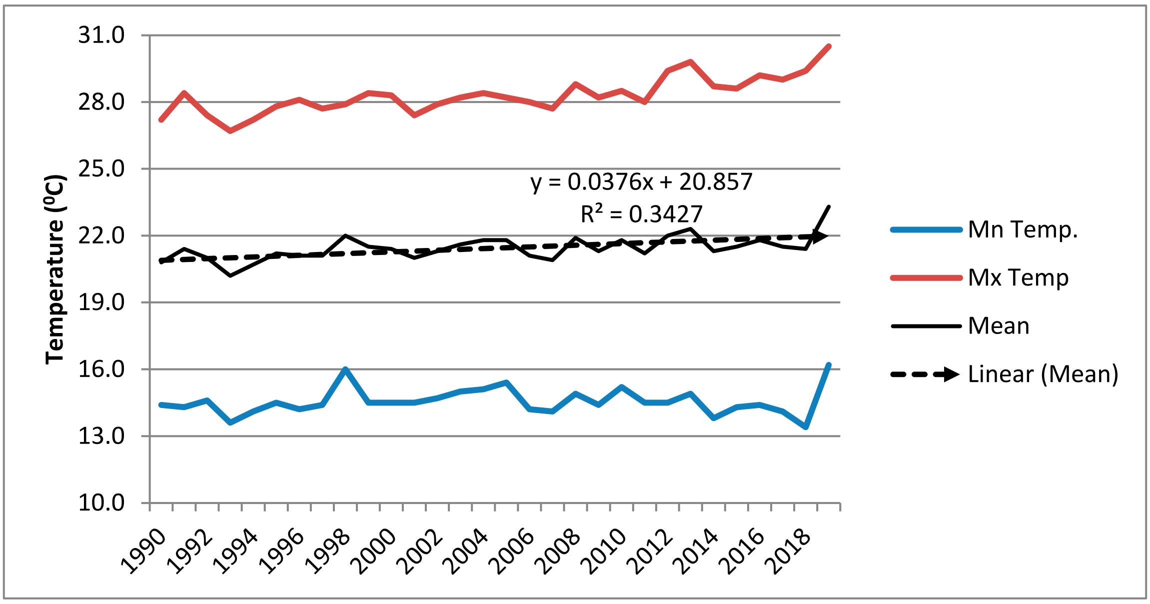

Figure 2. the Mn, max and Average/Mean Annual Temperature T°c (1990-2020) of study area (Source: Nekemte meteorology station, 2020).

The study area receives a high mean total annual rainfall (2,067.4mm), which is a typically of the tropical climate. In Figure 3, rainfall of Wayu-Tuka district is displayed by three lines: (i) a zigzag line showing the total annual rainfall in 1990-2019; that is, the total annual rainfall of the study area for 30 years (1990-2019) ranges from a minimum of 1,521mm in 2018 to a maximum 2,551.4mm in 1998 so that the range of the total annual rainfall of the area in three decades becomes about 1030.4mm indicating that inter-annual rainfall of the area is highly variable; (ii) a broken horizontal line displaying the mean total annual rainfall (mm) within 1990-2019; the mean annual rainfall for 30 years about 2067.4mm; and, (iii) a broken arrow illustrating the trend in the total annual rainfall for three decades; i.e the total annual rainfall of Wayu-Tuka had been decreased overtime in 30 years (1990-2019). This is observed from the negative coefficient Slope) of 'x' in the linear equation (y= -11.051x +2238.7) signifying the change of annual rainfall eventually (1990-2019) (Figure 3).

Afromontane upland forest, mid upland semi-deciduous forest, few riverine forest types and plantation types are the major vegetation types observed in the study area. The vegetation of the area belongs to the moist evergreen montane forest and this type of forest is known to occur in southwest Ethiopia (Assefa et al., 2020)

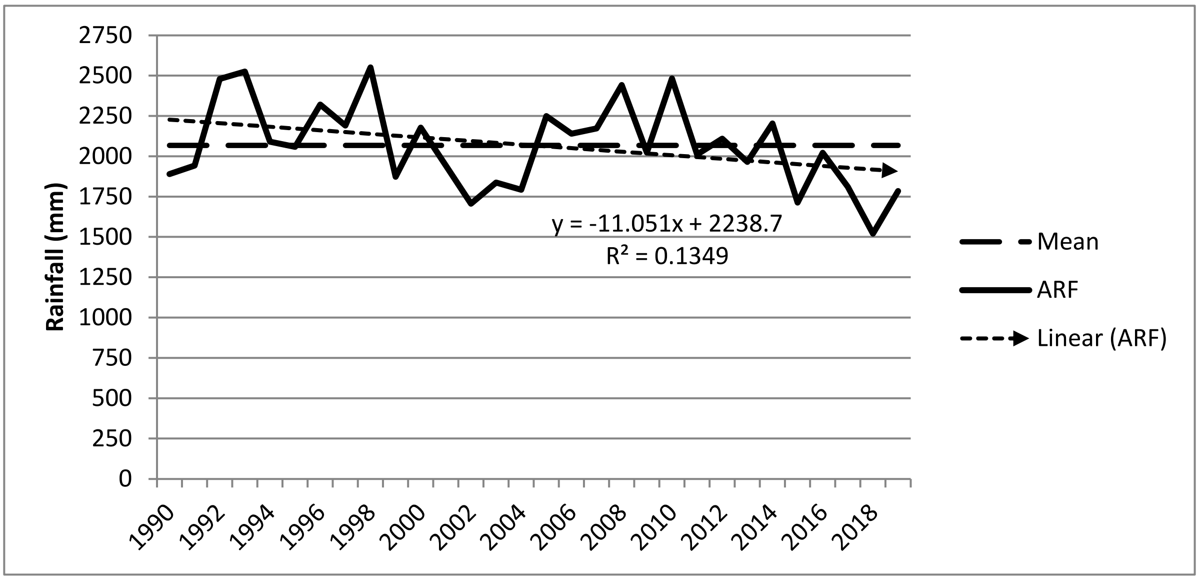

Figure 3. total Annual RF and Mean ARF (1990-2019) of Wayu-Tuka District (Source: NMA, 2020).

Soils of the study area deep and belong to the orders Oxisols and Ultisols (Megersa, 2020). Textural the major soil types and their spatial coverage in the district are clay loom 17,371.68 ha, sandy 10,133.49 ha and clay 1,447.64 ha which are suitable for agriculture such as cereal crops: maize, sorghum, and teff production in the district (WARDO, 2009 E.C.).

Subsistence farming is the main economic activities in the study area-crop framing and livestock rearing. Based on the 2007 population and housing census, the population of Wayu Tuka District is projected to be 66,194. Of which 32,391 were men and 33,803 were women.

2.2. Methods and Materials

2.2.1. Sources and Methods of Data Collection

Data sources for estimating ecosystem service values of land cover types over the past three decades landsat imagery downloaded from http://earthexplore.usgs.gov**.** Land cover data was obtained from data source for land cover dynamics which is freely downloaded Landsat imagery from http://earthexplore.usgs.gov. and derived from cloud-free Landsat satellite images captured in the dry season for the years 1990, 2000, 2010 and 2020 (Mohamed, 2021). Then, ecosystem service values over extended periods as a means of assessing their changes in response to LULC dynamics (Tolessa et al., 2017). The benefit transfer approach was used to estimate ecosystems service values (ESV) of different LULC types and their changes (Negassa et al., 2020). The benefit transfer approach is the process of using existing values and other information from the original study site to estimate ESV of other similar locations in the absence of site specific valuation information (Shiferaw et al., 2021).

A socioeconomic survey was carried out using questionnaire based household survey so as to complement data of Landsat images. The survey was carried in three villages namely Dalo-Komto, Gara-Hudha and Kich villages. The Cchran (1977) formula was used to determine the sample size. The 3 villages had a population of 1,340 households. The sample size was determined as:

$$n = \frac{\boldsymbol{t^{2*}(p)(q)}}{\boldsymbol{d^2}} \frac{\mathbf{(1.96)^2(0.5)(0.5)}}{\mathbf{(0.5)^2}} = 0.38416\text{x}100\text{~} \underline{384}$$

Therefore, for a population of 1,340, the required sample size is 384. However, since this sample size exceeds 5% of the total HH (520*.05=26), the Bartlett et al. (2001) correction formula was used to recalculate the final sample size as follows:

$$\text{nl}=\frac{no}{(1+\frac{no}{population})} \quad \underline{\text{n}}1=\frac{384}{(1+\frac{384}{520}}= 221.$$

Therefore the final sample size was 221.

Where: 'n' is the desired sample size when population greater than 10,000; 'n1' is finite population correction factor when the population less than 10,000; 't' is the standard normal deviation (1.96 for 95% confidence level); i.e. where t = value for selected alpha level of .025 in each tail = 1.96 (the alpha level of .05 indicates the level of risk the researcher is willing to take that true margin of error may exceed the acceptable margin of error); 'n' is the sample size; and, where (p)(q) = estimate of variance = 0.25. The total sample size became 221 HH; the sample size of each village was determine proportionally; that is, 79 from Dalo Komto, 63 from Gara Hudha and finally 79 from Kich (Table 1). The 221 sample HH units were selected using systematic random sampling; that is, each sample HH was identified by starting randomly and incorporating every 3rd HH from the list of total HH in the administration office of each of the three villages.

Table 1. selected Households in the Study area.

Sample *Kebeles* (Villages)	Sampling Frame (Total HH)	Sample Size	
		Number	Percent (%)
Dalo Komto	175	79	35.7
Gara Hudha	170	63	28.6
Kich	175	79	35.7
Total	520	221	100

Sources: Own summary based on data of CSA (2007).

2.2.2. LULC Classification

The satellite images were classified into five LULC classes (forest, settlement, farmland, water body and bare-land). These LULC classes are briefly described in (Table 2).

Table 2. LULC classes and their brief descriptions.

LULC class	Definitions/descriptions of LULC classes
Forest	A land portion covered with trees including higher & lower layers**.**
Settlement	Built-up areas taking all rural homes &villages, churches, and school sites.
Farmland	Areas used for different farming which are for subsistence consumption.
Water body	Areas covered with ponds, streams small and large courses streams.
Bare land	Land part no vegetation, hilly sites with bare land and covered with rocks.

Sources: Own summery, 2023.

2.3. Data Analysis

2.3.1. Estimating Ecosystem Service Values

The LULC classes of Wayu-Tuka district were classified upon Landsat-5 MSS (1990), Landsat-7 TM (2000), Landsat-7 ETM+ (2010) and Landsat-8 OLI (2020) using the supervised classification (maximum likelihood) technique via ArcGIS 10.8. The ESV of each LULC class were estimated by using the following formula (Kindu et al., 2013; Gashaw et al., 2018)

$$ESV = \sum (A_k \; VC_k) \tag{1}$$

Where: 'A_K' is the area (ha) and 'VC_K' is the value coefficient (USD ha^{-1} yr^{-1}) for land use land cover category k. The total ESV of the entire study area was obtained by summing the estimated ESV from each land use/cover category.

2.3.2. Estimate ESV Changes (Gross Gain/Losses)

The changes of ESV were obtained by calculating the difference between the estimated values in each reference year. The study has used the following formula to evaluate changes in ESV:

$$ESV_{cr} = \frac{ESV_{t2} - ESV_{tl}}{ESV_{tl}} x \; 100\% \ldots \tag{2}$$

Where, ESV_{cr} is the change rate of ESV from the initial year to the final year, ESV_{t1} and ESV_{t2} refer to the total ESV of the initial and final reference years under study, respectively. The specific ecosystem service values were estimated in USD (US$). Positive ESV indicate gain (increase) in service values; whereas, negative values imply loss in the ESV (Berihun et al., 2021).

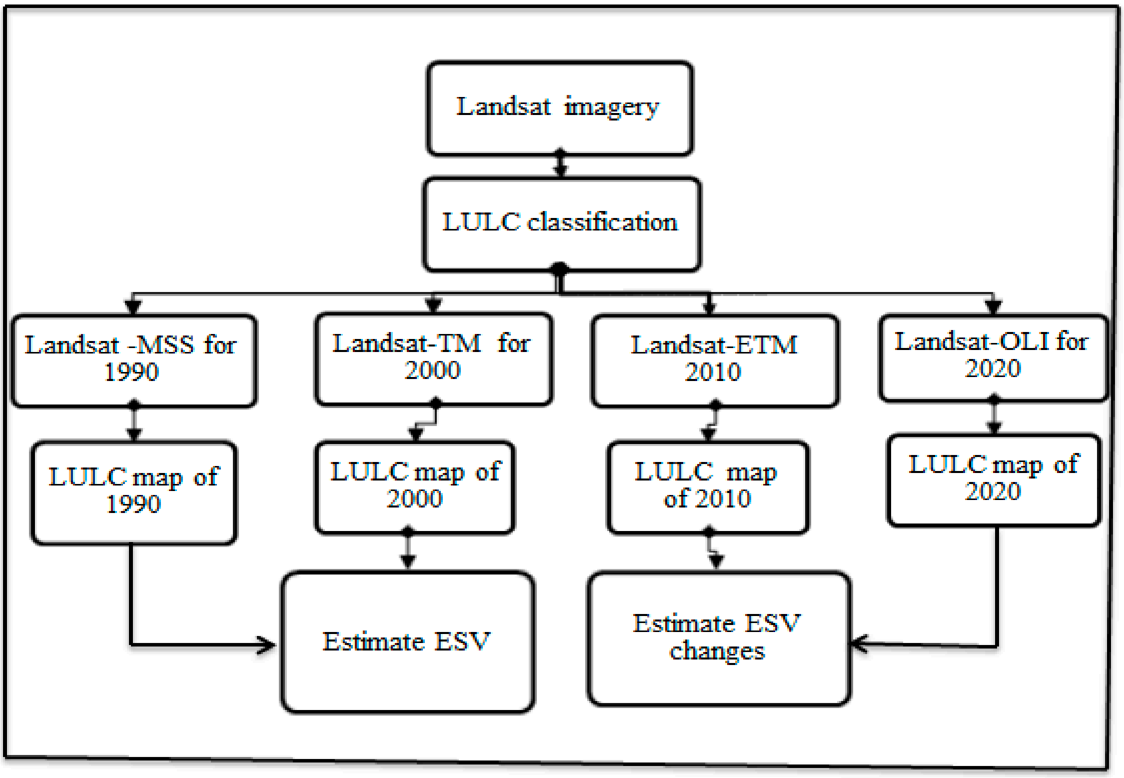

Figure 4. flow chart of the analysis for this paper.

2.3.3. Accuracy Assessment of LULC Maps

Accuracy assessment for LULC maps estimation was done based on the landsat images for each LULC classes of 1990, 2000, 2010, and 2020 individually. According (Jiang, 2011) to user's accuracy, producer's accuracy and overall accuracy should be recommended because they are directly interpretable as probabilities of correct classification. The overall accuracy level of LULC classification maps for all the four periods (1990, 2000, 2010 and 2020) were 83.3%, 86.6%, 80% and 83.3%, respectively. The overall kappa coefficients were 79.5%, 82.6%, 74.6% and 78.8% for LULC classified of four periods (1990, 2000, 2010, and 2020), respectively. These accuracy values fall within the range recommended by (Lucas et al., 2020).

3. Results and Discussion

3.1. LULC Dynamics and the Estimated ESV of Wayu-Tuka District

The area and proportions of Landsat images based LULC classes (forest, farmland, settlement, water and bare-land) of Wayu-Tuka district were estimated for four periods in 1990 - 2020 (Table 3).

Table 3. the LULC Classes of Wayu-Tuka District in 1990, 2000, 2010 and 2020.

N0	LULC Classes	1990		2000		2010		2020	
		Area (ha)	P (%)	Area (ha)	P (%)	Area (ha)	P (%)	Area (ha)	P (%)
1	Forest cover	5,015.6	12.4	3,321.9	8.2	1,665.6	4.1	1,054.9	2.6
2	Settlement	10,461.9	25.9	14,618.8	36.2	13,931.6	34.5	14,523.2	35.9
3	Farmland	13,344.6	33.0	17,509.9	43.3	20,917.1	51.7	23,111.1	57.2
4	Water body	214.0	0.5	885.4	2.2	121.9	0.3	1,535.7	3.8
5	Bare-land	11,392.5	28.2	4,092.6	10.1	3,792.4	9.4	203.7	0.5
	Total	**40,428.6**	**100.0**	**40,428.6**	**100.0**	**40,428.6**	**100.0**	**40,428.6**	**100.0**

Source: Own Computation via ArcGIS 10.8 (2022).

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In 1990, the farmland accounted the largest proportion (33%) of the area of Wayu-Tuka district, followed by bare-land (28.2%), settlement (25.9%) and forest cover (12.4%). Farmland constituted the largest share (%) of all the LULC classes of the district in all the study periods such as 1990 (33%), 2000 (43.3%), 2010 (51.7%) and 2020 (57.2%), and this land use class reveled an increasing trend within the period 1990 - 2020 (Table 3). The area extent of settlement showed significant increment within 1990 – 2000 when it grew from 25.9% (in 1990) to 36.2% (in 2000). However, the change in the proportion of area of settlement (in Wayu-Tuka district) was insignificant between the period 2010 (34.5%) and 2020 (35.9%). In study area, bare-land is the kind LULC class that has experienced a continuous and significant shrinkage from 28.2% in 1990 to 10.1%, 9.4% and 0.5% in 2000, 2010 and 2020, respectively (Table 3). The area of forest cover, water body and bare-land of Wayu-Tuka district reveled significant shrinkage in 2020 (Table 3; Figure 5 & Figure 6).

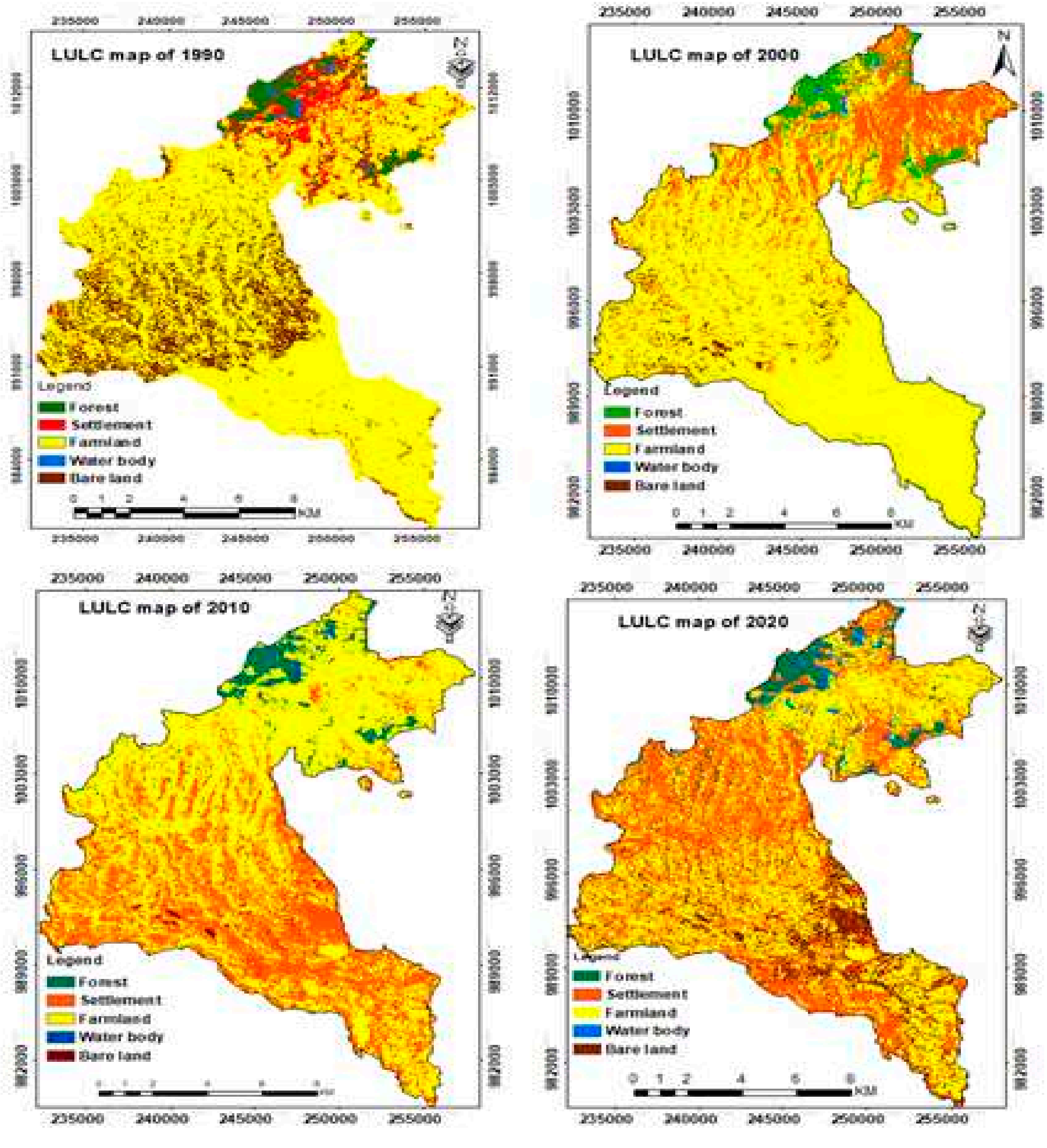

Figure 5. LULC map (1990-2020) of Wayu-Tuka District (Source: Landsat-image).

Figure 5 above displays the five LULC classes of Wayu-Tuka district in 1990 (top-left), 2000 (top-right), 2010 (bottom-left) and 2020 (bottom-right). Results of the LULC maps showed that farmland and settlement were the main LULC classes of Wayu-Tuka which experienced significant increasing trends in three decades (1990-2020). On the contrary, forest cover and bare-land revealed significant decreasing trend in 30 years (Fig 5 & Fig 6). Finally, bare-land cover (0.5%) accounted the least area share (%) of the overall LULC classes of the Wayu-Tuka district in 2020 (Fig 6).

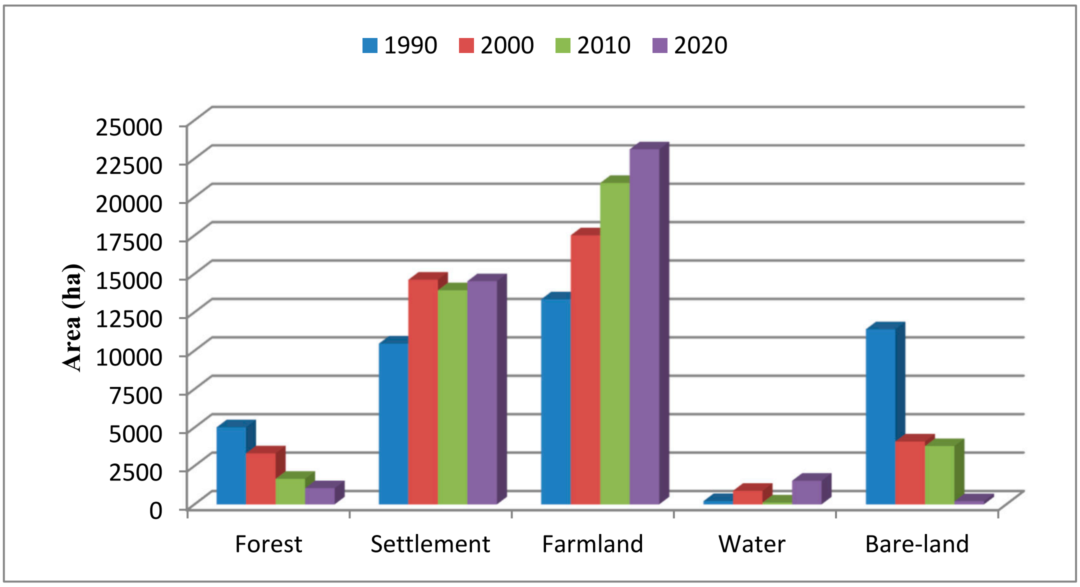

Figure 6. patterns of area (ha) change of the five LULC classes of Wayu-Tuka District in 1990 - 2020.

Forests in the different agro-climatic zones of Wayu-Tuka District consist of various trees species. State et al., (2013) indicated that *acacia abyssinica, croton macrostachyus, citrus limon, coccinia africana, grewia ferruginea, hagenia abyssinica, olea europaea (cuspidate), caylusea abyssinica, clutia abyssinica and coffea Arabica* are among the species of trees and shrubs which have medical values. Before analyzing the ESV changes, it is important to assess the services given by forest and farmland ecosystem. The main benefits of forests organized in Table 4.

The forest resource of the study area provides diverse products and services. It provides benefits ranging from the provisioning through regulatory and supportive to cultural services (Table 4). As it is observed in Table 4, large proportion of the sample households recognize most of the provisioning product such as firewood and charcoal (81%) for energy consumption, timber/logs and fibers (64.7%) for construction, fruits and seedlings (47.1%) for consumption and domestication of coffee, biomass or fodder for livestock (33%), honey (34.8%) for consumption and cash, and biochemical for medical treatment of diseases (Table 4). Regarding this, a study indicated that there are about 86 plant species of natural vegetation (forest) in Wayu-Tuka district whose leaves, roots and barks are used for medical treatment of both people and livestock diseases (State et al., 2013).

Table 4. forest benefits (products and services) of Wayu-Tuka District based on sample HH.

N0	Broad CS	Specific Products/Services	Purpose/Benefit of the Service	N0 of HH	%
1	Provisions	Firewood and charcoal	Home energy use and/or cash	179	81.0
		Timber/logs and fibers	Building houses and fences, and/or cash	143	64.7
		Fruits, seeds and seedlings	Consumption and domestication (e.g. coffee)	104	47.1
		Biomass (leaves)	Fodder for livestock	73	33.0
		Honey	For consumption and cash	77	34.8
		Bio-chemicals	Treatment of diseases	56	25.3
2	Regulatory	Carbon sink	Control air quality and regulate climate	68	30.7

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		Water infiltration	Control water quality and quantity	81	36.6
		Suppress runoff generation	Reduce soil erosion and flood hazard	122	55.2
		Detoxification (purification)	Purify hazardous chemicals of liquid waste	17	7.7
3	Supportive	Moisture supply	Trees' leaves support the hydrological cycle	44	19.9
		Habitat supply	Home for wildlife (plants and animals)	109	49.3
		Organic matter supply	Support soil formation and improve fertility	65	29.4
4	Cultural	Tourism and recreation	Generate income and entertainment	97	43.9
		Aesthetics	Beautify nature and satisfy sprit of people	78	35.3
		Education and research	Tour education and conducting research	13	5.9
	Total HH			**221**	**100.0**

Sources: own survey, 2022 (Note**:** CS = Category of Services. Data of Table 4 were gathered via questions having multiple response options).

The forest resource of the Wayu-Tuka district provides vital regulatory service such as carbon sink (30.7%) which is useful to control air quality by preventing pollution and regulating local micro-climate, infiltration and recharge of water/runoff (36.6%) which enables to regulate the quality and supply of water (for domestic consumption of the rural people), suppress runoff generation (55.2%) by increasing infiltration so that it reduces the risk of soil erosion and flood hazards (Table 4). The forest resource offers a number of supportive services, which are essential for primary production (i.e. crop and livestock farming) (see Table 4). Cultural values such as tourism and recreation services (43.9%) for income generation and entertainments, and aesthetics - the beautifying value of landscape and environment (35.3%) are also among the benefits of forest in district (Table 4).

As it is seen in Table 5, the improved ESV coefficients allocated for the global biome categories by Costanza et al (1997) vary from one another as all the biome classes do not provide similar types and amount of ecosystem services. For instance, forest ecosystem provides diverse local, regional and global level services so that its ESV coefficient per/ha/year (US$ 986.69) is significantly larger than the service value coefficient of farmland (US$ 225.56 per/ha/year) (Gelaw, 2019; Kindu et al., 2016); this is so because, farmland ecosystem provides largely local level benefits and less diverse services than forest (Costanza et al., 1997).

Table 5. biomes equivalent and ESV coefficients (US$ $ha^{-1}y^{-1}$) for LULC classes.

N0.	LULC Classes of Wayu-Tuka	Equivalent Global Biomes	ESV Coefficients (US$ $ha^{-1}y^{-1}$)
1	Natural forest	Forest/plant nursery	986.69
2	Settlement	Settlement	0
3	Farmland	Farmland/cropland	225.56
4	Water body	Water body	986.69
5	Bare-land	Bare soil/crops	225.56

Source: based on Abren (2019); Tolessa et al (2017); Kindu et al (2016); Costanza et al (1997).

Based on the ESV coefficient allocated for each of the LULC classes, the ESV of Wayu-Tuka District for periods 1990, 2000, 2010 and 2020 were estimated and organized in Table 6. In 1990, the annual total ESV of the district was estimated at US$ 10.74 million; of this, slightly less than half or 46.1% (US$ 4.86 million) of the ESV was accounted by forest ecosystem. The estimated ESV of farmland (28%) and bare-land (23.9%) was also relatively better in the earliest reference year (1990) under study (Table 6). The total ESV of the study area for the period 2000 was estimated at US$ 9.02 million. A decade later (in 2000), the largest proportion (43.8% or US$ 3.95 million) of the total ESV of the area was accounted by farmland, followed by the ESV of forest (36.4%). The area showed an improvements in the ESV of water body (9.6% or US$ 0.87 million) (Table 6).

Table 6. the Estimated ESV (in US$ x10^6 per/year) of the LULC Classes in Wayu-Tuka District.

LULC Classes	ESV (US$ x10^6 per/year)							
	1990		2000		2010		2020	
	ESV	%	ESV	%	ESV	%	ESV	%
Natural forest	4.95	46.1	3.28	36.4	1.64	22.4	1.04	12.6
Settlement	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.0
Farmland	3.01	28.0	3.95	43.8	4.72	64.3	5.21	63.3
Water body	0.21	2.0	0.87	9.6	0.12	1.6	1.52	18.5
Bare-land	2.57	23.9	0.92	10.2	0.86	11.7	0.46	5.6
Total	10.74	100.0	9.02	100.0	7.34	100.0	8.23	100.0

Sources: Own calculation based on data of Table 2 and Table 3 (2022).

In the third period (2010), the estimated total ESV of Wayu-Tuka district became lower than the estimated total service values of the previous decades (1990 and 2000) (Table 6). In 2010, the estimated total annual ESV (US$ 7.34 million) of the study area was significantly lower than that of the 1990 (US$ 10.74 million) and 2000 (US$ 9.02 million); this was due to better forest resource cover in 1990 and 2000, and the significant decline of this land cover class in 2010. In the third period (2010), the estimated ESV of farmland continued to be the largest share (64.3% or US$ 4.72 million) of the whole ESV of the district. This had happened due to the expansion of farmland largely at the cost of forest cover underlain by increasing human population. In fact, the 2010 estimated ESV of forest (22.4% or US$ 1.64 million) was still better than that of water and bare-land. Although the 2020 estimated total ESV (US$ 8.23 million) of Wayu-Tuka district was larger than that of 2010 (US$ 7.34 million), the variation (US$ 0.89 million) could not be said large; this means, the total ESV of the study area had not continued to decline in 2020 because of the fact that the continued shrinkage of forest ESV (to 12.6% or US$ 1.04 million) had been compensated by the high magnitude of increase in the ESV of water from 1.6% (US$ 0.12 million) in 2010 to 18.5% (US$ 1.52 million) in 2020 (Table 6 & Figure 7).

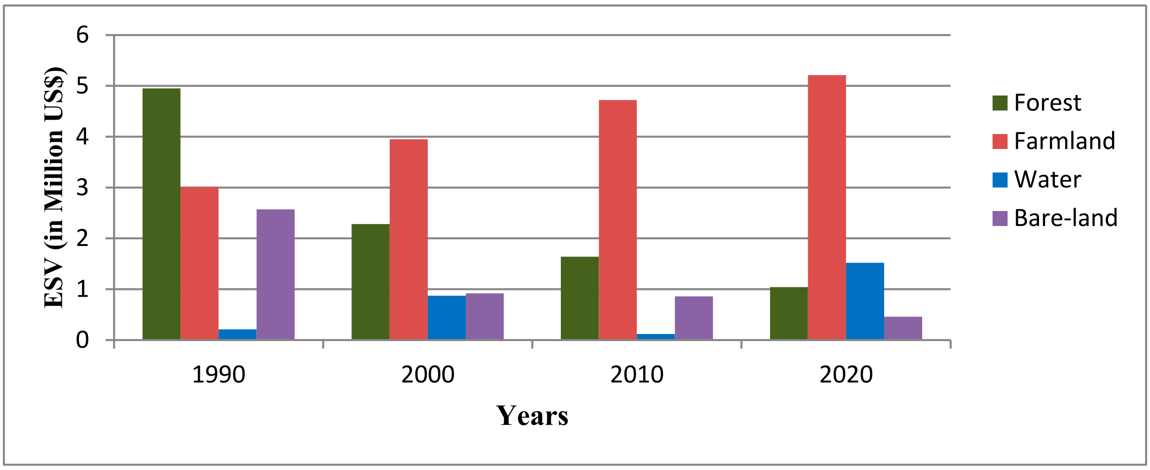

Figure 7. estimated ESV of LULC classes of Wayu-Tuka district (Source: own design, 2022).

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3.2. LULC Dynamics-Led Ecosystem Service Value Changes (Gross gain/loss)

The LULC dynamics of Wayu-Tuka district in three decades (1990 - 2000, 2000 - 2010 and 2010 - 2020) have led to the changes in the ESV of the area in the same periods. In the initial decade (1990-2000), the ESV of forest and bare-land had revealed decline by 33.7% (US$ 1.67 million) and 64.2% (US$ 1.65 million), respectively. However, the ESV of farmland and water body had increased by the respective magnitudes of 31.2% (US$ 0.94 million) and 304.3% (US$ 0.66 million) in 1990 – 2000. The estimated total ESV of Wayu-Tuka district showed a net loss by about 16% (US$ 1.72 million) within the first decade studied (Table 7).

Table 7. estimated ESV Changes (US$ x10^6) in Response to LULC change in Wayu-Tuka District.

LULC	ESV (in US$ x10^6)				Estimated ESV Changes (Gain/Loss) (in US$ x10^6)							
	1990	**2000**	**2010**	2020	1990-200		2000-2010		2010-2020		1990-2020	
					US$	P (%)	US$	P (%)	US$	P (%)	US$	P (%)
Forest	4.95	3.28	1.64	1.04	-1.67	-33.7	-1.64	-50.0	-0.60	-36.6	-3.91	-79.0
Settlement	0	0	0	0	0	0.0	0	0.0	0	0.0	0	0.0
Farmland	3.01	3.95	4.72	5.21	0.94	31.2	0.77	19.5	0.49	10.4	2.20	73.1
Water	0.21	0.87	0.12	1.52	0.66	304.3	-0.75	-86.2	1.40	1166.7	1.31	623.8
Bare land	2.57	0.92	0.86	0.46	-1.65	-64.2	-0.06	-6.5	-0.40	-46.5	-2.11	-82.1
Total	**10.74**	**9.02**	**7.34**	**8.23**	**-1.72**	**-16.0**	**-1.68**	**-18.6**	**0.89**	**12.1**	**-2.51**	**-23.4**

Source: own computation based on Table 4 and Table 5, 2022 .

In the second decade (2000–2010) studied, the ESV of forest, water body and bare-land experienced a declining trend while the service values of farmland continued to increase in the same decade; meaning, the ESV of forest, water body and bare-land had declined by the respective magnitudes of 50% (US$ 1.64 million), 86.2% (US$ 0.75 million) and 6.5% (US$ 0.06 million) in 2000 – 2010 but the ESV of farmland grew by 19.5% (US$ 0.77 million) in the same decade (2000 – 2010). The net LULC dynamics-induced ESV loss of the study area in 2000 – 2010 was estimated to have been about 18.6% (US$ 1.68 million). The overall magnitude of net ESV loss of 2000 – 2010 (US$ 1.68 million) showed relatively insignificant variation from the net ESV loss of the area during the previous decade (1990 – 2000) accounted in by the study (see Table 7). This was due to the continued shrinkage (loss) of forest ESV (by US$ 1.61 million) and also the observed water ESV loss (contrary to the period 1990 - 2000) by US$ 0.75 million during the second decade (2000 – 2010) studied.

In Wayu-Tuka district, the pattern of LULC change-induced ESV gain and loss in the 3rd decade (2010 – 2020) seems more or less similar to that of the 1st decade (1990 – 2000) studied although the magnitudes of ESV changes (gain/loss) vary between the two decades (Table 7). Similar to the period 1990 – 2000, the estimated ESV of forest and bare-land revealed a declining trend by 36.6% (US$ 0.60 million) and 46.5% (US$ 0.40 million), respectively, in the 3rd decade (2010 – 2020) studied. On the contrary, the estimated ESV of farmland and water body showed an increasing trend by the respective magnitude of 10.4% (US$ 0.49 million) and 1,166.7% (US$ 1.40 million) in the latest reference decade (2010 – 2020). Unlike the two previous decades (1990 – 2000 and 2000 – 2010), the Wayu-Tuka district experienced a net ESV gain (by US$ 0.89 million) in response to the LULC dynamics in the period 2010 - 2020. In comparison to the period 2000 – 2010, the overall estimated ESV change of the area revealed a net gain by 12.1% (US$ 0.89 million) in the last decade (2010 – 2020) studied. The declining magnitude of forest ESV loss and the high magnitude of water ESV gain have contributed to the overall net ESV gain of the study area in 2010 – 2020 (Table 7).

As it is displayed in Table 7, an assessment was carried out on the LULC dynamics-led ESV changes (gain and loss) of Wayu-Tuka district for three decades (1990 – 2020). The estimated ESV of forest revealed the largest magnitude of loss by 79% (US$ 3.91 million) in the three decades studied. The magnitude of ESV loss (82.1% or US$ 2.11 million) of bare-land was also significant. In contrast, water body and farmland experienced significant ESV gains by the respective magnitudes of 623.8% (US$ 1.31 million) and 73.1% (US$ 2.2 million) in 30 years (1990 – 2020). While the ESV of forest had declined with a decreasing magnitude of loss in 1990 – 2020, the ESV of farmland had increased with a declining magnitude of gain in the three decades; water body showed no clear trend of ESV change; however, bare-land experienced a clear and continuous ESV loss in 30 years (1990-2000, 2000-2010 and 2010-2020) (see Table 7 & Figure 6). The overall ESV of the study area indicated a net loss by 23.4% (US$ 2.51 million) within 1990 – 2020 (Table 7).

The LULC dynamics induced ESV loss has its own implication on the ecosystem services, overall environment and the livelihoods of the local people. Because of the depletion of the forest resource, the inhabitants of Wayu-Tuka District and its environment encountered huge loss of the diverse forest ecosystem products and services such as fuel-wood and construction materials, medicinal values, erosion control, biodiversity conservation, and air and climate regulation services. Again, the conversion of natural forest to cropland (used for growing annual crops and perennials or agroforestry) is among the main causes for forest resource degradation in Wayu-Tuka District of Eastern Wallaga, Western Ethiopia.

3.3. Discussion

This study estimated ESV changes over four periods (-1990, 2000, 2010 and 2020) in the study area. LULC changes induced ESV changes are the result are many complex and numerous factors (Hoque et al., 2022). ESV changes factors vary according to the nature and magnitude of the area (Imad et.al. 2020). In this study, the factors that induced ESV changes in the study area were agricultural land expansion, increasing demand of fuel wood, construction material, illegal settlement within forests, and illegal logging for trade.

Sample households of the study area were asked about the 'factors that influence ecosystem services (ESV) changes in their villages'. The respondents revealed that agricultural land expansion (44.8%) and illegal settlement (32.6%) within the forest cover of Wayu-Tuka District accounted the largest share of the ESV loss; besides, illegal logging for trade (10%), increasing demand for fuel-wood (6.3%), and construction material (6.3%) were the other causes that aggravated the ESV loss in the district. The finding of this research is similar with a study carried out by Mengesha (2017), who indicated cultivated land expansion (by 27.2%) as the main drivers of ESV changes in the Shenkolla watershed in over 44 years (1973–2017); and, where the focus group discussants and elders attributed the agricultural land expansion to the polygamous families induced raising demand for more farmland; the same study showed that forest cover decreased from 29.5% to 20.5% within 1973 - 2017. The result of this study is also consistent with the study of Bufebo and Elias (2021), whose significant share (85.4%) of respondents indicated that human interference (mainly agricultural expansion) was the main cause of the LULC change induced ESV dynamics in their study area.

4. Conclusions

This study was targeted to analyze the LULC dynamics induced ESV changes of Wayu-Tuka District based on data from Landsat images of the year 1990, 2000, 2010 and 2020, and from households. The study revealed that forest provides diverse provisions, regulatory, supportive and cultural services. While forest ESV had accounted the largest share (46.1%) of the total ESV of Wayu-Tuka district before 30 years (1990), farmland ESV constituted the lion share (63.3%) of total ESV of the area after three decades (2020). The ESV of forest and bare-land showed declining trends in three decades (1990-2000, 2000-2010 and 2010-2020) but the farmland ESV revealed an increasing trend in the same periods. Forest ecosystem exhibited the largest ESV loss in 1990-2020; whereas, the service value gains of farmland was very limited although farmland was responsible for the conversion of the largest area size from other land covers in 30 years. LULC change induced net ESV loss of the district in the three decades (1990-2020) was slightly less than one-fourth (23.4%).

Expansions of farmland (by 9,766.5 ha) and settlement (by 4,061.3 ha) were the main causes for the destruction of almost 4/5th (79%) of the forest cover and the significant ESV loss of the area in 1990-2020. The households also showed that farmland and settlement (illegal) expansion, and illegal forest exploitation for firewood, charcoal and timber (logs) for energy consumption, construction and/or for cash were the main driving forces for the degradation of the ecosystem services and their values overtime (1990-2020). The huge ESV loss of forest implies decline in carbon sink and recharge of the ground water, raising air pollution, erosion risks and climate variability, decline in agricultural yield and threatened livelihoods of people. Thus, the government and local people should cooperate so as to curb the steady degradation of forest and its ecosystem services, and for rehabilitation of forest and other resources in Wayu-Tuka district, Western Ethiopia.

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