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Research Article

Impacts of Sustainable Land Management Intervention on the Soil Condition and Landscape Greenness: Evidence from Jimma Arjo District, Southwestern Ethiopia

Mengie Belayneh, Mamush Masha, Alemayehu Abera, and Kitesa Terefa

Department of Geography and Environmental Studies, Mattu University, Metu, Ethiopia

Correspondence should be addressed to Mengie Belayneh; mengie1980@yahoo.com

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Soil degradation has been a major environmental and agricultural challenge in Ethiopia in general and in the study area in particular. Recently, several governmental and nongovernmental organizations have made efforts to reduce the problem and improve the productivity of land through sustainable land management (SLM) practices. The main objective of this study was to investigate the impact of sustainable land management practices on soil condition and landscape greenness in the Jimma Arjo District, Southwestern Ethiopia. The impact of SLM practices on soil condition was examined by collecting twenty-eight (28) composite and core (28) soil samples from treated (14) and nontreated (14) lands. Landsat satellite images of 2012 and 2022 were used to detect changes in landscape greenness using the Normalized Difference Vegetation Index (NDVI). ArcGIS® 10.3, ERDAS® 2014, and Microsoft Excel software packages were used for analysis. The significance test was performed using a one-way ANOVA. The result showed a significant difference in soil physiochemical properties (soil texture, soil pH, soil organic carbon, soil organic matter, total nitrogen, and available phosphorous and calcium) between treated and nontreated lands ($P < 0.01$). However, the landscape greenness result shows that the lowest NDVI value in the SLM-treated kebele during 2012 was −0.15 but increased to 0.09 in 2022. Similarly, the highest value was found to be 0.41 in 2012 and the value rose to 0.53 in 2022. It is concluded that sustainable land management practices implemented in the area have resulted in an important positive effect on improving the soil condition and landscape greenness. Hence, strengthening and scaling up SLM practices and continuous maintenance are advisable for better results in land productivity and livelihood improvement.

1. Introduction

Land degradation is the main environmental challenge in Ethiopia [1]. It mainly affects the soil resource and its productivity. Soil, an essential natural resource, provides food and social, economic, and environmental security for humankind [2]. Due to misuse and overuse, the soil experienced decreased soil fertility and crop productivity, disturbances to watersheds' hydrological processes, a rise in the frequency of floods and droughts, a reduction in the amount of water available, increased sedimentation of rivers and water bodies, increased susceptibility to climate change, and a general deprivation of people's socio-economic status [3].

In the Ethiopian highlands, fast population growth, soil erosion, deforestation, and low vegetation cover are the main factors contributing to land degradation [4]. These areas particularly suffer from severe soil erosion as a result of population pressure, land use changes and fragmentation, and intensive cultivation on steep and fragile lands [5–7]. Its adverse impacts are more significant in these regions where 90% of the population lives, 95% of the cultivated lands are situated, and 90% of annual national crop production is generated [5, 7–10]. Population pressure and its related consequences such as continuous cultivation, cultivation of steep and marginal lands, overgrazing, and clearing of natural vegetation (deforestation) are the identified human causes that facilitate soil erosion in cultivated lands [11–17], which consequently limit food security and agricultural productivity [18–21]. Besides, improper methods of plowing, poor technology, and traditional cultivation mechanisms pronounce soil degradation risks in the area [22].

As a result of this, the vegetation cover decreased and the extent of barren land (land without vegetation cover) increased over time. For instance, a significant increase in barren land was reported by Zeleke and Hurni [23], who found a rise in bare land from 0.1% in 1957 to 3% in 1995 and from 0.2 to 2.7 between 1995 and 2015 in the Tata Watershed [24]. This situation consequently leads to low water infiltration and underground water storage, desertification, and finally loss of livelihoods and food insecurity.

Several studies indicated that changes in land management methods and the use of appropriate and sustainable conservation approaches and initiatives can positively influence the agro-environmental processes through rehabilitation and restoration of land cover, landscape greenness, and soil fertility [24–26]. In this regard, both indigenous and introduced land management practices have been implemented in different parts of Ethiopia [25, 26]. This is because sustainable community-based land management practices are the best strategies to rehabilitate degraded landscapes, reduce poverty, and improve soil conditions, food security, crop yields, and the general livelihoods of rural farmers [26–28]. They are being advocated as an integral part of agricultural land management as they not only control soil erosion but also prevent land degradation [6, 29, 30]. Concerned with the improvement of soil fertility and rural livelihoods, they are the strategies at the local level and represent non-negotiable development intervention for the country [7, 31]. Although indigenous land management practices traced back to 400 BC, government-led institutionalized land management practices dominantly became significant after 1970, and later, the concept of SLM practices emerged in the 1990s through a community-based approach [6, 13, 32–34]. Nevertheless, its achievements are diversified and fragmented [32] due to differences in the scale of intervention, the amount of labor involved, and poor community participation [7, 31]. On top of that, several empirical studies focusing on the impact of sustainable land management practices were conducted in different parts of the country [32]; however, their findings were inconsistent, did not show agreement among each other, and were site-specific in nature [32, 35].

Sustainable land management practices have been implemented by government-led mass community mobilization for the last two to three decades in different parts of Ethiopia and for the last ten years in Jimma Arjo District. However, the problem of soil erosion is still continued as the greatest challenge and the effectiveness of implemented management efforts has not been sufficiently evaluated. According to previous studies, evaluating the roles of implemented community-based land management practices by considering different commonly implemented structures is vital to learn lessons from the past for future better conservation planning [26]. In contrast, in the northwestern, southern, and other highlands of the country, land management practices being implemented have resulted in a considerable effect on regenerating vegetation cover and rehabilitation of landscapes [19, 26, 30].

However, in the Jimma Arjo District of Southwestern Ethiopia (the current study area), the impacts of the implemented land management practices on soil condition and landscape greenness have not been adequately evaluated and documented. Currently, both soil erosion and land management practices are increasingly becoming major areas of scientific concern, and hence, the effective implementation and planning of the practices require a detailed understanding of the extent, risks, and spatial distribution of the problem [25]. Thus, the objective of this study was to investigate the impacts of implemented land management practices on soil conditions and landscape greenness for evidence-based planning.

2. Materials and Methods

2.1. The Study Area. Jima Arjo District is found in the East Welega Zone of the Oromia Region at 379 km west of Addis Ababa. It is bordered on the southwest by the Didessa River, which separates it from the Buno Bedele Zone, on the northwest by Diga Leka Woreda, on the northeast by Guto Wayu Woreda, and on the southeast by Nunu Kumba District. The district is geographically located at 8° 33′00″ to 8° 55′ 15″N latitude and 36° 22′ 34″ to 36° 44′ 43″ E longitude (Figure 1). It covers an area of 773 km^2 [36]. The elevation ranges 923–2642 meters above sea level.

The study area can be grouped into three agro-ecological divisions based on their elevation: the Kolla/tropical (<1500 m), Woina Dega/subtropical (1500–2300 m), and Dega/temperate (>2300 m) above mean sea level, representing 30%, 58%, and 12% of the districts, respectively. Geologically, the district is covered by volcanic trap basalt rocks and late Paleozoic to early tertiary sediment [37]. The steep side slopes and escarpments of mountain plateaus and gorges have very shallow soils. Soils of moderately stream-dissected plateaus with flat to gently undulation are deep to very deep, well-drained, clay loam to clay-textured soils. The Nagesso depression and some pocket areas of Didessa Valley have heavy clay-textured vertisols. Most areas of Didessa Valley and the foot slopes of Imbatu Ridge have silt clay loam, gravely clay, and sandy loam soils. According to the FAO/UNESCO Soil Classification System and data obtained from the Digital World Soil Map, the area has four major soil classes, i.e., dystric nitosols, pelvic vertisols, dystric gleysols, and orthic acrisols [38].

The area receives an average annual rainfall of approximately 1700 mm in a bimodal rainfall pattern. It attains the maximum rainfall in the summer season (June, July, August, and September) and a small rainy season in the autumn (February, March, April, and May). The species of trees grown in the area are Asta (*Erica arborea*), Kosso (*Hagenia abyssinica*), Woira (Oliva African), Girar (*Acacia abyssinica*), Tid (*Juniperus procera*), Bahir Zaf (*Eucalyptus camaldulensis*), and others.

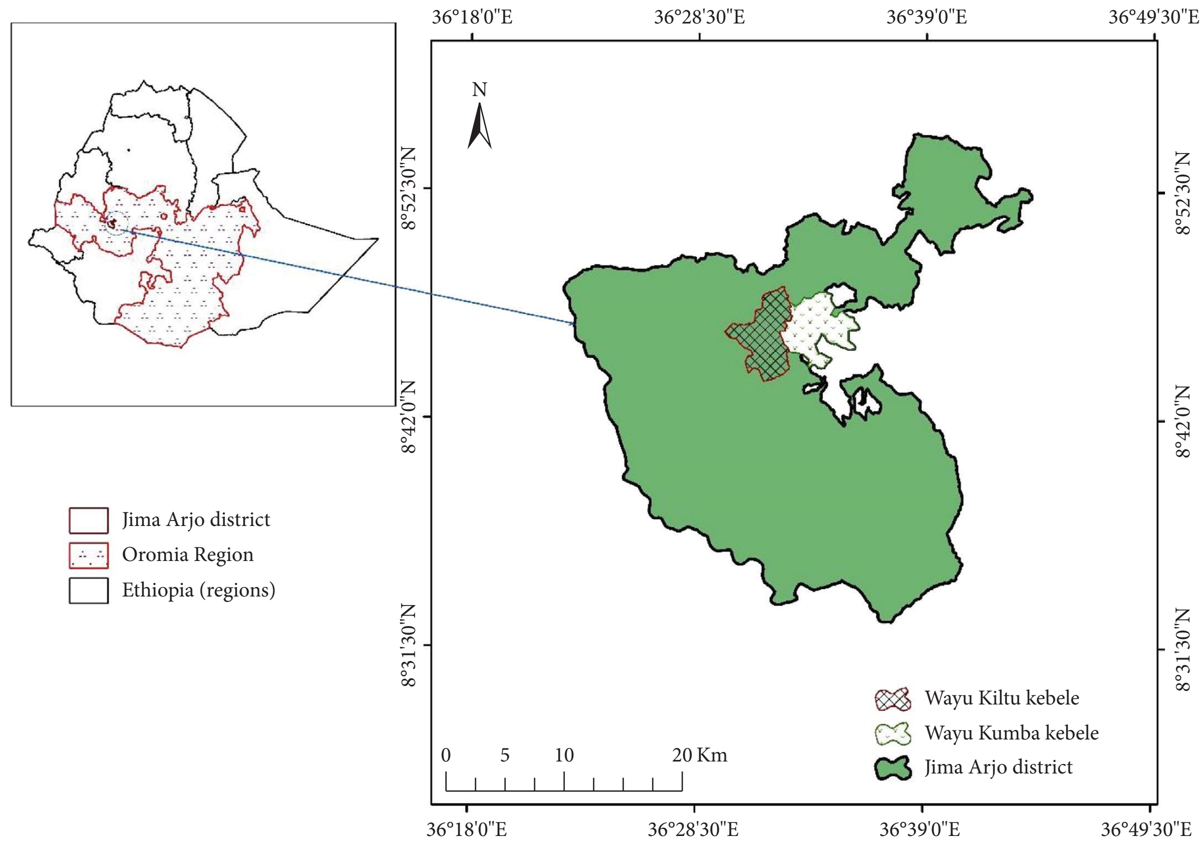

Figure 1: Location map of the study area.

2.2. Research Design. This study used a cross-sectional design to compare the land treated with sustainable land management practices and the bordering nontreated land. The motive for employing this design in the current study was that it is helpful to collect the data at a single point in time in which the pattern of association between variables is examined to detect the association of causal effects. Besides, to support the results of soil laboratory and satellite imageries, socio-economic data have been collected from the sampled farmers. For the collection of socio-economic data concerning sustainable land management practices and related limiting factors of SLM, three focus groups with nine members each were selected. They were purposefully chosen by considering their age, agro-ecology, and involvement in sustainable land management activities.

2.2.1. Soil Data Collection. The study employed adjacent land comparison in which soil samples were taken from similar land that had most likely comparable biophysical and socio-economic characteristics. Consequently, soil samples were collected using an augur and core sampler at a depth of 0–30 cm, which is the known plow depth of the local community in the area. A total of 28 composite and core soil samples were collected from treated and nontreated cultivated lands (14 soil samples from treated land, land with soil bund, Fanya juu (Fanya juu, a Swahili term meaning "to throw up," is a soil bund type wherein a ditch is dug along the contour and the soil is thrown up to form a ridge above. They are usually constructed in fields sloping above 10%), and stone bund structures, and 14 samples from adjacent nontreated land). This is because the study area is most commonly practicing the aforementioned structures, despite some adjacent land still remaining without SLM treatment due to interrelated socio-economic factors. Similarly, 28 undisturbed soil samples were collected for bulk density determination. Finally, 1 kilogram of composite soil was packed from each soil sampling site for laboratory analysis.

2.2.2. Satellite Image Data Collection. Satellite imageries were collected from the USGS website (https://earthexplorer.usgs.gov) to detect the improvements in landscape greenness in the area before and after sustainable land management implementation. For landscape greenness analysis, Landsat satellite images of 2012 (ETM^+) and 2022 (OLI) with 30 m × 30 m spatial resolution with path and row, 169/052 and 169/053, were taken during dry months (Table 1).

Then, image preprocessing such as image rectification, subsetting, topographic correction, and radiometric correction as an image enhancement was performed to make the map suitable and easy for the intended classification that best fits the then ground data. In this regard, a 1 : 50, 000 toposheet map and DEM (digital elevation model) were used for image preprocessing. Toposheet maps are important for satellite image rectification and geometric correction to better relate the exact location of the image with the ground.

Table 1: The data employed for landscape greenness analysis.

Satellite/sensor	Path and raw	Acquisition date	Source	Resolution
Operational Land Imager (OLI)	169/053	5/3/2022	USGS	30 m × 30 m
Thematic Mapper (TM)	169/052	3/3/2012	USGS	30 m × 30 m

DEM was used for preprocessing the satellite image such as topographic correction (c-correction) with a non-Lambertian model.

2.3. Methods of Data Analysis

2.3.1. Soil Data Analysis. The collected subsoil samples from five corners of the delineated plot were mixed to make a single composite sample for laboratory analysis. It was then air-dried, ground, and passed through a 2-mm sieve before the laboratory analysis. Samples for organic carbon and total nitrogen analysis were further sieved by a 0.5 mm sieve and taken to the Nekemte Soil Laboratory Center. Selected soil fertility indicators such as soil texture, bulk density, soil pH, total nitrogen, organic carbon, available phosphorus, cation exchange capacity, and exchangeable bases (Ca^{2+} and Mg^{2+}) were tested. The determination of soil texture was carried out by the hydrometer method [39]. Bulk density was determined by the core sampling method by dividing the weight of oven-dried (105°C for 24 hours) soil by the volume of the core soil sample [40]. Soil organic carbon (OC) concentration was determined using the Walkley and Black rapid titration method [39]. Total nitrogen (TN) was determined by the modified Kjeldahl method [39]. The soil pH was determined using 1 : 1.5 soil-water ratio based pH meter [41]. Available phosphorus (av. P) was determined using the Olsen extraction method [41]. The exchangeable bases (Ca^{2+} and Mg^{2+}) and CEC were determined using the ammonium acetate method [39].

2.3.2. Landscape Greenness Analysis. A normalized difference vegetation index was used to evaluate the variations in landscape greenness caused by SLM implementation in the area. Normalized difference vegetation index (NDVI) is a numerical expression of live green vegetation in an area using visible and near-infrared bands of the electromagnetic spectrum. The NDVI value extends from −1 (water bodies, exposed rocks, snow, etc.) to 1 (very dense vegetation). The NDVI method gives the best results for vegetation change detection and changes in vegetation growth and density. High absorbance of visible light and reflectance of NIR imply healthy vegetation and vice versa. Therefore, NDVI would be used to analyze vegetation density and healthiness. NDVI would be computed using the visible red reflectance (band 3 for ETM^+ and band 4 for OLI) and near-infrared reflectance (band 4 for ETM^+ and band 5 for OLI) of the satellite imagery bands using the following equation:

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED}}. \quad (1)$$

Two main methods can be used to evaluate the impact of land management interventions such as land use, land cover change, and Normalized Difference Vegetation Index (NDVI). Land use and land cover change is better when the SLM intervention is practiced for a little bit longer time. However, in this study case the SLM was practiced for a decade; therefore, NDVI can better detect vegetation cover and greenness or health as a result of SLM. Vegetation indices among other methods have been reliable in monitoring vegetation change. One of the most widely used indices for vegetation monitoring is the NDVI. Data on biophysical characteristics of vegetation can be derived from the visible, NIR, and mid-infrared portions of the electromagnetic spectrum.

3. Results and Discussion

3.1. Impact of Sustainable Land Management Intervention on the Soil Condition

3.1.1. Soil Dry Bulky Density. The mean value of bulk density in the *treated* and *nontreated lands* was 1.29 $g{\cdot}cm^{-3}$ and 1.34 $g{\cdot}cm^{-3}$, respectively. The fine-textured soil of the study area (dominated by clay fractions), which might contain high CEC, could significantly result in lower soil bulk density in general (1.29 $g{\cdot}cm^{-3}$ and 1.34 $g{\cdot}cm^{-3}$; Table 2). Nevertheless, its value was higher in the *nontreated land* than in the *treated land*, but the difference was not statistically significant ($P < 0.05$; Table 2). This might be due to the inappropriate design and implementation of land management practices, as they did not curb the movement of nutrients in the treated land [42]. The excessive removal of uppermost soil nutrients/materials by runoff might be the reason for the observed high bulk density value in the *nontreated land* compared with the *treated land*. Similar findings of [26] noted the role of land management practices on the mean value of soil bulk density, which was found to be minimal, and slightly lower values were observed in treated land.

3.1.2. Soil Texture. Soil textural class proportion (sand, silt, and clay contents) showed significant variations between treated and adjacent nontreated lands. According to the United States Department of Agriculture (USDA) soil textural classification triangle, the soil texture and textural class of the area were sandy clay loam in the treated land (*TL*) and sandy clay in the nontreated land (*NTL*). Despite the nonsignificant variations of textural classes, the soil of the area was dominated by clay fractions, and a higher mean value was observed in treated land than in nontreated land. A relatively high clay content observed in the treated land is primarily due to the impact of sustainable land management practices on soil erosion as it reduces the removal of soil particles in the treated land. These findings have been in line with the study of [26, 43], who reported a higher mean value

Table 2: Mean variation of soil physical properties in SLM-treated and nontreated lands.

	Soil particle size proportions			Textural class	Bulk density (g/cm^3)
	Sand (%)	Clay (%)	Silt (%)		
NTL	39.75	46.00	14.25	Sandy clay	1.3425
TL	49.50	22.75	27.75	Sandy clay loam	1.2963
F	9.092^{**}	47.336^{***}	75.6^{***}		2.631^{ns}

TL, treated plot; NTL, nontreated plot; P, P_value; ** and *** implies the variation is significant at $P < 0.01$ and 0.001, respectively; ns, not significant at $P < 0.05$.

Table 3: The mean and their significant variations of soil chemical properties in treated and nontreated lands.

	pH (H_2O)	SOC (%)	SOM (%)	TN (%)	Av. P (ppm)	CEC and exch. cations ($cmol^{(+)}kg^{-1}$)		
						CEC	Ca^{2+}	Mg^{2+}
NTL	5.24	0.72	1.25	0.06	0.96	22.4	8.35	4.90
TL	5.47	1.16	2.01	0.100	3.25	25.3	9.37	5.61
F	5.09^{*}	10.07^{***}	10.18^{***}	10.4^{***}	9.17^{***}	10.5^{ns}	3.96^{ns}	1.079^{ns}

TL, treated plot; NTL, nontreated plot; P, P_value; * and *** implies the variation is significant at $P < 0.01$ and 0.001, respectively; ns, not significant at $P < 0.05$.

of clay content in the treated land than in the nontreated land. Similarly, the average silt content of the soil was higher in the *TL* (25.91%) than in the *NTL* (24.94%). This may be due to the impact of community-based implementation of land management practices. The SLM practice affects soil erosion as it reduces the removal of soil particles in the *TL* more than that of the high runoff-led erosion in the *NTL*. The result was consistent with the findings of [44], who found a higher amount of silt content in treated land than in nontreated land. However, the sand content of the soil constitutes a relatively higher proportion of *NTL* than treated land. This was due to the impact of SLM on the removal of fine particulates through erosion.

3.1.3. Soil pH. The mean pH of the soil in the study area was 5.47 and 5.24 in treated and nontreated lands, respectively (Table 3). This indicates that the variation in soil pH was statistically significant between the treated and nontreated lands at $P < 0.05$, due to implemented land management practices. This could be because the high rainfall coupled with steeper slopes might have increased leaching, soil erosion, and a reduction in soluble base cations, leading to higher H^+ activity [45]. On the contrary, different researchers observed lower pH values in the nontreated cultivated land as compared to treated land [46].

3.1.4. Soil Organic Carbon. The soil organic carbon (SOC) shows a significant variation between treated and nontreated lands ($P < 0.01$). The decomposition of plant and animal matter constitutes organic carbon in the soil, and living and dead microorganisms, roots from plants, and soil biota can also contribute to its availability. The soil organic carbon under the nontreated land was lower than that on the treated land. Similarly, [47] reported that the nontreated fields had significantly lower soil organic carbon as compared to the treated fields. Besides, the mean soil organic carbon content was rated low in treated and very low in nontreated land according to the rating standard developed for tropical soils [48]. It could be explained by soil erosion, continuous cultivation, harvesting crop residues, and animal dung. The use of animal dung may reduce the effectiveness of SWC practices in SOC concentration [49].

3.1.5. Soil Organic Matter. The result revealed that there was a higher organic matter content in the soils taken from the treated land than the nontreated land. The mean values of soil organic matter in the treated and nontreated lands were 2.01 and 1.25, respectively (Table 3), and showed a significant variation ($P < 0.01$). This could be attributed to the effect of management practice implemented and biomass accumulated. However, physical soil and water conservation measures complemented with organic manure application raised soil organic matter content better than soil without the construction of any structures. Also, the higher organic matter contents in treated areas than in untreated areas can be explained by the difference in soil erosion and biomass return. This was consistent with the study of [46], which showed a higher value of soil organic matter on farmlands treated with SWC and an increasing age of structures when compared to nonconserved land.

3.1.6. Total Nitrogen (TN). The mean nitrogen content of the soil in the area was 1 and 0.6 in SLM-treated and nontreated lands, respectively (Table 3). It revealed that the total nitrogen content of the soil was significantly affected by the implemented land management practices ($P < 0.01$). Similarly, [45] reported that the land treated with different soil conservation measures has a high total nitrogen content compared with the untreated land. In view of this, the work of [50] also found higher total nitrogen content in farmland with physical conservation measures than nontreated lands. This might be attributed to the effect of implemented land management practices, as they reduce the loss of finer soil particles, increase soil organic carbon, and subsequently

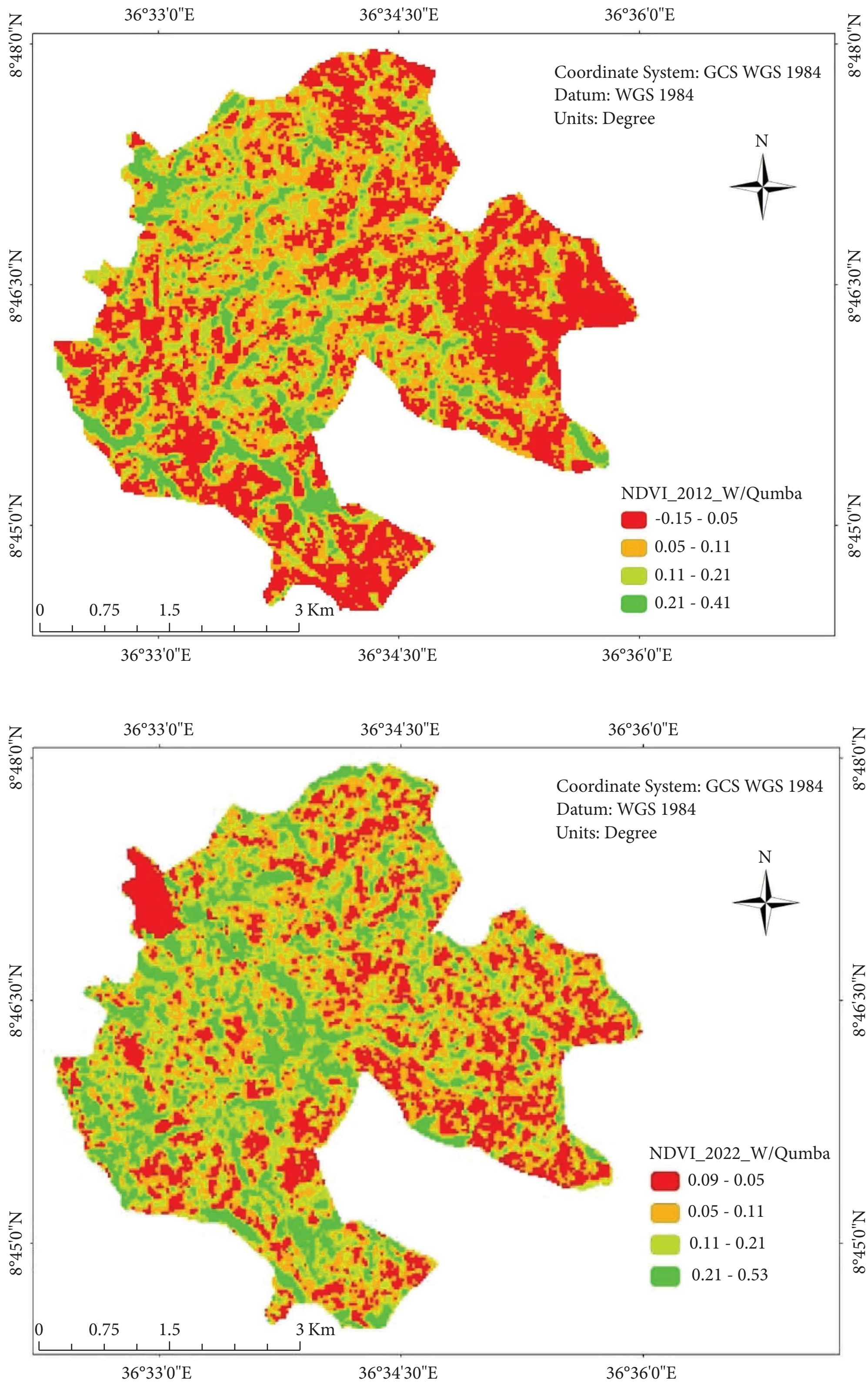

Figure 2: NDVI map of Wayu Qumba Kebele showing landscape greenness before SLM intervention (2012) and after ten years of intervention (2022).

Table 4: NDVI map of the study area in 2012 and 2022.

No	2012			2022		
	NDVI density classes	Area (Ha)	Area (%)	NDVI density classes	Area (Ha)	Area (%)
1	<0.05	831.5	36.6	<0.05	787.8	28.05
2	0.05–0.11	886.8	39.2	0.05–0.11	916.6	41.8
3	0.11–0.21	422.8	18.5	0.11–0.21	399.02	22.25
4	>0.21	127.4	5.7	>0.21	165.3	7.9
	Total	2268.72	100	Total	2268.5	100

increase the concentration of total nitrogen in the treated soils. The result is relatively in agreement with the findings of [44], who stated a statistically nonsignificant difference between treated and nontreated lands.

3.1.7. Available Phosphorous. The differences in available phosphorus content of the soil between lands treated with different conservation structures and that of the nontreated land were significant ($P < 0.01$; Table 3). The mean value of available phosphorous in the soil in the area ranged from 0.96 ppm in the nontreated land to 3.25 ppm in the treated land. This shows that the concentration of available phosphorus in the current study was estimated as medium [51]. Nevertheless, a relatively higher mean value of available phosphorus was found in treated land than in nontreated land. This might be related to the moderate acidity level of the soil environment in the area.

3.1.8. Cation Exchange Capacity (CEC). According to the ranking principles of [48], the cation exchange capacity of the soil in both the treated and nontreated lands in the area was ranked high. This might be due to the inherent characteristics of the soil. However, the value in the nontreated plot was found to be slightly lower, which is considered to be caused by the short-term (10 years) effect of the SLM intervention in the treated kebele. Nevertheless, the mean value of CEC exhibited differences between *TL* and *NTL*. In this regard, a relatively high CEC of the soil was observed in treated land than in nontreated land. Similarly, according to the rating standards of [48], the CEC content of the soil in the Gumara Watershed was rated as high (25–40 $cmol^{(+)}$ kg^{-1}) in both *TL* and *NTL* [26].

3.1.9. Exchangeable Bases. The sustainable land management practices in the area did not significantly affect the exchangeable basic cations (Ca^{2+} and Mg^{2+}) ($P > 0.05$; Table 3). On average, the nontreated kebele experienced 8.25 $cmol^{(+)}$ kg^{-1} exchangeable calcium and 4.90 $cmol^{(+)}$ kg^{-1} exchangeable magnesium. Similarly, the conserved kebele soils contain nearly similar amounts of exchangeable calcium and exchangeable magnesium. This might be due to the development of soils from young rocks [31].

3.2. Changes in Landscape Greenness as a Result of SLM Intervention. The NDVI analysis results show that there is a significant improvement in landscape greenness and vegetation density in the study area in 2022 as compared to its previous equivalent in 2012 (before the implementation of SLM) (Figure 2 and Table 4). The lowest and highest NDVI values during 2012 and 2022 were −0.15 and 0.41, and 0.09 and 0.53, respectively. The highest NDVI value has increased from 0.41 to 0.53 over the period 2012–2022. The highest land greenness class in 2012 ranging from >0.21 covered 127 hectares (5.7%), but in 2022 it becomes 165.3 hectares (7.9%) (Figure 2 and Table 4). This implies that the greenness of the area and the land cover have been improved [26].

Before and after the sustainable land management practice in the area, landscape greenness and vegetation density experienced greater variation. The NDVI map also showed that the proportion of land covered by high greenness areas increased, but conversely, the lowest greenness values decreased in 2022 compared with 2012 (Figure 2 and Table 4). This result indicated that the vegetation cover and vegetation density of the area have improved significantly after the implementation of SLM practices. This might be attributed to the plantation of trees and grasses and afforestation and reforestation activities conducted by SLM [21]. Besides, the improvements in soil moisture content as a result of different physical and biological measures might have contributed to improving vegetation density and greenness.

During 2012, the area covered by NDVI values ranging from 0.05 to 0.11 was 39.2%, but in 2022 it became 41.8%. This shows an increase mainly because of conservation activities, and the already degraded and barren lands have been rehabilitated by the plantation of grasses and trees. Despite these promising facts about the impacts of the implemented land management measures, the survey results indicated that the current continued implementation of land management practices by local farmers has been influenced by several interrelated socio-economic and biophysical factors. For instance, poorly designed structures, poor quality and quantity of construction, lack of maintenance, grass coverage, and long-term adoption problems by some households were some of the principally stated factors. Field observation results also verified that the involvement of local farmers in the planning, maintenance, and selection of conservation measures has been very low, which collectively determines soil fertility and landscape greenness. The study also specified that the majority of rural farmers partially integrated land management practices with grass strips and vegetation covers, which would have poorly resulted in soil fertility improvement and landscape greenness.

4. Conclusion

This study examined the impact of implemented land management practices on selected soil property indicators and landscape greenness. The result showed that there was a significant difference in soil physiochemical properties (soil texture, soil pH, soil organic carbon, soil organic matter, total nitrogen, and available phosphorous and calcium between treated and untreated lands) ($P < 0.01$). In the treated land, both the lowest and highest NDVI values improved from −0.15 to 0.09 and from 0.41 to 0.53. It is concluded that sustainable management practices implemented in the area have resulted in important positive effects on improving the soil condition and landscape greenness. The land management practices implemented in the area have made considerable contributions to improving the soil condition/landscape greenness, but still, their continued acceptance, implementation, and adoption by local farmers have been low. Thus, the local government and other stakeholders should work cooperatively to strengthen the implementation, continued adoption, and maintenance of conservation structures in the area.

Abbreviations

ANOVA: Analysis of variance
TL: Treated land
NTL: Nontreated land
NDVI: Normalized Difference Vegetation Index
SLM: Sustainable land management
ETM^+: Enhanced Thematic Mapper Plus
OLI: Operational Land Imager

Data Availability

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

MB conceptualized and designed the study and commented, edited, and reviewed the manuscript. MM and AA structured and reviewed the manuscript. KT conceptualized and designed the study, collected relevant data, analyzed the data, and involved in report writing. All authors approved the manuscript for publication.

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