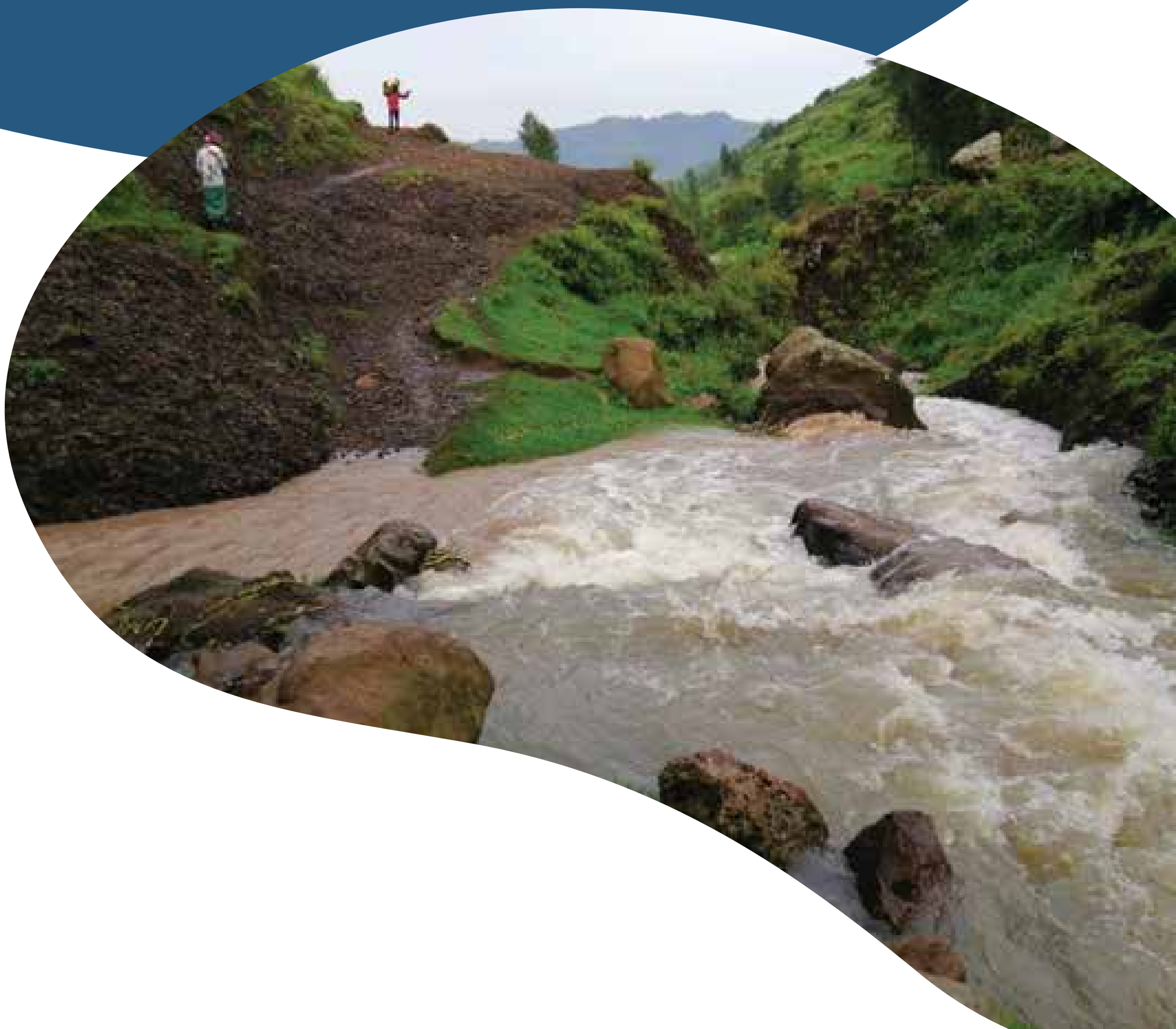
International Water Management Institute

Impacts of Landscape and Household Climate-smart Water Management Practices in the Awash River Basin, Ethiopia

Synthesis Report

Wolde Mekuria, Fitsum Hagos, Likimyelesh Nigussie, Wondye Admasu and Awoke Bitew



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Cover photo: A stream coming from differently managed watersheds, Borkena catchment, Awash River Basin, Ethiopia (*photo*: Wolde Mekuria)

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Contents

Summary

There is growing evidence that climate-related risk is increasing, and this will affect the livelihoods of small-scale producers (SSPs), with the effects being more severe in agropastoral and pastoral farming systems. In the Awash River Basin, the vulnerability of SSPs is mounting because of anthropogenic and climatic factors. Investigating the impact of landscape management practices and the interaction of SSPs with natural resources would inform sustainable planning, implementing and managing interventions.

This study was conducted in four watersheds in the Awash River Basin: Maybar-Felana, Gelana, Ewa and Afambo. The overarching objective was to assess the biophysical and socioeconomic impacts and gender dimensions of landscape management practices. The researchers also investigated the links between natural resource degradation and the vulnerability of natural resource-dependent people, and the contributions of landscape management practices to address these issues.

The study analyzed data gathered through 500 household surveys, 51 key informant interviews, 96 in-depth household interviews, 36 focus group discussions, and Geographic Information System (GIS) and remote sensing techniques. The results indicated that diverse household-, farm- and watershed-level landscape management practices were adopted in the four watersheds. The findings indicated that implementing these practices could improve natural resources and the services they provide. The adopted practices contributed to reducing livelihood vulnerability by minimizing the effects of weather extremes (floods and droughts), improving food and water security, enhancing resource availability and building livelihood assets. Practicing small-scale irrigation (SSI) has a positive and significant effect on the household Food Consumption Score (FCS) and the Household Dietary Diversity Score (HDDS). Stone bunds and SSI have a significant impact on lowering the score on the Household Food Insecurity Access Scale (HFIAS).

The findings suggest that women and other marginalized groups (children, the elderly and resource-poor households) are the most affected by climate change and natural resource degradation. Government and non-government organizations recognize the needs of women and marginalized social groups in designing and implementing landscape management initiatives by prioritizing their participation in initiatives to empower them economically (e.g., involving them in income-generating activities) and socially (e.g., building social capital).

Despite efforts to achieve gender equality and women's empowerment in landscape management initiatives, women and marginalized social groups remain vulnerable and benefit less due to various factors, including social norms and limited institutional capacities. Gender norms, values and practices embedded within individuals, households, communities and institutions hinder progress. Limited institutional capacities, such as financial and human capacities remain challenges. This study offers recommendations to maximize and sustain the contributions of landscape management practices to reduce the vulnerability of SSPs.

Introduction

Agriculture is recognized globally as a sector highly vulnerable to climate change. The risks from climatic variations pose an imminent danger to food security and livelihood sustainability (Singh et al. 2021). Ethiopia's agriculture is overwhelmingly rainfed, with 95% of the cropped area under small-scale rainfed farming (EPCC 2015). It suffers from the risks associated with weather extremes (e.g., floods and droughts) and weather variability (Dorosh and Rashid 2012; Kassie et al. 2014; EPCC 2015; Asfaw et al. 2021). Agropastoral and pastoralists, solely dependent on rainfed systems, are more exposed to climate change and variability than households dependent on highland crop systems (EPCC 2015).

In Ethiopia's Awash River Basin, the vulnerability of small-scale producers (SSPs) is attributed to multiple environmental, social and economic factors (Murendo et al. 2011; Tola and Shetty 2021; Mitiku et al. 2023). In recent years, the vulnerability of SSPs in the basin has been rising, and indicators such as rainfall variability, flooding, low agricultural productivity and poor water resources planning and management are common (Mekonen and Berlie 2021). Despite an abundant water supply, the basin routinely suffers from localized water shortages at specific times and is prone to destructive episodes of floods and droughts.

The vulnerability of SSPs and the status and sustainability of natural systems are closely interlinked in the Awash River Basin and Ethiopia at large (Wassie 2020). Natural resources such as forests, woodlands, wetlands, exclosures, grasslands and rangelands yield resources that are used directly to generate income and subsistence, sometimes as SSPs' sole livelihood source but often combined with other livelihood activities (Fekadu et al. 2021). These natural resources are important for poor households and often provide the ultimate safety net when other sources of subsistence and income fail (Shackleton and Gumbo 2010).

SSPs' livelihood activities have the potential to deplete, convert, pollute or otherwise further degrade natural systems – or restore them. Overgrazing, deforestation and land use conversions (e.g., forests and wetlands to agricultural lands) all degrade and deplete natural systems (Kuma et al. 2022). As natural systems become degraded, livelihoods are weakened, the economic welfare of SSPs suffers (Awimbo et al. 2004) and they will be more vulnerable (World Bank 2021). Conversely, restoring degraded natural resources can sustain and strengthen community livelihoods (Erbaugh and Oldekop 2018), build their resilience and improve the environment (World Bank 2021).

Effective landscape management practices (LMPs) reduce this dependence and enhance productivity (FAO 2013; African Union 2020; AfDB 2020; Sikka et al. 2022; Tabe-Ojong et al. 2023). In this study, LMPs refer to household-, farm- and watershed-level climate-smart land and water management practices. These practices include afforestation, reforestation, the establishment of exclosures, terraces, soil and stone bunds, water harvesting structures, soil fertility management, including compost and manure, and small-scale irrigation practices.

Investigating the benefits and costs of LMPs and the interaction of SSPs with natural resources is needed to sustainably plan, implement and manage interventions. It is crucial to understand that SSPs are not a homogenous group (Naah and Braun 2019; Vincent 2022). For example, evidence across Sub-Saharan Africa shows that women SSPs are likely to be most affected by climate change (Mangheni et al. 2019; Yiridomoh et al. 2021). This is due to a number of factors, such as gendered responsibilities at home (UN Women 2022), the lack of representation and voice in water use decision-making (Hlahla 2022), the relative lack of access to extension, technology, inputs, credit and markets (Awiti 2022) and the gender-blind design and implementation of technological innovations (Rai et al. 2021).

The objectives of this study were to (i) characterize the distribution, status and availability of natural resources; (ii) assess the long-term dynamics of land use and land cover and associated changes in aboveground biomass and soil loss; (iii) assess the link between natural resource degradation and livelihood vulnerability; (iv) investigate SSPs' opinions on the contributions of landscape management practices to reducing livelihood vulnerability or building resilience; (v) assess peoples' interactions with and perceptions about natural resources (e.g., water resources, exclosures and communal grazing lands) and natural resource management (e.g., agricultural water management interventions and water resources planning); (vi) examine the landscape management practices and technologies adopted by households in the sample area; (vii) assess the impact of these technologies on land productivity and food security and nutrition; (viii) explore the impacts of climate change on livelihoods, and water access, needs and use by women and other marginalized SSPs; (ix) explore the impacts of existing LMPs on specific social groups; and (x) identify the elements of a gender-responsive design and implementation of LMPs.

Study Area and Methods

This study was conducted in four watersheds in the Borkena, Mille, Logia and Lower Awash Terminal catchments of the Awash River Basin (Maybar-Felana, Gelana, Ewa and Afambo) (Figure 1). The study conducted 51 key informant interviews and 96 in-depth household interviews to assess the perspectives of local communities on the availability and distribution of natural resources, changes in the watersheds and the gender dimension following the implementation of LMPs. Thirty-six focus group discussions were held to assess the environmental, economic and social advantages and disadvantages of diverse farm- and watershed-level LMPs implemented and assess the gender dimension of those interventions (Table 1).

Cross-sectional data was collected through computer-assisted personal interviews in 2023 from 500 randomly selected households from 6 *woredas*[1] (districts) and 20 *kebeles*[2] (wards) in two zones in the Amhara and Afar regions. To complement local perspectives on the availability and distribution of natural resources, land use and land cover analyses were conducted. The study integrated a Geographic Information System (GIS) with the Revised Universal Soil Loss Equation (RUSLE) to estimate soil loss and map erosion risk areas (Renard et al. 1991). The study combined GIS and remote sensing techniques and a literature review to estimate the long-term changes in aboveground biomass following the implementation of LMPs.

To analyze the quantitative data collected from household surveys, the researchers used the multivariate endogenous switching regression model. Specifically, the model was used to estimate the factors for adoption. During the first stage, the researchers accounted for interdependencies across choices. In the second stage, the procedure in multiple bias-adjusted regression models was followed. The qualitative data analysis was processed using manual topic coding and building categories which involved repeated readings of transcribed data.

To analyze the perceived benefits and costs of LMPs, the first themes were identified (e.g., type, distribution, status and availability of natural resources, management and allocation of natural resources, personal interactions and biophysical impacts) and keywords and phrases representing each theme were categorized. Then, using deductive coding, each identified word or phrase was further coded (e.g., forest resources, water resources, uniform or uneven spatial distribution, degraded or pristine state, impact on water availability, impact on agricultural productivity, environmental impact, economic impact and social impact).

Themes such as resources, agency and institutional structures were first distinguished to analyze the qualitative data related to the gender dimensions of LMPs. Then, key terms and phrases for each theme (e.g., resource ownership and access, participation in collective action and decision-making, and formal and informal rules and institutions) were identified. Finally, each response was tagged with all themes and sub-themes in the dataset and analyzed. Geospatial analysis (GIS and remote sensing techniques and related software) was used to analyze the long-term land use and land cover changes and map the severity of soil erosion.

[1] *Woreda* is the third-level administrative division of Ethiopia.

[2] *Kebele* is the smallest administrative unit of Ethiopia.

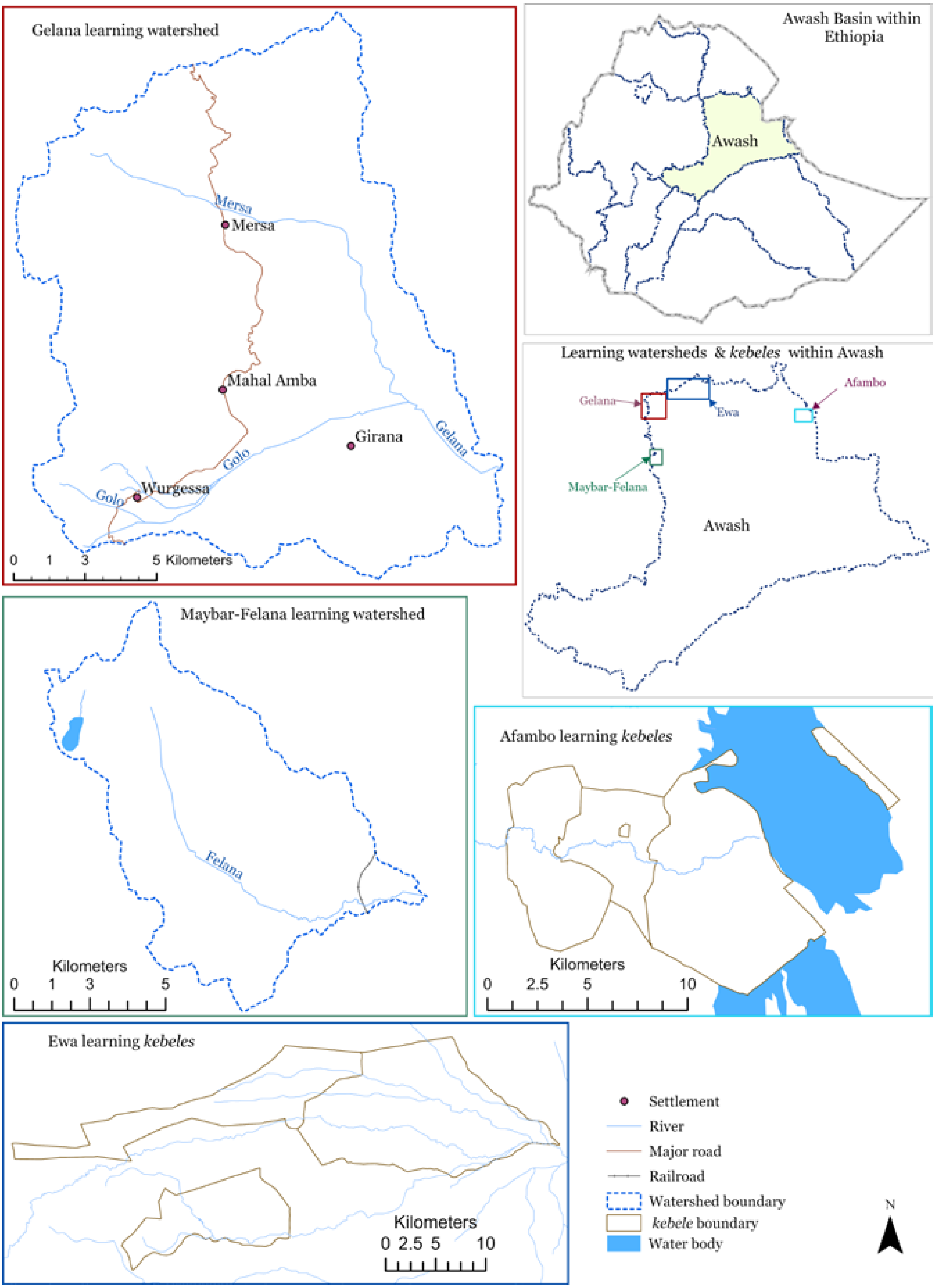


Figure 1. Location map of the study sites.

Table 1. Assessed landscape management in the learning watersheds and their description as provided to local communities.

Landscape management practices	Descriptions
Hillside terraces	Soil and water conservation measures implemented in mountains and steep slopes
Afforestation/reforestation	Raising, planting and managing trees
Exclosures	Restoring degraded landscapes through restricting human and livestock interference
In situ water harvesting structures (trenches, micro-basins, farm ponds)	Micro-catchment water harvesting technologies used to collect and use water
Bunds	Soil and stone bunds constructed on farmlands
Gully rehabilitation measures	Check dams made using small rocks, logs or gabions
Soil fertility management	Application of cow dung or compost to the soil and using mulches and agronomic practices such as crop rotation and intercropping
Irrigation water management	Using both surface water and groundwater resources for irrigation
Spring development and shallow groundwater use	Developing springs and shallow groundwater resources for multiple uses (e.g., domestic, irrigation and livestock)

Note: Most focus group discussion participants engaged in rainfed and irrigated agriculture.

Findings

Forest and Landscape Management Practices Supported Restoration of Degraded Ecosystems

The results indicate that forest cover showed positive changes in Maybar-Felana and Gelana watersheds, while both forest cover and shrublands showed positive changes in the Maybar-Felana watershed over 21 years (Figure 2, Table 2). The positive changes in forests and shrublands could be attributed to the effectiveness of landscape restoration initiatives implemented since the 1980s through community-based watershed development, sustainable landscape management and productivity safety net programs.

These initiatives involved tree planting, establishing exclosures and implementing diverse soil and water conservation measures. The results suggest that designing and implementing better forest and landscape restoration measures that consider both the human and environmental dimensions helps in restoring degraded landscapes and increasing tangible economic benefits and ecosystem services. In the Afambo watershed, forests decreased over eight years (2013–2021), while shrublands increased. The decrease in forestlands is mainly attributed to the expansion of croplands at the expense of forests (Figure 3). The increase in shrublands could be attributed to the spread of Prosopis, an invasive watershed plant.

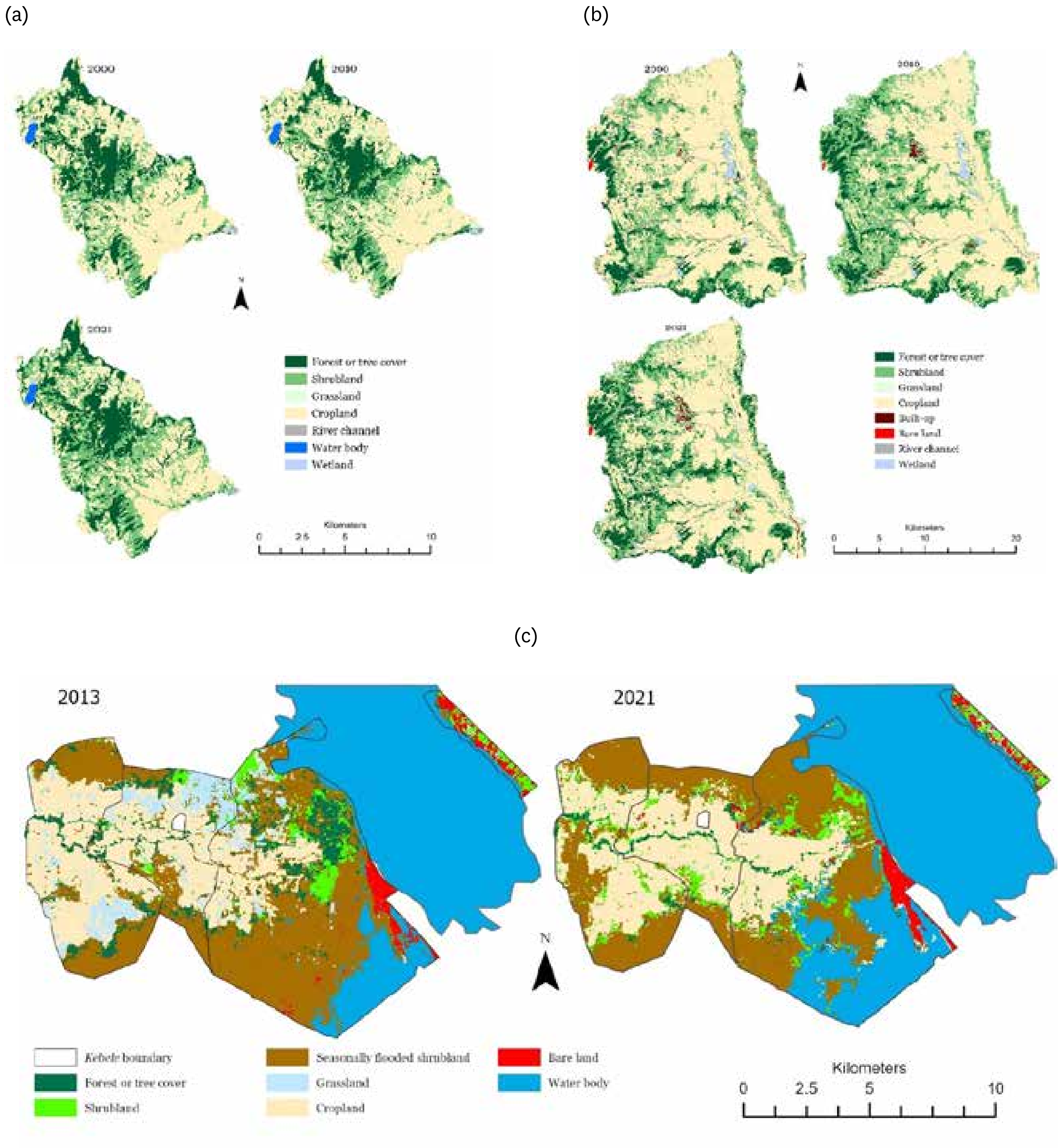


Figure 2. Land use and land cover in three learning watersheds: (a) Maybar-Felana, (b) Gelana and (c) Afambo.

Table 2. Area and changes in major land use and land cover types in the study area watersheds.

LULC* classes	Maybar-Felana learning watershed						Change in area cover (%)		
	2000		2010		2021		2000–2010	2010–2021	2000–2021
	(ha)	(%)	(ha)	(%)	(ha)	(%)			
Forests	1,913	23.3	1,801	21.9	2,133	26.0	-5.9	18.4	11.5
Shrublands	1,913	23.3	2,123	25.8	2,699	32.9	11.0	27.1	41.1
Grasslands	476	5.8	373	4.5	359	4.4	-21.6	-3.8	-24.6
Croplands	3,803	46.3	3,810	46.4	2,916	35.5	0.2	-23.5	-23.3
Water bodies	53	0.6	51	0.6	54	0.7	-3.8	5.9	1.9
River channels	34	0.4	34	0.4	34	0.4	0.0	0.0	0.0
Wetlands	23	0.3	23	0.3	18	0.2	0.0	-21.7	-21.7
Total	8,215	100	8,215	100	8,213	100			
				Gelana learning watershed					
Forests	5,715	12.6	5,362	11.8	8,143	17.9	-6.2	51.9	42.5
Shrublands	10,289	22.6	13,409	29.5	10,066	22.2	30.3	-24.9	-2.2
Grasslands	570	1.3	1,632	3.6	539	1.2	186.3	-67.0	-5.4
Croplands	27,270	60.0	23,588	51.9	25,422	56.0	-13.5	7.8	-6.8
Built-up areas	76	0.2	271	0.6	369	0.8	256.6	36.2	385.5
Bare land	382	0.8	38	0.1	43	0.1	-90.1	13.2	-88.7
River channels	712	1.6	712	1.6	712	1.6	0.0	0.0	0.0
Wetlands	416	0.9	416	0.9	134	0.3	0.0	-67.8	-67.8
Total	45,430	100.0	45,428	100.0	45,428	100.0			

Notes: *LULC - land use and land cover; ha - hectares

No water bodies were visible at the classification scale in the Gelana watershed. Instead, the river channels were digitized from Google Earth images and masked (excluded) during post-classification analysis.

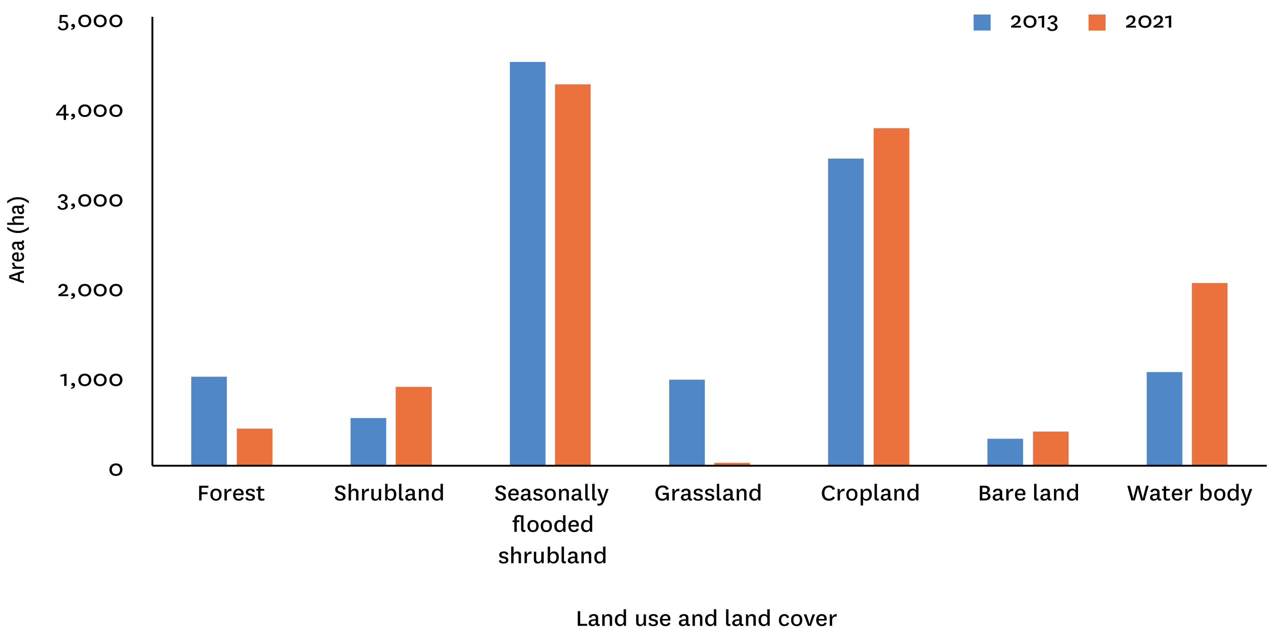


Figure 3. Area of major land use and land cover types in the Afambo watershed.

Note: ha - hectares

Basin-scale analyses indicated different results: croplands, grasslands, built-up areas and water bodies increased, while forests, shrublands, bare lands and wetlands decreased over 21 years (Table 3). Forests increased from 2010 to 2021. The results suggest that scaling up good practices across the entire basin is crucial to restoring degraded ecosystems and improving their services.

Table 3. Area and changes in major land use and land cover types in the Awash River Basin.

LULC*	Area (ha)			Changes (%)		
	2000	2010	2021	2000–2010	2010–2021	2000–2021
Forests	329,395.4	278,857.4	319,489.8	-15.3	14.6	-3.0
Shrublands	3,698,039.0	2,988,304.0	2,696,496.0	-19.2	-9.8	-27.1
Grasslands	4,472,617.0	5,014,870.0	5,356,586.0	12.2	6.8	19.8
Croplands	2.488,370.0	2,748,862.0	2,646,887.0	10.5	-3.7	6.4
Built-up areas	11,104.5	17,683.02	37,209.0	59.2	110.4	235.1
Bare land	281,074.9	235,087.7	207,142.1	-16.4	-11.9	-26.3
Water bodies	75,145.2	75,416.4	100,261.1	0.4	32.9	33.4
Wetlands	38,075.8	34,742.0	29,750.7	-8.76	-14.4	-21.9
Total	11,393,822.0	11,393,822.0	11,393,822.0			

Notes: *LULC - land use and land cover; ha - hectares

Landscape Management Practices Contributed to Adaption to Climate Change

We investigated the implications of land use and land cover changes for aboveground biomass in two of the four watersheds (Figure 4). Aboveground biomass accumulation was mainly associated with changes in forestlands and shrublands, and it has increased over 21 years (Figure 5). For example, in the Maybar-Felana and Gelana watersheds, the aboveground biomass in forestlands increased from 57 to 169 t ha^{-1} and it increased from 33 to 67 t ha^{-1}, in shrublands. In the Gelana watershed, these values increased from 84 to 163 t ha^{-1} and 36 to 76 t ha^{-1}. The results suggest the importance of restoring degraded landscapes through forest and landscape restoration measures to sequester carbon and adapt to climate change.

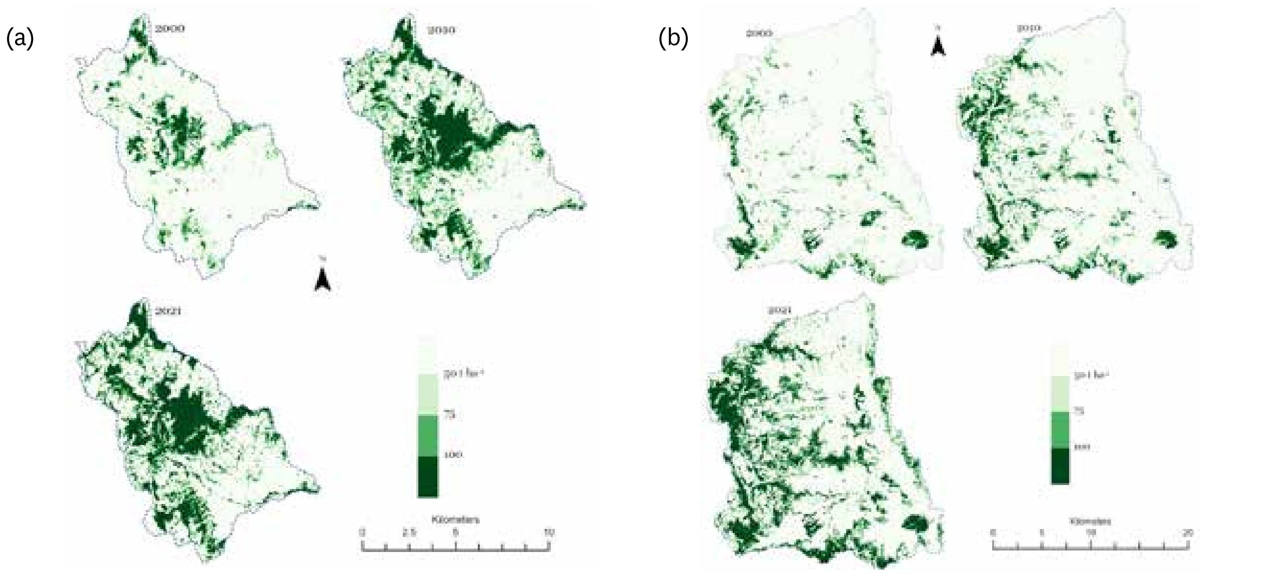
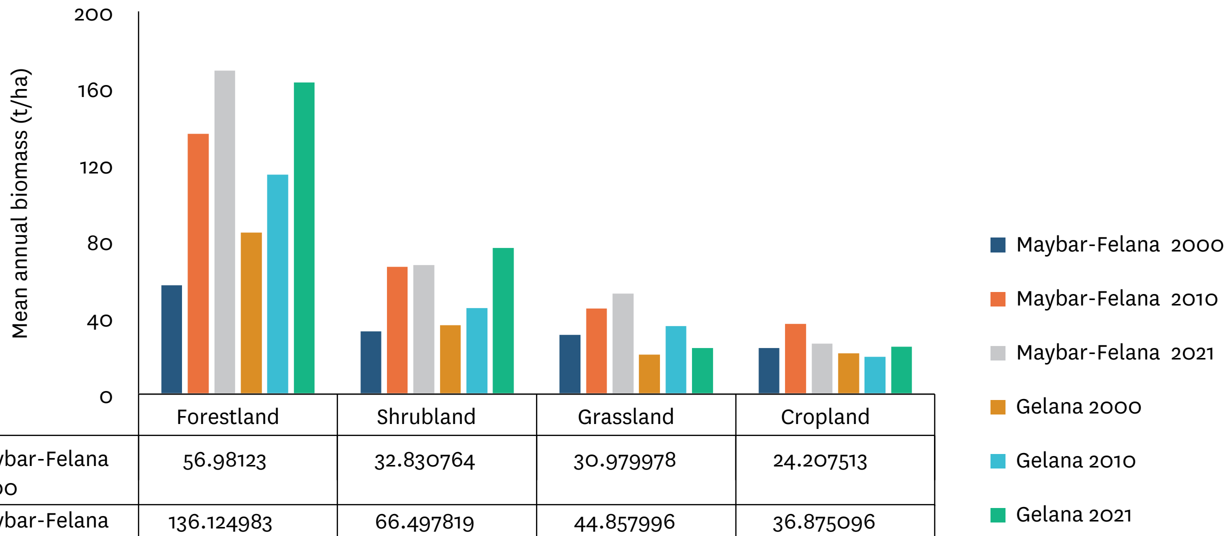


Figure 4. Spatial distribution of aboveground biomass accumulation: (a) Maybar-Felana watershed and (b) Gelana watershed.



	Forestland	Shrubland	Grassland	Cropland
Maybar-Felana 2000	56.98123	32.830764	30.979978	24.207513
Maybar-Felana 2010	136.124983	66.497819	44.857996	36.875096
Maybar-Felana 2021	169.173341	67.506367	52.614614	26.355022
Gelana 2000	84.491352	36.025856	20.717627	21.472623
Gelana 2010	114.694763	45.050886	35.652109	19.670956
Gelana 2021	162.905472	76.38113	24.149441	24.963113

Major land use and land cover

Figure 5. Mean annual aboveground biomass in Maybar-Felana and Gelana watersheds.
Note: t/ha – tonnes per hectare

Landscape Management Practices Reduced Sheet and Rill Erosion

We analyzed the spatial distribution of sheet and rill erosion in two erosion-prone catchments in Maybar-Felana and Gelana (Figure 6 a, b). In the Maybar-Felana watershed, the average annual soil loss across the five severity classes (i.e., very slight, slight, moderate, severe, very severe) varied between 1.6 and 66.6 tonnes per hectare per year ($t\ ha^{-1}\ yr^{-1}$) and in the Gelana watershed it varied from 1.3 to 130.7 $t\ ha^{-1}\ yr^{-1}$. The weighted mean of annual soil loss from sheet and rill erosion has decreased over 21 years (Figure 7).

The total annual soil loss from the Maybar-Felana watershed in 2000 was estimated at 121.9×10^3 tonnes, whereas it was estimated at 93.2×10^3 tonnes in 2021. The total annual soil loss from the Gelana watershed in 2000 was estimated at 571.5×10^3 tonnes, compared to 376.7×10^3 tonnes in 2021. This is a 23.5% and 34.1% decrease in the total annual soil loss in the Maybar-Felana and Gelana watersheds, respectively. The reductions in sheet and rill erosion during the last 21 years could be attributed to the effectiveness of LMPs in reducing runoff and soil loss.

The results suggest the effectiveness of the community-based watershed development activities implemented since 2010. This argument is further strengthened by the considerable decrease in mean annual soil loss between 2010 and 2021 compared to the observed changes between 2000 and 2010 (Figure 7).

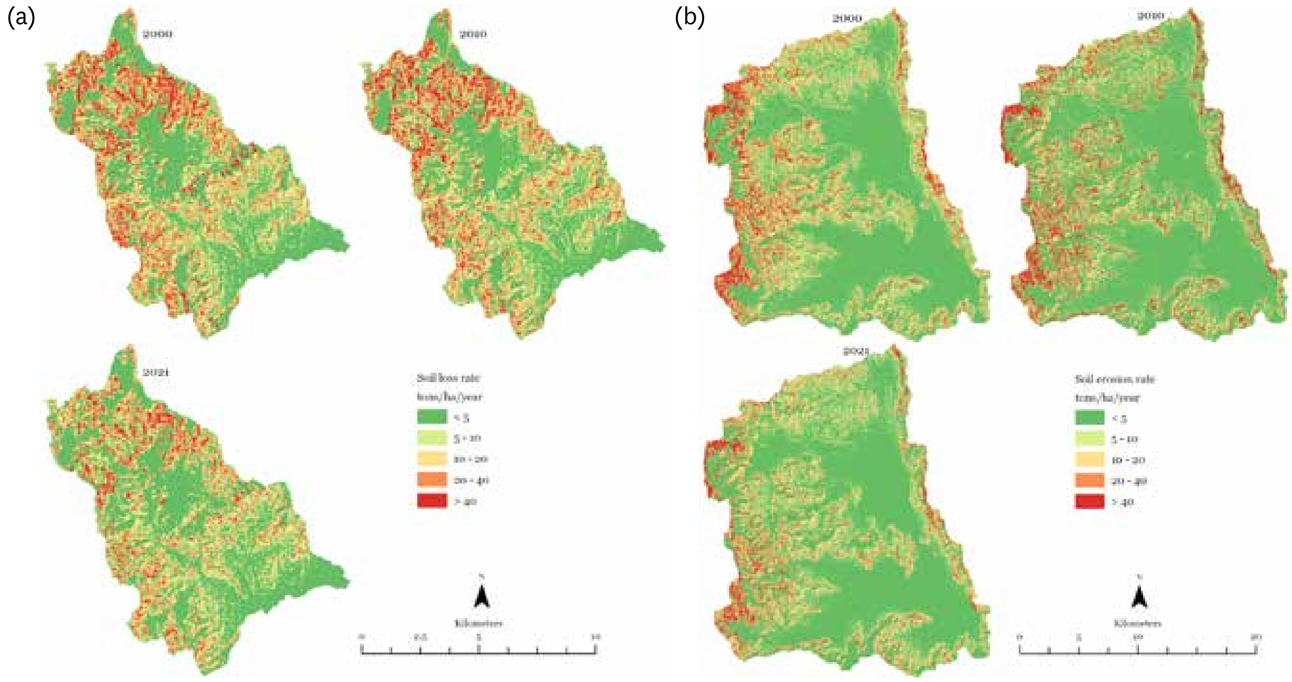


Figure 6. Spatial distribution of the severity of soil erosion: (a) Maybar-Felana watershed and (b) Gelana watershed.

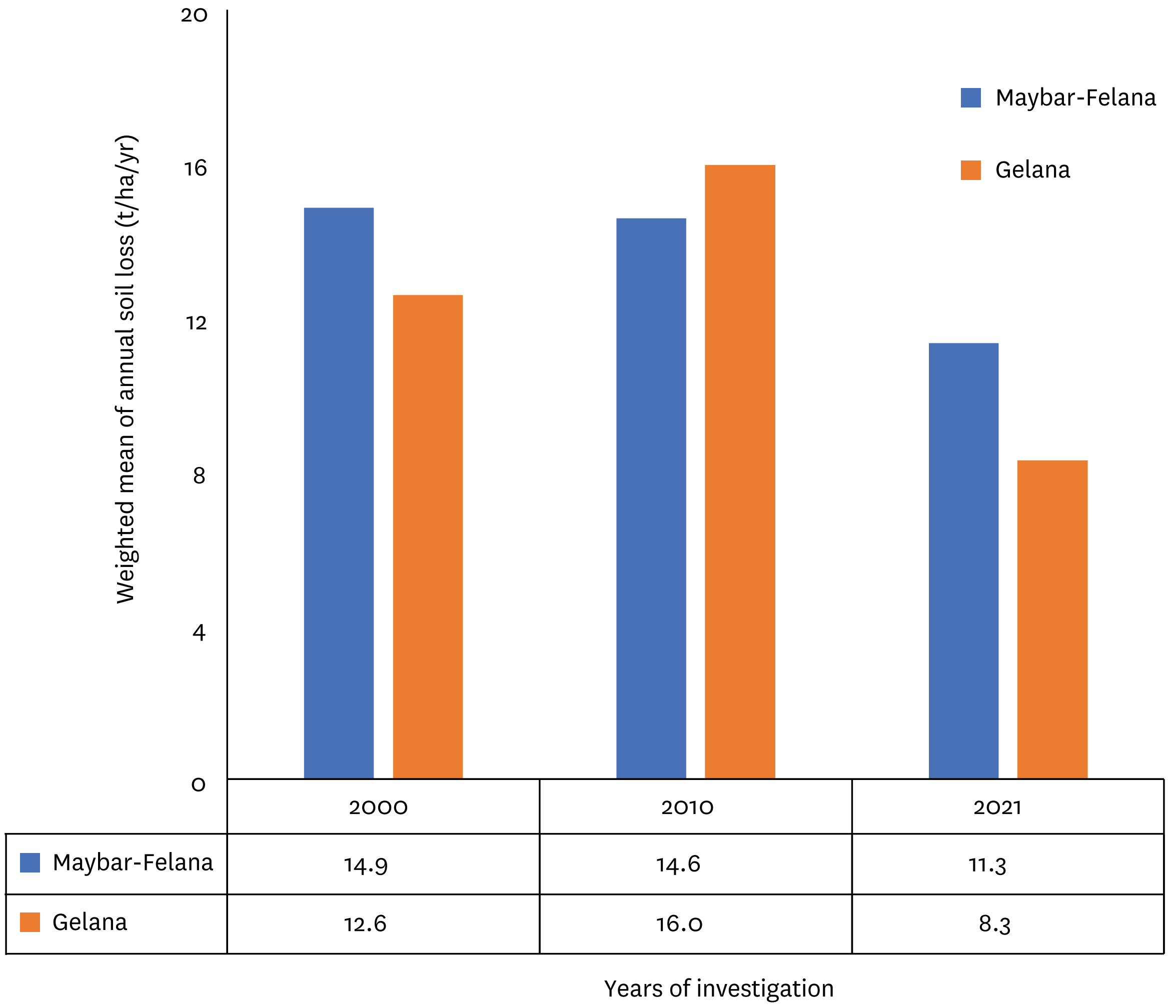


Figure 7. Estimated weighted mean of annual soil loss for the years 2000, 2010 and 2021.

The Vulnerability of Small-scale Producers Is Linked to Natural Resources Degradation

SSPs in the four watersheds are vulnerable to the degradation of natural resources. The degradation has resulted in increased floods and droughts, water scarcity, food insecurity and increased internal displacement and conflicts over resource use, putting the livelihoods of SSPs at risk. Increased incidents of flooding in the watersheds are linked to the degradation of wetlands, which had the potential to regulate floods (Figure 8).

Many environmental, socioeconomic, policy and rule enforcement, and land use and management factors have resulted in natural resource degradation. For example, point-source (e.g., expansion of recession agriculture and use of unregulated agrochemicals) and nonpoint-source pollution (e.g., runoff and sedimentation) have degraded the quality of water resources. These have reduced water-related ecosystem services, leading to increased livelihood vulnerability.

The results suggest that governance of natural resources in the watersheds is complex. Degradation in the upstream areas might be seen as an opportunity for some groups downstream because of the conflicting interests of upstream and downstream communities. Specifically, the increasing of sand which creates sand mining opportunities in downstream areas is an example of conflicting interests between the two communities. This suggests that addressing conflicting interests and power relations among the different groups of a community is crucial to reducing the degradation of natural resources and addressing the vulnerability of poverty-stricken rural communities. Managing natural resources for resilient communities and the environment is constrained by the lack of commitment to enforcing rules and regulations by different levels of local administrative bodies. One key informant stated:

> *"When free riders are caught red-handed or under suspicion while cutting trees and encroaching into protected areas, the government authorities do not sanction as required. Authorities receive bribes and release the free riders."*

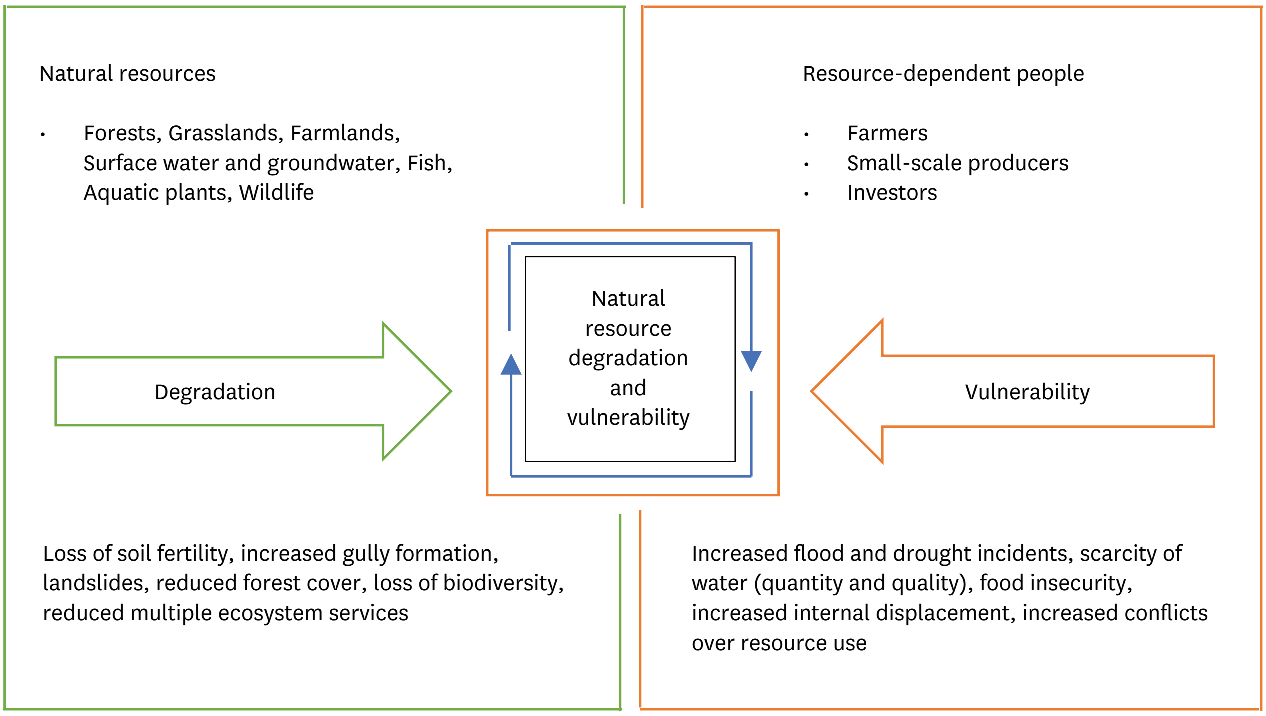


Figure 8. Natural resource degradation and vulnerability nexus in Awash River Basin, Ethiopia.

Landscape Management Practices Supported to Reduce Vulnerability

Local communities identified multiple benefit and cost factors of assessed LMPs (Figure 9). The identified benefits included:

i. environmental (e.g., improve local microclimate, conserve soil moisture or water, improve, increase, or sustain soil fertility, reduce runoff and soil erosion and restore vegetation);
ii. economic (e.g., increase wood products for multiple uses, increase income, increase livestock feed and crop production); and
iii. social benefits (e.g., reduce the impact of droughts, enable better movement of people and livestock, ensure food and nutrition security).

The respondents also mentioned several costs including:

i. environmental (e.g., cause waterlogging, increase runoff and soil loss and increase soil salinity);
ii. economic (e.g., increase damage to crop and livestock by wildlife, reduce crop production, reduce farmlands or grazing lands, high labor and financial requirement); and
iii. social costs (e.g., cause conflicts among members of a community and cause waterborne diseases).

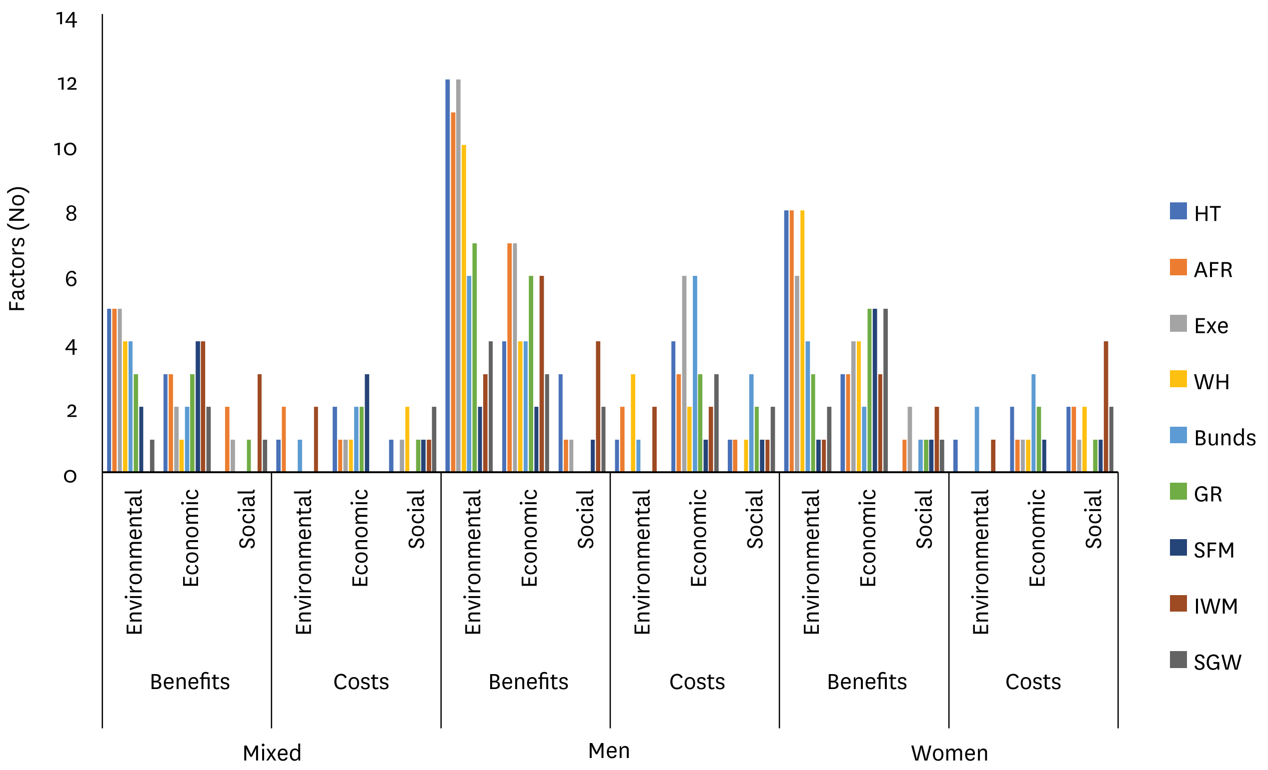


Figure 9. Benefit and cost factors of landscape management practices as identified by the participants of focus group discussions.

Notes: HT - hillside terraces; AFR - afforestation/reforestation; Exe - exclosures; WH - water harvesting; GR - gully rehabilitation; SFM - soil fertility management; IWM - irrigation water management; SGW - shallow groundwater use and management

Although the assessed LMPs had limitations, the benefits outweighed the costs of the interventions, as the mean ratings of the importance values of benefits were higher than those of costs (Figure 10). All the assessed LMPs were evaluated as positive (Table 4). This suggests that local communities have a positive opinion of the contribution of LMPs to restoring ecosystems and the services they provide.

The respondents were interested in the role of LMPs in reducing soil erosion, soil fertility degradation, and vegetation restoration. The respondents were also interested in reducing livelihood vulnerability by minimizing flooding and the impacts of droughts, improving the availability of resources, enhancing food security and building livelihood assets (Table 4).

Both environmental and economic factors were considered more important than social factors in their overall assessment of the landscape management practices. This suggests that generating short-term economic benefits is key to sustaining LMPs and associated tangible benefits and ecosystem services and reducing community vulnerability. The results also suggest improvements are needed to maximize benefits and build resilient communities and environments. Specifically, addressing the economic and social costs and sustaining LMPs is key to addressing livelihood vulnerability.

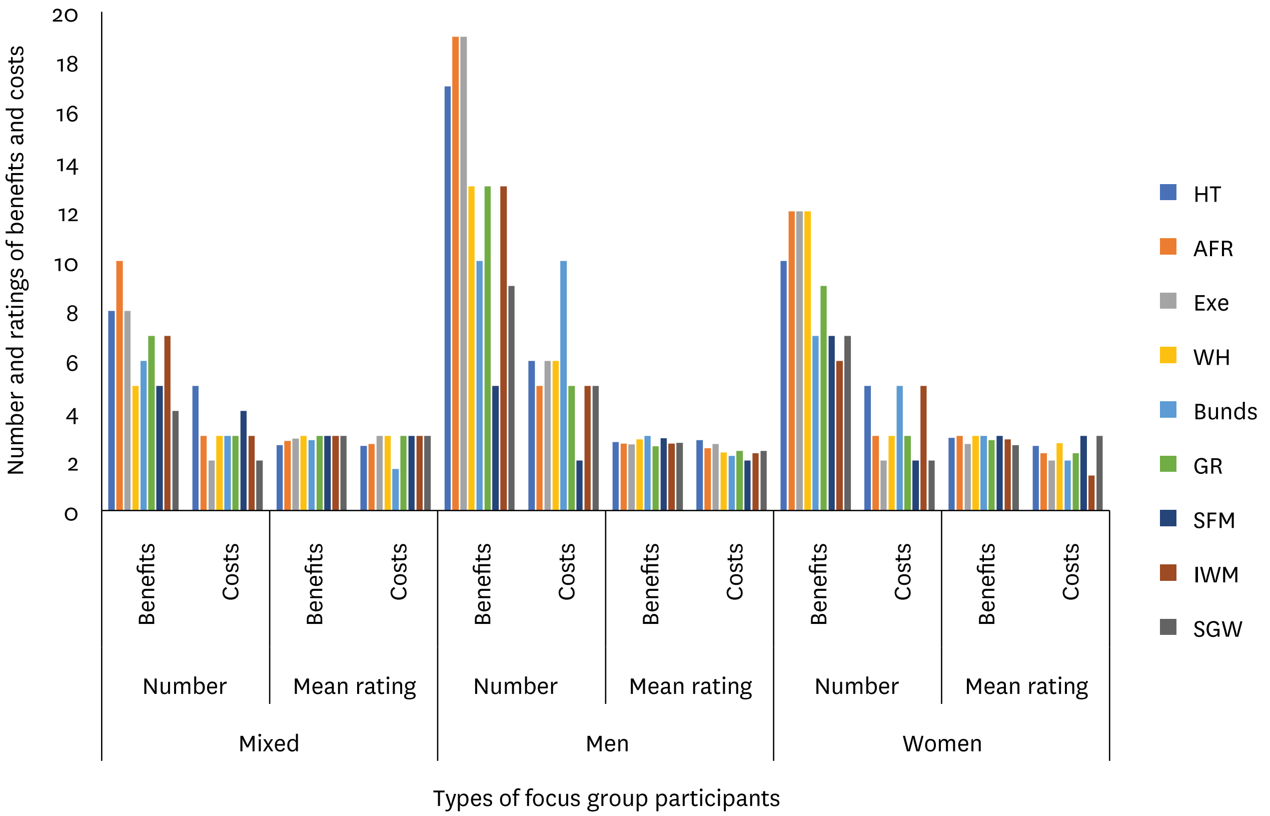


Figure 10. Number and ratings of the importance of benefit and cost factors from the perspective of the local communities.

Notes: HT - hillside terraces; AFR - afforestation/reforestation; Exe - exclosures; WH - water harvesting; GR - gully rehabilitation; SFM - soil fertility management; IWM - irrigation water management; SGW - shallow groundwater use and management

Table 4. Local community overall assessment of the assessed landscape management practices.

Practices	Contributions to improving natural resources	Contributions to reducing vulnerability
Hillside terrace	Improves in situ soil fertility, reduces runoff, conserves water, protects natural and built resources in downstream areas and enhances vegetation restoration	Improves production, reduces food insecurity and loss of livelihood assets, reduces flooding and improves resource availability
Afforestation/reforestation	Reduces runoff, improves the local microclimate, restores degraded landscapes, increases wood products and access for multiple uses (e.g., fuelwood, construction material)	Reduces flooding, improves resource availability and moderates weather extremes
Exclosures	Restore degraded vegetation, improve soil fertility and livestock feed, reduce runoff, conserve water and create job opportunities	Improve production, reduce food insecurity, improve resource availability, build livelihood assets and reduce flooding
Water harvesting	Conserves water and increases availability in dry seasons, reduces sedimentation and increases crop production	Improves resource availability
Bunds (soil and stone)	Conserve water and increase its availability in the dry season, reduce soil erosion and improve soil fertility	Improve resource availability, reduce flooding and improve food security
Gully rehabilitation measures	Convert unproductive lands into productive lands, create opportunities to develop livestock feed and high-value crops	Improve food security and resource availability and reduce flood incidents
Soil fertility management practices	Rehabilitate soils and increase production reducing the cost of inorganic fertilizers	Reduce food insecurity, improve resource availability and build livelihood assets
Irrigation water management	Diversifies livelihoods, increases production frequency, supports production of high-value crops and increases income	Builds livelihood assets and improves food security
Shallow groundwater	Increases water availability for multiple uses (e.g., homestead, livestock and agriculture)	Improves resource availability

Household-level Landscape Management Practices Are More Adopted in Mixed Crop-livestock Systems

There are various LMPs implemented at farm and watershed levels (Figure 11). The most dominant LMPs implemented at the household level are stone bunds, soil bunds and small-scale irrigation (SSI) practiced mainly in the mixed crop-livestock system and agropastoralist systems.

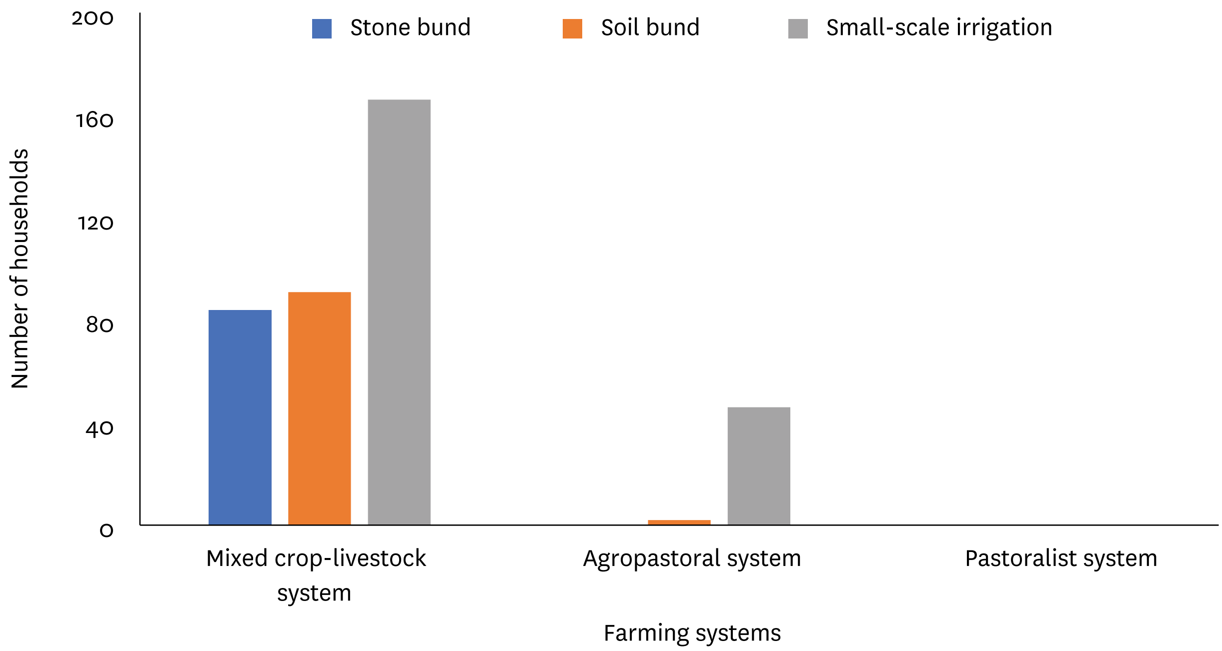


Figure 11. Agricultural water management practices widely adopted by households.

Soil and stone bunds are complements (significant at a 5% level), while small-scale irrigation is substituted with soil and stone bunds (Table 5), the latter being significant at a 5% significance level. Hence, the results show these technologies are interdependent choices. This implies that LMPs need to be promoted as a bundle to understand their relationship.

Table 5. Pearson correlation between the dominant landscape management practices.

Variables	Soil bund	Stone bund	Small-scale irrigation
Soil bund	1.000		
Stone bund	0.161*	1.000	
Small-scale irrigation	-0.074	-0.184*	1.000

Source: Household surveys conducted by authors or researchers in this study (2023).

Note: * = Indicates significance at $p < 0.05$

Contributions to Increasing Crop Yield and Income Vary with Landscape Management Practices

The change in land productivity and crop income arising from using different LMPs may require additional data. From the survey data, the study found that small-scale irrigation and other combinations of LMP technologies have higher yields (Figure 12) and crop income (Figure 13). However, the Analysis of Variance indicated these effects are not significantly different.

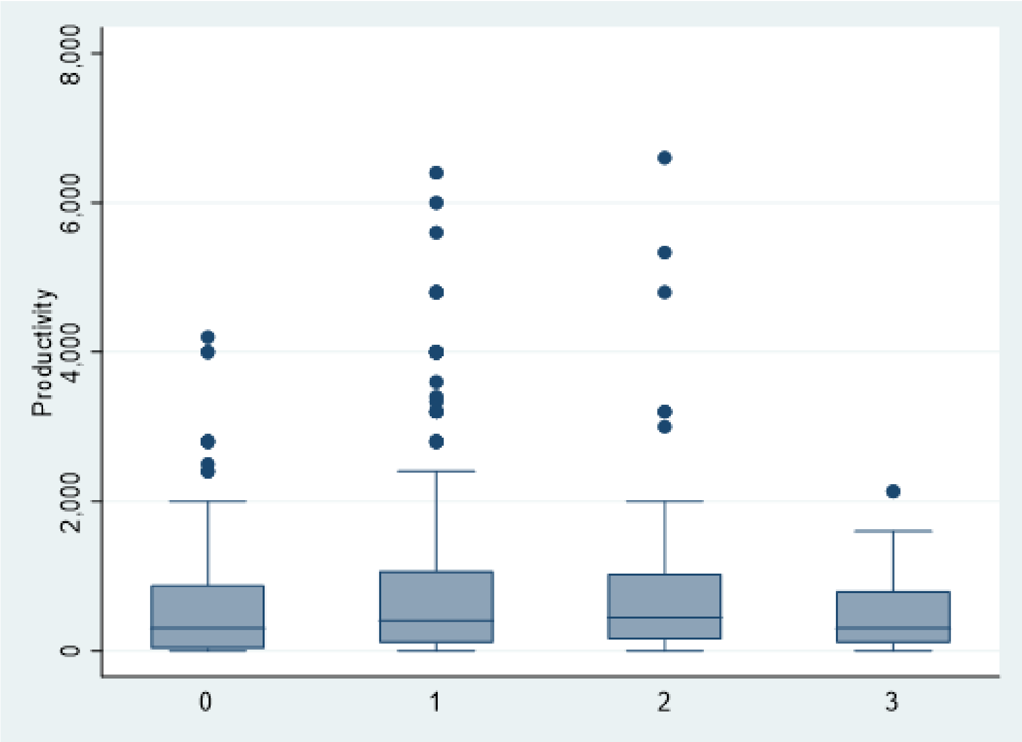


Figure 12. Landscape management practices and crop productivity (kilogram/hectare).

Source: Surveys conducted by authors or researchers in this study (2023).

Notes: 0 = no technology, 1 = soil bund, 2 = stone bund, 3 = small-scale irrigation, 4 = combination of technologies

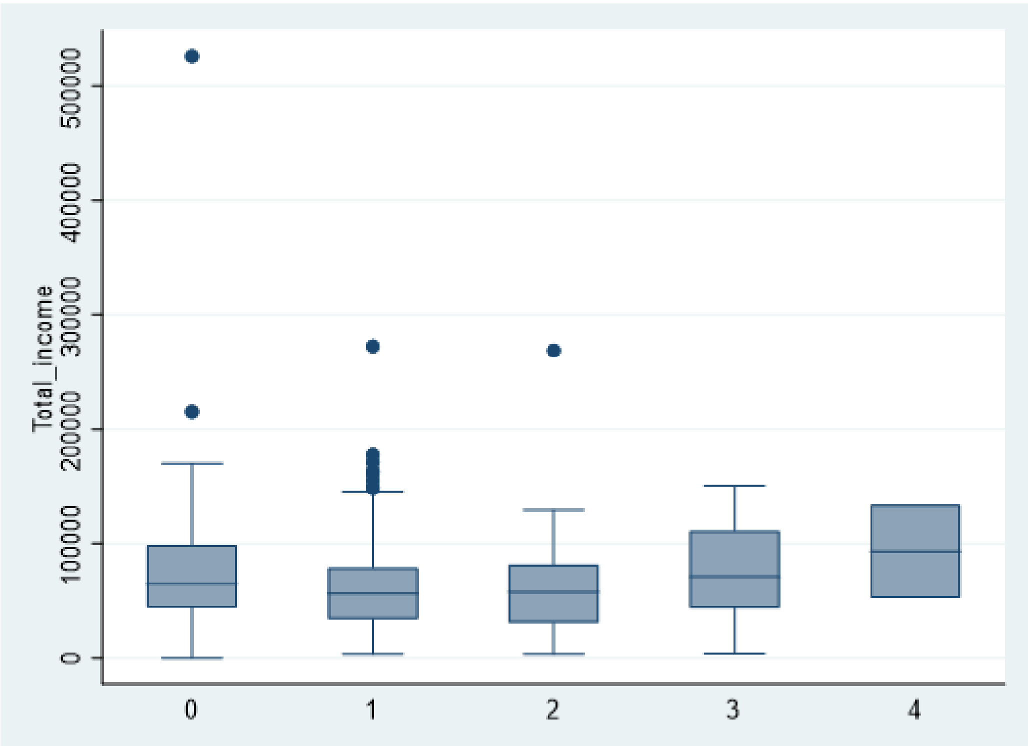


Figure 13. Landscape management practices and crop income (in ETB per hectare).

Source: Surveys conducted by authors or researchers in this study (2023).

Notes: Total income in Ethiopian birr (ETB); 0 = no technology, 1 = soil bund, 2 = stone bund, 3 = small-scale irrigation

Landscape Management Practices Had Different Contributions to Food Security

We collected and analyzed data based on standard measures of food security such as the Household Food Consumption Score (HFCS), the Household Diet Diversity Score (HDDS) and the Household Food Insecurity Access Score (HFIAS) using well-established procedures (Coates et al. 2007; WFP 2008; INDDEX Project 2018a; INDDEX Project 2018b).

The results indicated that households that adopt small-scale irrigation (SSI) are more likely to have a higher caloric intake than nonadopting households (Table 6). The average treatment effect for the treated (ATT) is the difference between actual and counterfactual impact and shows a positive association between SSI and HFCS.

The coefficient equals 10.8, implying that access to SSI increases HFCS by about 11%. The coefficient for average treatment effect for the untreated (ATU) equals 4.5, implying that if nonadopting households had access to SSI, it would have increased the potential gains of HFCS by about 5%. Similarly, households adopting SSI are more likely to consume more nutritionally diverse foods than nonadopting households.

The ATT on HDDS for practicing SSI is significant. The coefficient equals 1.7, implying that in households with access to SSI, the HDDS increases by about 2%. It also shows potential gains if households could have access. However, both ATT and ATU on HFCS and HDDS for soil and stone bunds are negative and significant. The coefficients for HFCS equal 9.7 and 3.8 for soil bunds and 15.8 and 12.1 for stone bunds. Similarly, the coefficients for ATT and ATU for HDDS are 1.3 and 0.4 and 1.8 and 0.2, respectively.

Stone bunds and SSIs have a significant impact on lowering HFIAS. The coefficients equal 9.32 and 0.5 and 22.0 and 21.0, respectively. Soil bunds increase the perception of food insecurity, with coefficients for ATT and ATU equal to 7.9 and 16.0, respectively. The results support the argument that irrigation development enhances calorie intake and dietary diversity and reduces food insecurity.

Table 6. Impact of landscape management practices on different measures of food security.

LMP	HFCS		HDDS		HFIAS	
	ATT	ATU	ATT	ATU	ATT	ATU
Stone bund	-15.81 (-14.96) ***	-12.12 (-2.71)***	-1.88 (-21.67)***	0.16 (3.29)***	-9.32 (-4.65) ***	-0.55 (0.39)
Soil bund	-9.73 (-11.36)***	-3.82 (-6.18)***	-1.28 (-11.17)***	-0.43 (-6.38)***	7.94 (1.93)**	15.74 (6.85)***
SSI	10.82 (18.56)***	4.46 (6.64)***	1.73 (26.16)***	0.74 (11.77)***	-22.01 (-25.51)***	-20.96 (-22.57)***

Source: Socioeconomic surveys conducted by authors or researchers in this study (2023).

Notes: t-test in parenthesis; *** significant at 1%, ** 5% and * 10% level of significance

LMP - landscape management practices; HFCS - Household Food Consumption Score; HDDS - Household Diet Diversity Score; HFIAS - Household Food Insecurity Access Score; ATT - average treatment effect for the treated; ATU - average treatment effect for the untreated; SSI - small-scale irrigation

Gendered Dimensions of Landscape Management Practices

Climate change unequally burdens the most marginalized

Climate change has differential impacts on individuals based on various factors, including gender and other cross-cutting disparities such as age, wealth status and livelihood activities. Children, pregnant women, the disabled and elderly people are most affected because of their limited ability to escape or withstand shocks. Those with fewer assets have less ability to withstand climate impacts or recover from droughts or floods and must rely on aid from wealthier people and the government.

Women are most affected by climate change because of their close relationship with natural resources and their greater domestic obligations. The sociocultural expectations surrounding gender roles within the home and community disproportionately increase the workload, stress level and risk of exposure for women. The workload disparity between women and men increases significantly during a drought. Women frequently travel long distances each day under harsh conditions to collect water and firewood, exposing them to a higher risk of animal attacks and injuries, illness and strain. In the Afar Region, in cases of relocation due to floods or droughts, women bear the responsibility for constructing new houses and preparing the household setting, indicating the immense burden on them. A key informant from Afambo *woreda* in Afar said:

> *"Women often prioritize the needs of their family members, including their husbands, children and elders, which adds to their stress levels. Furthermore, women are often engaged in activities that expose them to environmental risks, such as gathering firewood and fetching water. This puts them at a higher risk of being attacked by unexpected floods such as those from the Awash River."*

Respondents further elaborated that the changes in the environment due to climate change, such as unexpected rains, cause disease outbreaks. These outbreaks disproportionately affect women because they are responsible for taking care of sick household members.

Due to either droughts or floods, crop and livestock losses and difficulty in accessing water emerge as the primary impacts of climate change that threaten the income, livelihood security and well-being of pastoralists and agropastoral communities. These impacts are experienced across age, gender and wealth dimensions, which calls for comprehensive solutions to build resilience among at-risk populations.

Women have less control over resources needed to adopt landscape management practices

We assessed how resource ownership, access and use by diverse social groups shape participation in and benefit from LMPs. Access to productive resources such as land, water, livestock and credit is vital for empowering community members and fostering economic growth. However, women face severe constraints in accessing these resources as traditional customs give men the primary responsibility for controlling high-value resources. Land remains a joint resource for spouses. However, women require a husband's approval to exercise land rights, although this principle of needing consent also applies to men as per cultural expectations around mutual agreement on resource use. Although women work on the land alongside men, they have little decision-making power over using and managing land resources. Depending on the household structure, they feel their access to and control over land is constrained and depends on the will of their husbands and male relatives.

For example, in polygamous households in the Afar Region, first spouses tend to have full access to and use of land for farming and other purposes. The second and third wives' access depends on their husbands' permission. Women can become landowners and sole decision-makers in the absence of their spouses. However, this is not always true as the power to make decisions is sometimes passed on to other male household members. Women's limited decision-making power on land undermines their access to other productive resources, such as irrigation water and farm inputs, which could enhance resilience capacities. It also limits their economic productivity and participation in development programs.

In the case of Wollo, in the past, the government allocated land from communal property to young men and women. Recently, youth, in most cases, obtain land from their parents when they marry or form a new family. However, because the land has continually been fragmented among children for generations, the size of land holdings for most households is already small, and parents face difficulty in transferring land to their children.

Concerning irrigation water, only community members with farmlands have access. The schedule for water access might be during the day or at night. However, the night schedule excludes access to water for women household heads with no adult male labor, as going to the farm at night involves risk. This forces them to give the land to a sharecropper.

Regarding livestock access, ownership and use, livestock such as cattle and shoats are considered as shared property across the study sites. However, married women rarely make autonomous choices regarding selling or buying livestock without first consulting their husbands. Unlike other livestock, camels are considered to be men's property. A woman is only permitted to make decisions regarding a man's camel or other livestock type if he is deceased or if she inherited them from her family. Inherited items usually benefit all family members equally. However, custodial control remains with the named recipient, who independently directs distribution according to their discretion.

In addition to cultural norms that give men the primary responsibility for controlling high-value resources, other sociocultural factors such as polygamy and the value of assets or independent incomes introduce nuanced variations in participation levels and authority regarding resource ownership, access and use. For example, in a polygamous household, particularly in Afar, the property rights of wives differ. The first wife retains control over assets acquired before other wives joined the family. Younger wives have no rights to these assets, although they may decide on new acquisitions after giving birth. Income earned solely from individual labor, such as craft micro-enterprises, principally stays under the control of the person who generated the income. For example, women tend to have more control over low-value products such as milk and butter and small volumes of vegetables such as onions, tomatoes and kale, as well as fruits such as mangos and papayas.

Both male and female informants pointed out the difficulties they face in physically accessing infrastructure such as roads, transport and financial institutions, causing barriers to economic benefit. The lack of roads and transport options and the absence of financial institutions, particularly in Afar, severely restrict people's ability to access opportunities that could improve their livelihoods, social interactions and access to markets.

Social groups benefit differently from participating in landscape management practices

Men and women from different socioeconomic backgrounds participate in watershed- and farm-level landscape management initiatives to develop natural resources, respond to risks such as floods and droughts and support livelihoods. Participation includes activities performed collectively in communal areas and on private farmlands. Local organizations such as youth groups and women's associations, as well as leaders including religious and clan leaders (in the case of Afar), play a significant role in mobilizing diverse social groups. Women (and men) informants perceive that participating in landscape management practices provides economic, social and environmental benefits.

Economically, by acknowledging that disasters such as floods and droughts heavily affect certain marginalized populations, priority is given to these social groups in providing economic support and opportunities through landscape management initiatives. Men and women from chronically food-insecure households who are physically unfit to participate receive financial or in-kind aid (food, shelter) from local governments and development institutions. In watershed-level landscape management initiatives that have cash-for-work programs and wage employment opportunities, priority is given to men, women and youth from resource-poor households. Wage employment opportunities are usually available in soil and water conservation activities, nursery centers and infrastructure development. Constructing irrigation canals in Afar has created a new working culture for pastoralist men and women with land in the command area to work on irrigation. For unemployed young men and women in Wollo, landscape management practices have enabled them to participate in beekeeping in rehabilitated forest areas to generate income.

Specific to women, the agriculture office, in collaboration with development partners, aims to include and empower women and other marginalized groups to participate in income-generating activities by organizing them in cooperatives and associations. Associations aimed at empowering women provide them with opportunities to work together and enhance their livelihood opportunities through skills development, business activities, improved natural resource management and asserting their rights. For example, the local government and development partners in Afar encourage women to organize village savings and credit associations to help them access finance and technical training to participate in small businesses (including selling milk, vegetable farming, livestock rearing and retail sales). Another example from the Afar Region is that nongovernmental organizations provide technical and in-kind support related to rangeland management through measures such as restocking female goats and supplying livestock vaccines and medicines to assist livestock production. In the Amhara Region, the Gender and Nutrition Department promotes technologies that save women's time and labor, including fuel-saving stoves, solar lighting, biogas and water pumps.

Socially, across the study sites, marginalized social groups benefit from the longstanding traditions of mutual aid and collaboration. There is a strong communal spirit in development work. For example, in Humeydota *kebele* of the Afambo *woreda* in Afar, which is highly vulnerable to unexpected flash flooding of the Awash River, the entire community collaborates on flood preparedness, response and recovery work. Clan leaders in Afar help coordinate and facilitate such efforts. A key informant from the region said:

> *"In our watershed- and farm-level landscape management activities, youth, women and men participate. They perform public works such as digging canals, planting trees and protecting against floods. Moreover, clan leaders participate by coordinating and facilitating the entire work. In contrast, children, the elderly and the disabled will not participate. They are supported with direct assistance."*

To ensure fair access to communal resources such as irrigation water, fodder and labor, communities have implemented bylaws. For example, to ensure fair access to fodder on communal land, which is difficult to benefit all households at once, households either buy grass or feed their animals in stalls by practicing the cut-and-carry system. A specific example from a resource-poor woman from Kalu *woreda* in Wollo further illustrates this case. The woman received no direct economic benefit from her participation in small-scale irrigation activities because she did not have irrigable land. She received assistance from labor exchange group members while weeding, an activity that she could not complete alone. A quote from an elderly woman from Habru *woreda* in Wollo illustrates how women benefit from social bonds.

> *"Mostly, we do watershed and other development activities communally. We use it to form social bonds with different people and make new friends. We consult with our friends and get valuable advice that we cannot buy with money."*

Environmentally, farm- and watershed-level landscape management practices protect the soil from degradation. An elderly woman said this about the benefits of conserving soil and water:

> *"When the soil is properly protected, we can harvest a good crop. That means it has an economic advantage converted into money."*

In addition, planting trees and allowing the vegetation to recover makes the area beautiful. Elaborating on this, an informant farmer used the following metaphor:

> *"For example, if your lunch is always taken away by somebody, you will not survive. Similarly, soil is the lunch for forests. If it is continually taken away by floods, the trees will not survive."*

His message is clear and emphasizes that by performing natural resource management, the community allows the plants to grow and the vegetation to recover. Otherwise, there will be no forest.

Limited representation of women and marginalized groups in decision-making undermines their participation and access to benefits

We investigated the participation of SSPs in various decision-making processes at the household and community levels to assess their ability to engage in watershed- and farm-level landscape management practices and influence decisions. At the household level, the participation of a household member in decision-making is context-specific. Both men and women make independent decisions about routines. For other matters, decision-making at the household level generally tends to be hierarchical, but this is evolving. Unlike in the past, men or household heads include other household members in discussions, although power dynamics vary by situation.

Informants indicated changes in the engagement of spouses and other household members in decision-making driven by training and awareness campaigns. Both men and women have to discuss with their partners before going outside the village. For example, participating in new income-generating activities and going to places outside their villages for meetings, markets or training requires prior discussion with marital partners or family members due to gender norms. Due to the traditional gendered division of labor, women are solely responsible for household work, and they are assumed to prioritize their domestic responsibilities, while adult men are rarely engaged in domestic work.

Sole-decision rights are reserved for men. In principle, women can acquire full autonomous decision-making power over family matters when they do not have a spouse. However, this is not always the case. For example, in the Afar culture, the power to make decisions when a husband dies is sometimes passed on to another male household member, such as the elder son. Within the household, women rarely make decisions without male consent. This is partly driven by an inadequate understanding of the contributions women make, especially in valuing unpaid domestic work. Women have multiple responsibilities that include labor-intensive and demanding tasks such as collecting water or firewood, going to the grain mill, caring for babies, cleaning the barn and caring for the elderly and the sick. Failing to recognize and value the time and labor of women hampers their participation in decision-making processes at the household level.

At the communal level, leadership positions of mixed groups have traditionally been held predominantly by men who are rich and influential. For example, the *Dura'abba* in Afar and the *Gan geffi* in Amhara (leaders of water user associations) are meant to ensure equal distribution of irrigation water. These positions are dominated by men selected by the community. Women's lower social status and limited decision-making power mean that their needs are often given lower priority.

Although women are denied leadership positions in a mixed group, they do hold leadership positions in women-only associations. However, prevalent social norms perpetuate the idea that women are subordinate to men, and women should stay at home rather than go outside. Women are further restricted by the prevalence of early marriage (especially in the Afar Region).

The many burdens of domestic work and their limited exposure in public spaces restrict the ability of women to take on leadership roles. Unless specifically invited, women across the study sites have difficulty expressing their views because of social norms, a lack of self-confidence and experience, and the low value given to their voices.

Conclusion and Recommendations

The study assessed the biophysical and socioeconomic impacts and the gender dimensions of landscape management practices. It also investigated the links between natural resource degradation and the vulnerability of resource-dependent people and the contributions of landscape management practices to address the vulnerability of small-scale producers. The study gathered and analyzed data through household surveys, key informant interviews, focus group discussions, and GIS and remote sensing techniques. The results indicated that diverse household-, farm- and watershed-level landscape management practices were adopted in the study watersheds.

Survey results indicate that soil bunds, stone bunds and small-scale irrigation are widespread landscape and agricultural water management practices adopted at the household level. These were found predominantly in mixed crop-livestock systems. The findings indicated that properly implementing landscape management practices could improve natural resources and the services they provide.

The adopted practices contributed to reducing livelihood vulnerability by reducing incidents of weather extremes such as floods and droughts, improving food and water security, enhancing resource availability and building livelihood assets. Practicing small-scale irrigation has a positive and significant effect on actual and counterfactual impact on the Household Food Consumption Score and Household Diet Diversity Score, whereas both stone bunds and small-scale irrigation have a significant impact on lowering the Household Food Insecurity Access Score. The results strengthen the idea that irrigation development enhances caloric intake and dietary diversity, suggesting potential gains in food security for non-adopters of agricultural water management practices should they adopt them.

The vulnerability of small-scale producers due to climate change and the contribution of landscape management practices to address these challenges are gendered. Specifically, women and other marginalized groups (children, older people and resource-poor households) are the most affected by climate change. In recognition of this, government and nongovernment organizations consider the needs of women and marginalized social groups in designing and implementing landscape management initiatives. They support marginalized groups by prioritizing their participation in initiatives to empower them economically and socially while participating in natural resource management activities.

For women, these initiatives provide opportunities to participate in income-generating activities, build social capital where they can learn and share and exercise agency that enhances their resilience. Despite efforts to achieve gender equality and women's empowerment in landscape management initiatives, women and marginalized social groups remain affected and benefit less due to various factors, including social norms and limited institutional capacities. Gender norms, values and practices of individuals, households, communities and institutions hinder progress. Limited institutional capacities (such as financial and human capacities) also remain challenges.

The promotion of successful landscape management practices supports achieving Sustainable Development Goals (SDGs), particularly SDG 2 (zero hunger), SDG 5 (gender equality), SDG 6 (clean water and sanitation), SDG 13 (climate action) and SDG 15 (life on land). To maximize and sustain the contributions of landscape management practices to reducing the vulnerability of small-scale producers and achieving SDGs, the following are recommended:

- Landscape management practices should be diverse and include forest and landscape restoration measures, livestock feed development and crop-based and soil-based amendments.
- Practices should be bundled instead of promoting individual practices piecemeal.
- Planning and implementing landscape management practices should balance short-term economic benefits with long-term environmental goals.
- The selection and implementation of landscape management practices should be guided by specific goals; for example, if the goal is to ensure food security, small-scale irrigation practices might be the most viable option.
- Promoting new technologies and scaling promising technologies need to be supported by policy measures.
- The planning and design of landscape management practices need to be gender-responsive to ensure equity and inclusiveness.

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