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Research Article

Community needs-based prioritization of landscape restoration technologies in Basona-Worena and Doyo-Gena Woredas, Ethiopia

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Abstract

Land degradation in Ethiopia is a pressing issue that demands immediate attention. Although various sustainable land management options have been introduced through top-down approaches, farmers have shown low adoption rates. The objective of this research was to assess the community prioritization of landscape restoration technologies and the appropriation of ecosystem services in the Basona-Worena and Doyo-Gena woredas of Ethiopia. The evaluation of land management option tool was used to survey farmers' preferences and compare different land management options based on input, cost, perceived advantages, and potential drawbacks. Data from 64 participants revealed that farmers were interested in a wide range of benefits. However, their top three preferences were increased food supply, enhanced soil fertility, and improved water supply. The study emphasized the need for site-specific land management measures. Farmers in Basona-Worena favored terrace and bund practices, while farmers in Doyo-Gena preferred exclosure and agroforestry practices. Conversely, the propensity of terracing to attract rodents and pests, the lengthy time takes to see results from bunding, and the cost of gabions were among the shortcomings that farmers identify in conservation techniques. Terracing was the first option for supplying fundamental ecosystem services in both locations, followed by biological measures, water percolation pits, and bunds. All farmers ranked the business-as-usual option as their least preferred option because they perceived it to have limited potential for yielding desired benefits. These findings provide a robust model for informed decision-making on suitable restoration technologies, holding promise for landscape restoration initiatives in Ethiopia and similar locations worldwide.

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Introduction

The escalating deterioration of land is becoming a significant global and regional threat. Research conducted by Edrisi et al. (2022) reveals that approximately one-fourth of the Earth's land surface has experienced varying degrees of degradation. Millions of hectares of fertile and productive land undergo severe degradation, rendering them unusable landscapes (TerAfrica, 2006). This degradation significantly reduces agricultural productivity and depletes water resources, leading to a decline in human well-being (Nedessa et al., 2005). The countries of Sub-Saharan Africa are the most severely impacted by this issue (Byaro et al., 2023). In this region, Ethiopia confronts the daunting challenge of severe land degradation, manifesting in forms such as soil erosion, loss of soil fertility, desertification, deforestation, and decline in agricultural productivity (Megerssa and Bekere, 2019; Nyssen et al., 2019).

Land degradation is a serious threat to Ethiopia's ecosystem services, as it affects both the national economy and the livelihoods of residents (Gashu and Muchie, 2018). Ecosystem services, including soil fertility, crop production, water yield, carbon storage, and habitat quality, are being severely hampered as a direct result of land degradation (Hurni et al., 2015). Specifically, the loss of arable land and soil fertility due to erosion and deforestation has resulted in decreased agricultural productivity, which is the sustenance base for the majority of Ethiopia's population (Gebrehiwot et al., 2020). Reduced vegetation cover also raises carbon emissions and decreases sequestration capacity, which increases human susceptibility to climate change effects like floods and droughts (Moisa et al., 2017; Hailu et al., 2021; Muluneh and Worku, 2022).

The repercussions of soil degradation go beyond agricultural productivity. The loss of soil fertility leads to reduced crop yields, which can result in food insecurity and malnutrition (Nyssen et al., 2019). The erosion caused by land degradation can lead to the sedimentation of rivers and lakes, thereby reducing water quantity and quality (Moges et al., 2016). According to a report by the Ethiopian Biodiversity Institute (2016), land degradation has resulted in the decline of various plant and animal species in Ethiopia, including endangered ones. By disturbing the delicate balance of these vital ecosystem services, land degradation fosters a cycle of poverty and subsistence hardship, amplified by negative environmental feedback loops. Thus, conservation measures should be implemented to restore degraded land and to ensure the provision of basic ecosystem services.

Recently, a concentrated effort has been made in Ethiopia to apply soil and water conservation measures to reduce erosion. These practices include terracing, contour plowing, and agroforestry, as well as reforestation and afforestation efforts (Admassu et al., 2017; Abera et al., 2019; Desta et al., 2021; Eshetu et al., 2024). A notable example is the implementation of physical soil and water conservation measures like terracing, plantation, composting, and check dams, which have enabled the restoration of soil fertility and improved water infiltration (Adgo et al., 2013). Simultaneously, biological measures such as reforestation and agroforestry have enhanced carbon sequestration and created alternative livelihood options (Mekuria et al., 2011). Moreover, exclosure areas have substantially improved vegetation cover and productivity, thereby reinstating soil nutrient cycling and carbon storage (Aerts et al., 2009). Community participation in implementing and maintaining these practices has been instrumental to their success, demonstrating that restoring ecosystem services calls for a holistic approach involving both biophysical and socio-economic interventions. An integrated strategy that considers the ecological, social, and economic aspects of land is essential for the effective application of land restoration measures.

However, the implementation of soil and water conservation measures can face considerable limitations, rooted primarily in two key areas: the disregard for community needs and priorities in the technology selection process and a predominantly top-down approach (Wolka et al., 2018; Diop et al., 2022; Belayneh, 2023). Often, technologies implemented are generic and inadequately address specific needs considering social context, agroecology, and site-specific requirements (Adego et al., 2018; Kassa et al., 2022). As a result, these practices may not deliver the ecosystem services most required by the local communities (Reed et al., 2017). Furthermore, the top-down nature of these efforts, rather than being inclusive and participatory, fails to meaningfully address restoration initiatives on communal and private lands (Mazengia et al., 2007). This kind of strategy could render the implementations ineffectual and discourage farmers from embracing sustainable land management measures. Many attempts have been made to restore landscapes, but little is known about the best strategies, suitable locations, appropriate methods, and the constraints that arise when conservation measures are scaled up (Pistorius et al., 2017; Wiegant et al., 2023).

In the absence of this critical information, efforts to rehabilitate degraded lands with limited resources can be futile. Furthermore, the ability to argue for the facilitation of payments for ecosystem services is likewise impacted without clarity on the most effective practices (Abebe et al., 2019; Ahmed et al., 2022). Another neglected yet critical aspect lies in comprehending and documenting farmers' preferences and needs for different land restoration options. Most efforts remain influenced by top-down strategies rather than involving community participation in restoration endeavors. Insufficient dialogue around technology selection for specific areas during community restoration campaigns further exacerbates this knowledge gap. Prioritizing and promoting land restoration technologies may be challenging due to a lack of understanding of sustainable land management strategies that farmers select and the factors influencing their decisions (Derpsch et al., 2014; Yami and Mekuria et al., 2022).

The study aimed to evaluate how farmers make decisions and perceive landscape restoration measures for the appropriation of ecosystem services. It was designed to answer the following question: What factors influence farmers' decisions to accept or decline various land management options? and what do farmers perceive about land management inputs, costs, benefits, advantages, and disadvantages? The research employed a participatory field survey approach in Basona-Worena and Doyo-Gena woreda to assess the perception of farmers about land management preferences. This quantitative evidence on farmers' preferences is crucial for informing decision-making, promoting climate-smart agriculture and multifunctional landscapes, and enhancing the success and sustainability of landscape restoration efforts. Ultimately, it can contribute to improving ecosystem service provision and livelihoods. The findings carry significant implications for policymakers, researchers, and practitioners involved in landscape restoration and ecosystem service management. By gaining a more profound comprehension of farmers' perspectives and priorities, interventions can be tailored to address specific community challenges.

Materials and Methods

Description of the study area

The research was carried out in the Basona-Worena and Doyo-Gena woreda located in the central part of Ethiopia (Figure 1). Bosona-Worena woreda is situated in the North Shewa zone in the Amhara regional state, 130 km from Addis Ababa. It is located between a latitude of 9.43° and 9.94° North and a longitude of 39.25° and 39.75° East. Doyo-Gena woreda is found in the Kembata-Tembaro zone in the Southern Nations, Nationalities and People (SNNP) regional state. It is situated between a latitude of 7.27° and 7.48° North and a longitude of 37.72° and 37.88° East, 272 km southwest of Addis Ababa. For the majority of farmers in Basona-Worena woreda, rain-fed agriculture is their source of income. The level of agricultural productivity is medium. However, regular floods and land degradation pose a serious threat to farmers' aspirations to achieve food self-sufficiency. The woreda is characterized by diverse agroecological zones such as dega, kola, and woyina dega. The terrain predominantly consists of hilly and mountainous features, with a few plains scattered throughout the area. The average elevation reaches a height of 2750 meters above sea level (masl). The soil composition in Basona-Worena woreda is primarily characterized as black loam, with certain regions exhibiting a clay loam texture. This soil type provides a favorable foundation for agricultural activities. The area's average temperature is 13.3°C. The average annual rainfall is between 900 and 1,500 mm, creating suitable conditions for different crops. The agroecological setting in Doyo-Gena woreda is slightly different from Basona-Worena. The altitude in this woreda spans from 1,900 to 2,800 masl, with approximately 70% of the area classified as highland and the remaining 30% as mid-altitude. The average temperatures experienced here range from 10°C to 16°C, providing a relatively cool climate for agricultural activities. The annual rainfall in Doyo-Gena woreda varies between 1,200 mm and 1,600 mm, ensuring adequate moisture for crop growth. In terms of farming practices, both Basona-Worena and Doyo-Gena woredas adopt a mixed farming system. This approach involves a combination of animal rearing and crop production. The overall population of the Doyo-Gena and Basona-Worena woreda is 140,386 and 93,265, respectively (CSA, 2017). Since 2010, the Agricultural Bureau and the International Center for Tropical Agriculture (CIAT) have been involved in land rehabilitation projects at both locations.

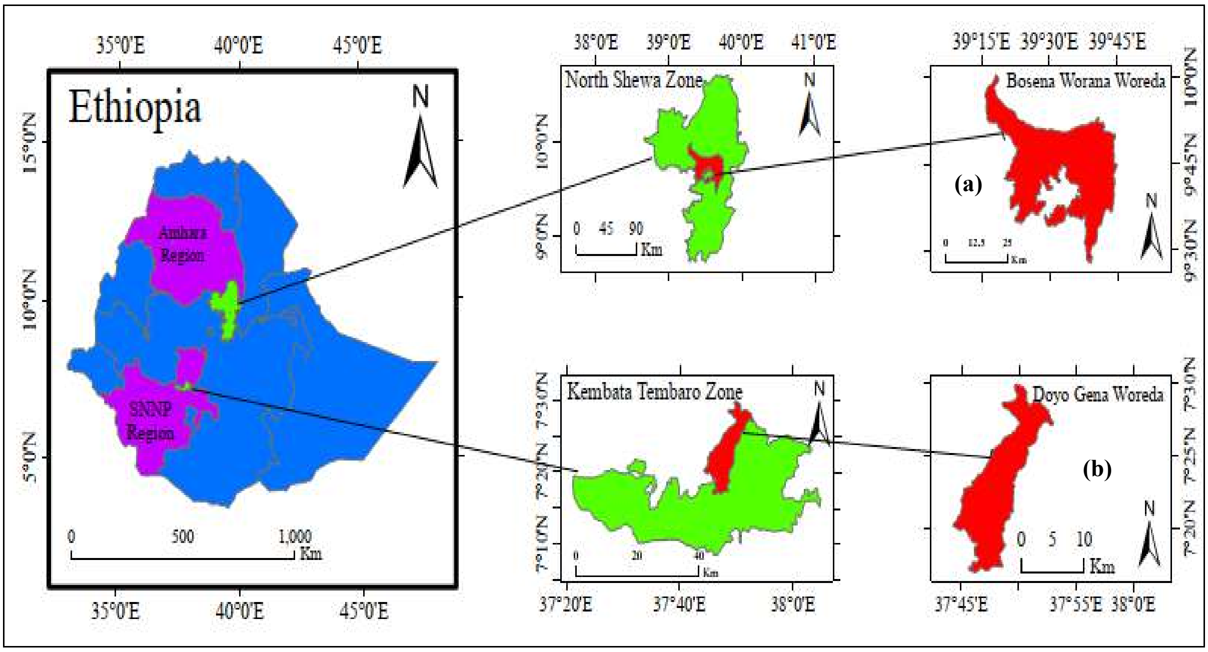

Figure 1. Location of the study areas: (a) Basona-Worena woreda in the Amhara regional state and (b) Doyo-Gena woreda in the Southern Nations, Nationalities and Peoples (SNNP) regional state.

Study design and sampling

This research employed a cross-sectional study design. The sampling technique used was multi-stage stratified purposive sampling. Four-stage stratification process was used to select participant farmers. The Amhara and SNNP regions were chosen in the first phase based on their representativeness of Ethiopia's level of land degradation. Next, considering the representativeness of the restoration technique, one woreda was chosen from each region. Basona-Worena woreda was selected from the Amhara region, and Doyo-Gena woreda was selected from the SNNP region. Then, one kebele (sub-district) from each woreda was selected to conduct a detailed survey based on the degree to which land restoration measures had been implemented. Addisgay and Lemisuticho kebele were selected from Basona-Worena and Doyo-Gena woreda, respectively. In the fourth stage, participant farmers were purposively selected based on their experience and knowledge of restoration technologies. The selection process involved consultation with local key informants and development agents. A total of 32 participant farmers were selected from each kebele. By using this multi-stage stratified purposive sampling technique, the study aimed to ensure representation from different regions, woredas, and kebeles.

Data collection

This study used a participatory Evaluating Land Management Options (ELMO) survey tool to collect qualitative and quantitative data. The effectiveness of this tool in delivering useful information about farmers' preferences, attitudes, and decisions on sustainable land management measures has been demonstrated by its widespread use across the globe (Emerton et al., 2016; Emerton and Snyder, 2018). The ELMO survey questionnaires are structured to collect information concerning the background, motivations, and preferences that influence farmers' choices for land management. To investigate farmers' preferences and the perceived benefits, advantages, disadvantages, and risks associated with various sustainable land management options, information was gathered regarding the fundamental socio-economic and biophysical conditions and characteristics that support farmers' decisions, as well as positive and negative factors that influence farmers' choices and preferences for alternative practices. These data helped to identify the drivers of land degradation, characterize farm and landscape-level interventions, assess the biophysical, socio-economic, and technological viability, and evaluate the sustainability of conservation measures. Besides, it could help to understand how the farmers perceived the effects of various sustainable land management measures on various ecosystem services, such as soil fertility status, water availability, and biodiversity.

Focus group discussions (FDGs) were conducted with the selected kebeles' representatives. These members comprised female and male households of different ages and wealth categories with the consultation of woreda and kebele leaders. Discussions were guided by a semi-structured and open-ended list of questions. The biophysical resources and their status, key livelihood sources, a preliminary list of land restoration measures, and the provision of ecosystem services were identified during the FGDs.

Following FGDs, 64 farmers participated in the ELMO interviews to collect data on the socio-economic attributes of their households, such as the number of family members, household assets, land restoration measures, land tenure/ownership, household income, and farmland size. A participant farmer was asked to rank, weigh, and score the identified land management practices and business-as-usual (BAU) options based on the following criteria: input and cost need, outcomes and benefits, advantages and positive attributes, and risk/disadvantages.

Data analysis

Three types of analysis were performed on the data obtained using the ELMO tool: qualitative, quantitative, and descriptive. The description focused on how the farmers perceived and understood the benefits, outcomes, drawbacks, risks, and trade-offs associated with various land restoration options, especially as it related to how these options impacted the provision of ecosystem services. The ELMO analysis centers around three primary questions about farmers' views of characteristics linked to various land management (LM) techniques. These characteristics include cost and inputs, which enumerate the physical materials needed by farmers for implementing the LM technique; benefits/outcomes, which detail the financial and non-financial outputs and profits generated as a result of farming; advantages/positive attributes referring to the appealing features of LM practices that make them easy to adopt and maintain; and disadvantages/negative attributes indicating the less appealing aspects of LM practices and their potential to create obstacles to livelihoods. Free material, purchased input, technical know-how, and family labor requirements for land management options were compared.

Based on the respondents' answers, a weighting and ranking analysis were performed for each of the LM options. The outcomes of the focus group discussion were analyzed qualitatively, descriptively, and logically, utilizing various data representations. A star/radar graph was used to present farmers' views about resource requirements for several LM technologies. This type of graph is a two-dimensional chart displaying at least three quantitative variables originating from the same point. Alongside the radar graph, bar graphs were also employed to indicate the proportions of farmers providing specific responses within the overall sample.

Results and Discussion

Respondent characteristics

The gender distribution of the respondents varied significantly between the two woredas (Table 1). The respondents' average age was 41 years old, and their ages ranged from 20 to 66. The average family size was 5.7, ranging from 1 person to 14 people. Both sites had small land holdings on average, with an average of 0.795 hectares per farmer. However, the two woredas' farmland categories were very different in size. In Basona-Worena woreda, the largest proportion of farmers (37.5%) had farmland sizes ranging from 0.5 to 1.25 hectares. On the other hand, in Doyo-Gena woreda, the majority of farmers (68.8%) had farmland sizes ranging from 0 to 0.5 hectares. This suggests that farmers in Basona-Worena generally had larger landholdings compared to those in Doyo-Gena. Furthermore, the majority of farmers in both woredas had a medium soil fertility status. This indicates that soil fertility is a common concern for farmers in the surveyed areas.

Table 1. Socio-economic characteristics of the respondent households.

Socio-economic attribute		Frequency (%)		
		Basona-Worena	Doyo-Gena	Total
Gender	Female	37.5	9.4	23.4
	Male	62.5	90.6	76.6
Age	20-35	31.3	56.3	43.8
	36-50	31.3	31.3	31.3
	51-66	37.5	12.5	25.0
Family size	1-7	93.8	59.4	76.6
	8-14	6.2	40.6	23.4
Farmland size (ha)	0-0.5	28.1	68.8	48.4
	0.5-1.25	37.5	28.1	32.8
	1.25-2.00	34.4	3.1	18.8
Soil fertility status	Good	30.0	26.7	28.3
	Medium	46.7	73.3	60.0
	Poor	23.3	0.0	11.7

Overall, the survey results highlighted significant differences in the distribution of respondents based on various factors, including gender, age groups, family size classes, farmland size categories, and soil fertility status categories between the two woredas. These variations may indicate differing socio-economic conditions, agricultural practices, and resource availability in the respective areas. It is crucial to consider these differences when designing and implementing interventions or policies to restore degraded land.

Cost and input requirements for different land management practices

The study findings indicated that farmers adopted various sustainable land management practices including bunds, terracing, water percolation pits, exclosure, gabion, agroforestry, and biological measures. However, gabion and agroforestry measure were applied in Basona-Worena and Doyo-Gena woreda, respectively. Purchased inputs (including hired labor), family labor, technical know-how, and free materials (resources) were the four cost and input requirement categories that had a significant impact on farmers' decision-making (Figure 2).

The input and cost requirements of various conservation measures in Basona-Worena woreda varied significantly (Figure 2a). Compared to others, the Business-as-Usual (BAU) option required very little financial outlay and free materials. High amounts of purchased inputs and specialized knowledge were required for gabion and biological measures. These practices required expensive materials and complex application procedures to implement. Drilling water percolation pits required a relatively high level of technical expertise, particularly in design and site selection. On the other hand, bunds and terraces were familiar practices for farmers, requiring little additional technical expertise and purchased inputs. These practices often utilize locally available free materials such as stone and earth. Although the average family labor was slightly higher for biological concertation measures, water collection pits, and bunds due to additional activities required during implementation, relatively similar and low labor requirements were observed for the rest of the land management strategies. Similar variation existed in Doyo-Gena-woreda's input and cost needs for various conservation measures (Figure 2b).

The BAU option also required lower inputs compared to other alternatives. Relatively low purchased materials, family labor, and specialized knowledge were needed for water percolation pit drilling. Conversely, terraces, exclosure, and agroforestry required highly purchased inputs, technical know-how, and free materials. Agroforestry, in particular, was time-consuming and requires substantial follow-up, irrigation, and weeding, necessitating technical expertise for successful implementation. Biological conservation was also perceived as demanding technical know-how, primarily related to variety selection and spacing. Similarly, farmers believed that correctly implementing bunds was somewhat difficult. The results from studies conducted in two woredas support the idea that the costs and inputs associated with sustainable land management practices can vary based on factors such as the price of the inputs, technical knowledge, availability of free materials, and labor constraints.

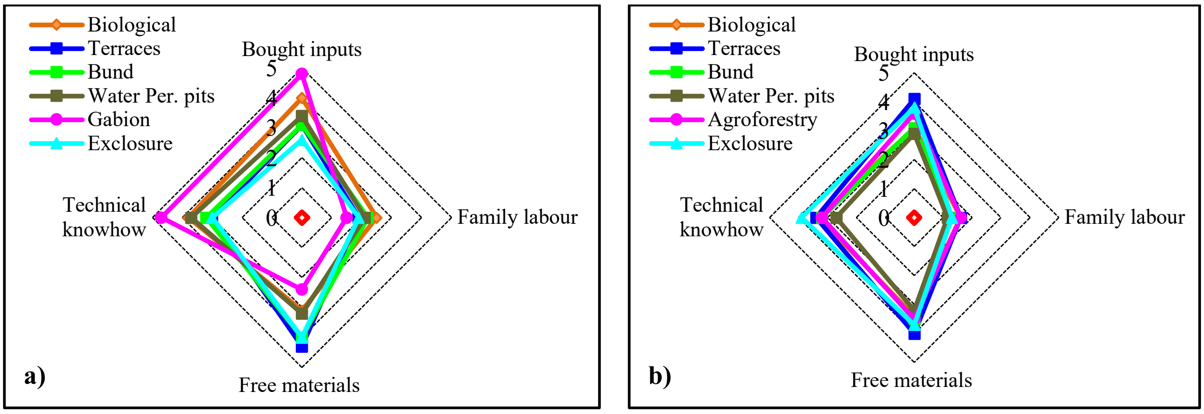

Figure 2. Input and cost requirements for different land management practices in Basona-Worena (a) and Doyo-Gena (b) woreda.

The expertise of farmers, the availability of local resources, and the supply of resources play a significant role in the execution of land restoration measures. A study by Do et al. (2020) found that the decision to choose agroforestry options was influenced by initial financial incentives, income, and input price. Adopting expensive input-intensive conservation measures was challenging for farmers with limited financial resources. The cost of gabions, for example, was perceived as expensive by farmers, which discouraged their adoption of gully rehabilitation practices. These findings align with previous studies by Gosling et al. (2021), Haregeweyn et al. (2023), and Ullah et al. (2023), who underlined the significance of input costs and availability of labor on farmers' decisions to adopt land restoration measures.

This study also highlighted the impact of a technical knowledge gap on some land management practices. Farmers lacking information and understanding of proper construction and maintenance techniques for gabions and exclosures were less likely to adopt these practices. Similarly, Dimtsu (2018), Gadisa and Midega (2021), and Gebregergs et al. (2022) studies showed that a lack of technical knowledge and awareness delayed the adoption of conservation measures. Bridging the technical knowledge gap through training programs, extension services, and knowledge-sharing platforms can help overcome this obstacle and facilitate greater adoption of land management practices (Kumar et al., 2021; Legesse et al., 2021; Somanje et al., 2021; Yifru and Miheretu, 2022; Meena et al., 2023). However, the issue of family labor was not raised as a reason for the non-implementation of conservation measures by the majority of farmers. The adoption of land restoration projects has expanded in Ethiopia due to the availability of free resources, including soil, stone, and family labor. The findings of Kessler (2006), who highlighted the importance of easy availability of materials, especially stones, in motivating farmers to implement conservation measures, are consistent with this conclusion. Farmers who had access to free materials (e.g., stones, grass, and tree branches) and could rely on family labor were more inclined to adopt practices like bunds, terraces, and tree planting. A study conducted in Ethiopia by Mekonnen et al. (2018) and Wondimu et al. (2020) emphasized the value of family labor and free materials in the adoption of conservation measures. Promoting the availability of free materials and encouraging the involvement of family labor can facilitate the adoption of these practices by reducing the financial burden on farmers and making them more feasible to implement (Mango et al., 2017; Savari et al., 2022; Yifru and Miheretu, 2022).

Weight up land management benefits and desired outcomes

This result showed the perspectives of farmers regarding the benefits and desired outcomes of implementing different land management options. Increased water availability, increased soil fertility, improved food availability, increased soil moisture, drought resistance, and increased income were the six categories of benefits identified by farmers. However, they perceived that there were differences in the extent to which various land management strategies could yield these benefits (Figure 3).

The business-as-usual option was recognized as generating a significantly lower level of desired outcomes in all categories at both study sites. The majority of farmers perceived the biological control measure significantly improved all benefit categories except for soil fertility in Doyo-Gena woreda. Previous studies have shown that biological measures, such as the use of green manures, cover crops, and organic manure, positively influence soil fertility (Govaerts et al., 2009). These approaches may offer higher benefits by improving soil organic matter, nutrient cycling, and soil structure and having less reliance on external inputs, which could be reasons why farmers in Basona-Worena preferred biological measures. On the other hand, terracing was a conservation strategy to enhance soil fertility, reduce soil erosion, and increase crop yields (Dabi et al., 2017; Hishe et al., 2017; Dimtsu et al., 2018; Gemeda et al., 2024). This may be why farmers in Doyo-Gena perceived that terraces offered higher benefits. In Basona-Worena woreda, terracing was regarded as the second-best conservation measure for improving soil fertility, improving moisture, protecting against drought, and increasing income (Figure 3a). This practice was also perceived to perform relatively well in helping soil fertility improvement, drought protection, soil moisture enhancement, and food supply in Doyo-Gena woreda (Figure 3b). This result is consistent with a study by Kosmowski (2018), which reported that the built terraces helped to mitigate Ethiopia's 2015 drought. In Basona-Worena woreda, conversely, gabion and exclosure, and to a lesser extent, water percolation pits, were given relatively low importance, particularly in resisting drought and improving moisture, soil fertility, and food supply. Agroforestry was generally assumed to have very little benefits in Doyo-Gena woreda in terms of enhancing moisture content, soil fertility, food supply, and income. The adoption of conservation practices was positively correlated with farmers' perceptions of the benefits of land management measures (Mosissa et al., 2019; Belayneh, 2023).

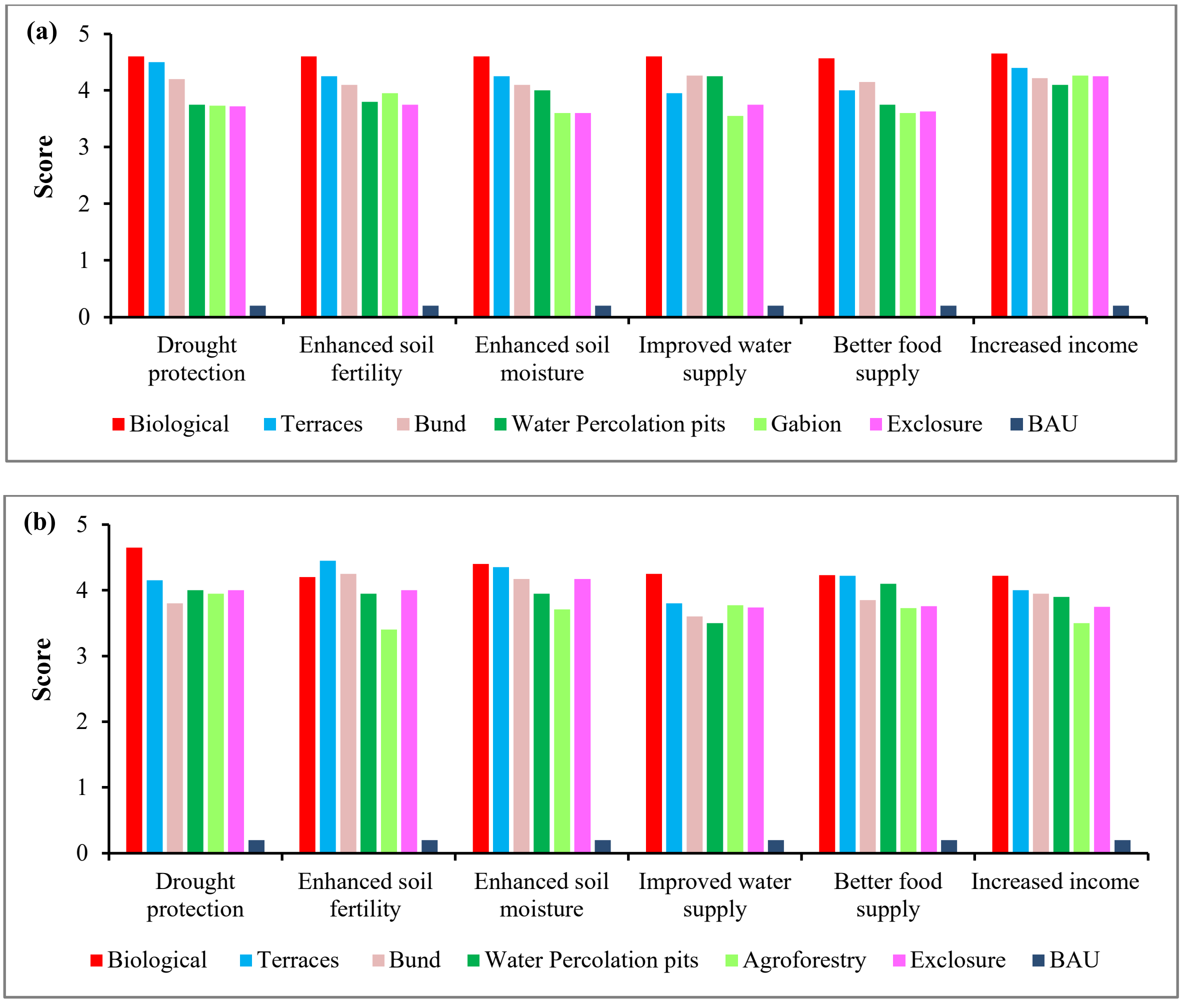

Figure 3. Desired outcomes and benefits of the various land management measures in Basona-Worena (a) and Doyo-Gena (b) woreda.

Overall, the majority of land restoration strategies, except for the BAU option, had ratings of three or above, suggesting that more implementation may be required to reap several benefits. The least advantageous conservation measures were enclosure and gabion construction. This could be due to the long-term land use restrictions during the closure of communal areas in the context of land scarcity in rural

Ethiopia, as well as the costs associated with materials and technical expertise required for gully treatment using gabion. However, the benefits of each strategy could depend heavily on local conditions, and what works well in one region may not be as effective in another (Degfe et al., 2023). Land management strategies were recognized by farmers at both locations based on how well they provided ecosystem services, which seems to align with current scientific understanding. For example, they determined that the biological conservation measure, which seems to be supported by science, was the optimum land management technique for improving soil fertility, water availability, and drought resilience. These results highlighted that farmers were well-versed in the benefits and outcomes of various conservation measures.

Rank land management benefits and desired outcomes

In both woredas, all farmers considered these ecosystem services to be of high importance and desirable to household livelihood needs (Figure 4). In Basona-Worena woreda, all ecosystem services were considered to be of high importance, but improved soil fertility and better food supply were typically thought to be the most crucial (Figure 4a), demonstrating farmers' preferences for increased land productivity and food security. Most farmers perceived that soil moisture improvement with land management practices was a less important service than others. Conversely, the majority of farmers believed that access to better food and water supplies was what mattered most to them in Doyo-Gena woreda (Figure 4b).

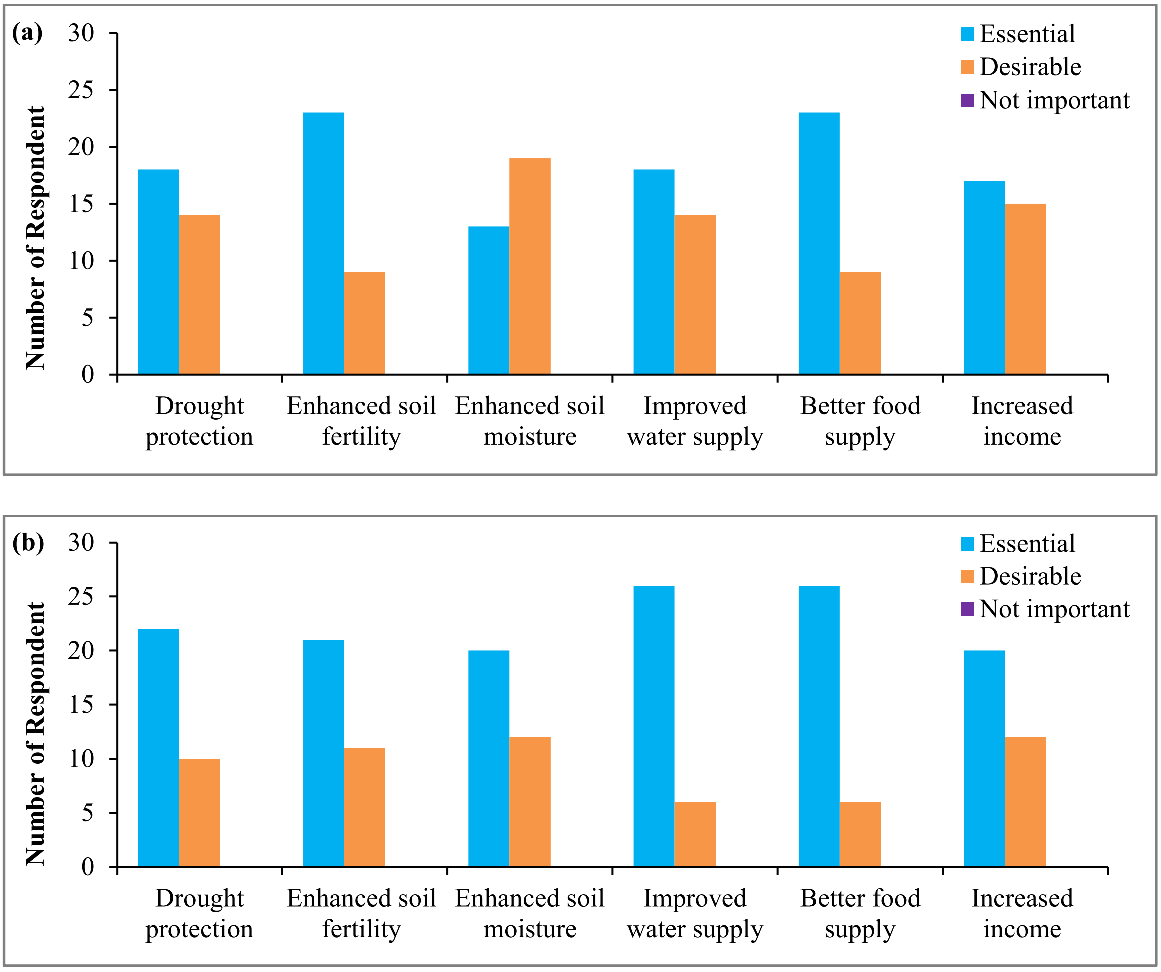

Figure 4. Farmers level of interest in ecosystem services in Basona-Worena (a) and Doyo-Gena (b) woreda.

The majority of farmers in this area recognized that drought protection and enhanced soil fertility were the second most important services that were generated from land management practices. However, only half of the farmers gave a high rank for increased income. This observation underscored that farmers valued ecosystem services that satisfy their primary needs and productivity over direct income generation (Xun et al., 2017; Zhou et al., 2023).

These results highlighted the levels of variation in priorities and needs across different agricultural communities, emphasizing how environmental factors contribute to these differences (Vignola et al., 2015; Giller et al., 2021).

Advantage and positive attributes of land management practices

Farmers categorized the advantages of using various land management strategies into four groups: filling food gaps at critical times, helping to reduce risk, and having a long-lasting impact, and requiring low upfront investment. The degree to which various conservation measures exhibited variation in these advantages and positive attributes (Figure 5). All farmers in both woredas perceived that BAU provided no advantages except for a small upfront investment by a few farmers in Doyo-Gena woreda.

All of the farmers in Basona-Worena woreda stated that the biological measure had a lasting effect and significantly helped to bridge the gap in the food supply during difficult times (Figure 5a). More than half of the farmers perceived that the contribution of exclosure to fill the food gap was minimal and that water percolation pits did not show long-lasting impacts. Most farmers ranked biological and gabions highly when it comes to risk reduction and upfront investment. On the other hand, most farmers perceived that terraces and bunds were seen as having a smaller advantage in requiring a small investment. In Doyo-gena woreda, most farmers perceived that biological, agroforestry, and terraces had a lot of contribution in filling the food supply gap during critical times, reducing risk, and providing long-lasting impact (Figure 5b). Contrarily, most farmers perceived that bund provided a low advantage in all respects. Farmers' opinions of the returns and positive attributes attached to land management technologies had a significant impact on their decisions to accept or reject these technologies (Deng et al., 2021). Teshome et al. (2014), Yigezu et al. (2018), and Shikuku (2019) further elaborated that farmers' uptake of conservation measures was influenced by their perception of the relative advantage, including economic benefits, simplicity of the technology, compatibility with their current situation, and observability of the results. Connor et al. (2020) study in the Mekong River of Vietnam found that the perception of benefits outweighing the costs was a crucial factor in adopting sustainable agricultural practices. Similarly, a study in India by Meena et al. (2010) highlighted the critical role of farmers' perceptions of the benefits and effectiveness of an innovation in its adoption. Therefore, developing strategies to enhance farmers' positive perceptions of land management technologies is fundamental for increasing their adoption rate.

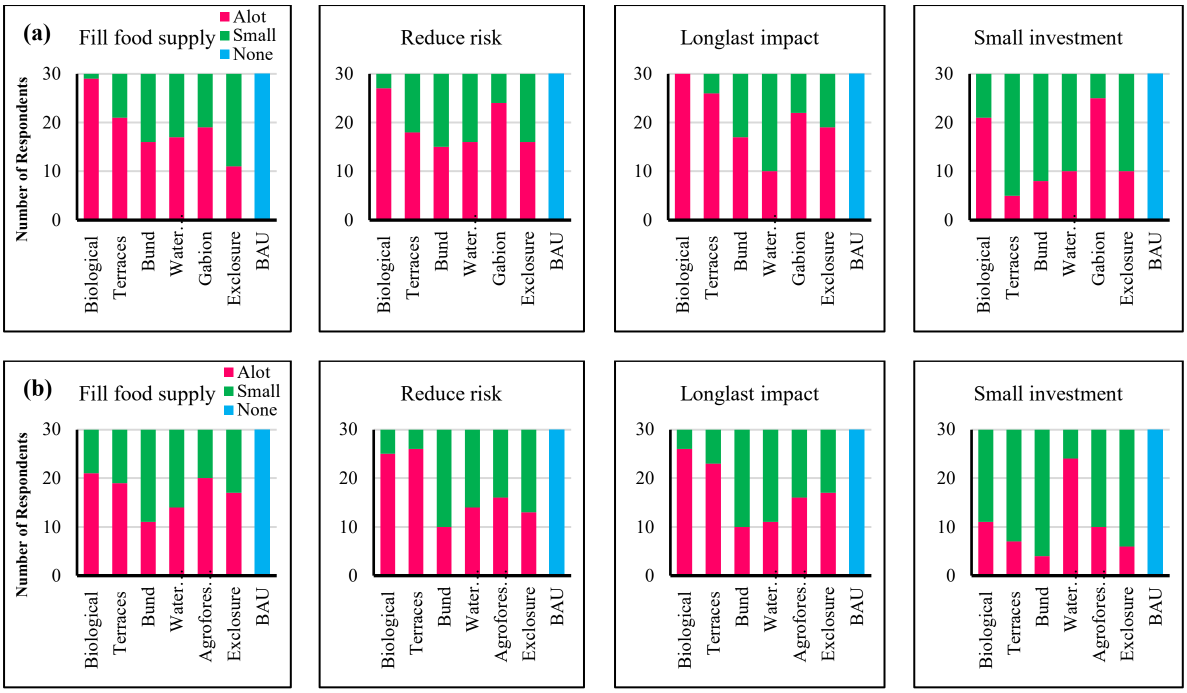

Figure 5. Advantages and positive attributes of the various conservation measures in Basona-Worena (a) and Doyo-Gena (b) woreda.

Disadvantage and negative attributes of land management options

Farmers categorized probable drawbacks and unfavorable characteristics into four groups that prevent the implementation of various conservation measures: labor-intensive, high cash demand, taking too long to see results, and introducing termites and other pests (Figure 6). In the case of Basona-Worena woreda, some farmers perceived that bunds and terracing became shelters for mice, termites, and pests, which caused damage to grain yield and fodder (Figure 6a). In comparison to other conservation measures, biological, gabions, and exclosure had a low effect on the invasion of termites and pests. However, these technologies had several drawbacks, such as large investment requirements and lengthy payback periods. Gabion and the biological measure required high cash, while bund and exclosure required less cash. Many farmers perceived that biological measures took a lengthy time to see the benefits and outcome, followed by gabion, exclosure, and terraces. Conversely, applying water percolation pits provided the expected benefits and desired outcomes quickly. Water percolation pits and biological protection measures were regarded as the most labor-intensive management methods next to gabion works, while a small amount of labor was required for enclosure and BAU. In Doyo-Gena woreda, a similar trend was observed. Only a very few farmers perceived that terracing and, to a lesser extent, water percolation pits and agroforestry had a high risk of termites and pests (Figure 6b). The other methods of land management were rated as having little to no risk of causing a termite and pest infestation.

The land management strategy with the highest financial demand was water percolation pits, followed by biological and agroforestry measures. However, bunds and BAU required the least amount of cash. Exclosures and terracing had a moderate financial requirement. Bunds required less labor than water percolation pits, which were ranked highest in labor demand, followed by terraces and biological methods. Enclosure followed biological measures, which took a lengthy time to show advantages. Regarding the amount of time needed to provide advantages, all the other conservation measures exhibited essentially comparable trends.

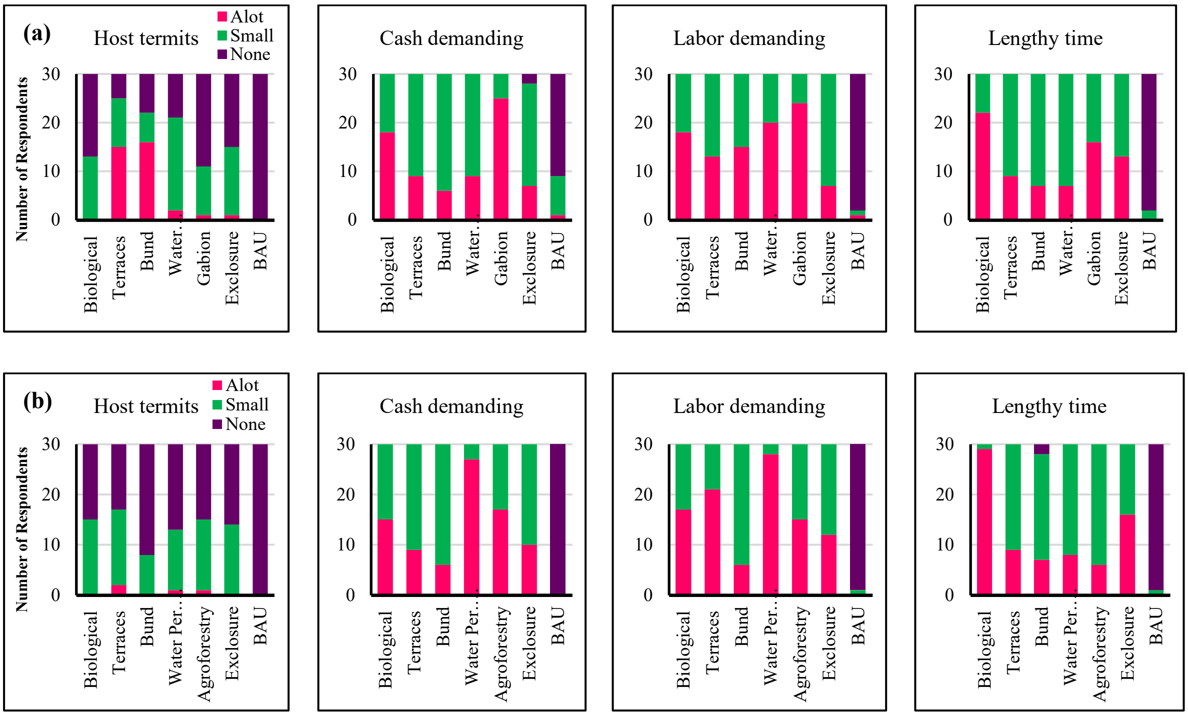

Figure 6. Disadvantages and negative attributes related to each land management option in Basona-Worena (a) and Doyo-Gena (b) woreda.

The results showed that conservation measures like gabions and biological measures were cost and labor-intensive to implement and maintain, which could be a hardship for a household with limited financial and human resources (Sileshi et al., 2019). Moreover, these measures required substantial financial investment, potentially excluding poorer farmers with limited access to funding (Takele et al., 2023). These high initial costs, coupled with a prolonged return on investment could deter farmers from adopting such technologies (Bewket, 2007). The heightened perception of risk, increased workload, and potential yield reduction associated with these practices could hinder their adoption (Adimassu et al., 2017). Physical structures like bunds and terraces could inadvertently foster habitats for pests, potentially damaging crop yield (Wordofa et al., 2020). The perceived negative impacts on farm productivity, complexity of technologies, and potential effects on current farming practices, all play in the decision-making process, affecting a farmer's willingness to adopt sustainable land management measures (Knowler and Bradshaw, 2007). In conclusion, the perceived disadvantages and potential negatives of land management technologies strongly influenced farmers' decisions, which could slow the adoption rate of such methods.

Farmers preferences inland management practices

After weighing the benefits and drawbacks of each land management strategy, farmers at both locations selected their top choices. Variations in the two sites' geography, climate/environment, and socio-economic conditions could point to minor variations in land management strategy preferences (Figure 7). At both sites, terracing was considered the most favored option over all other conservation measures, while BAU was ranked as the least preferred option by most farmers. The biological measure was the second preferred conservation strategy in Basona-Worena woreda, followed by gabion and water percolation pits (Figure 7a).

In Doyo-Gena woreda, most farmers preferred water percolation pits as the second and bunds as the third of the six land management options (Figure 7b). Exclosure and agroforestry were the least ranked next BAU at Basona-Worena and Doyo-Gena, respectively. These results align with the research conducted by Admassu et al. (2017), Aberea et al. (2019), and Desta et al. (2021), which demonstrated that farmers preferred land management measures when they believed the restoration efforts could enhance soil fertility and crop productivity. Terracing was preferred at both sites, possibly because it has been used widely in Ethiopia since the 1970s. Due to their extended experience with this land management measure, farmers may possess extensive knowledge regarding the technical know-how and benefits of this approach. The strong preference for this measure could have been influenced by this notion. Comparable research by Chuma et al. (2022) demonstrated that farmers' perceptions of the advantages of conservation measures and their acquaintance with construction techniques had a significant impact on their choices and decision-making. Surprisingly, the BAU was the least desired option at both locations, suggesting that most farmers strongly believed that failing to take remediation action would have a detrimental effect on national attempts to achieve food self-sufficiency.

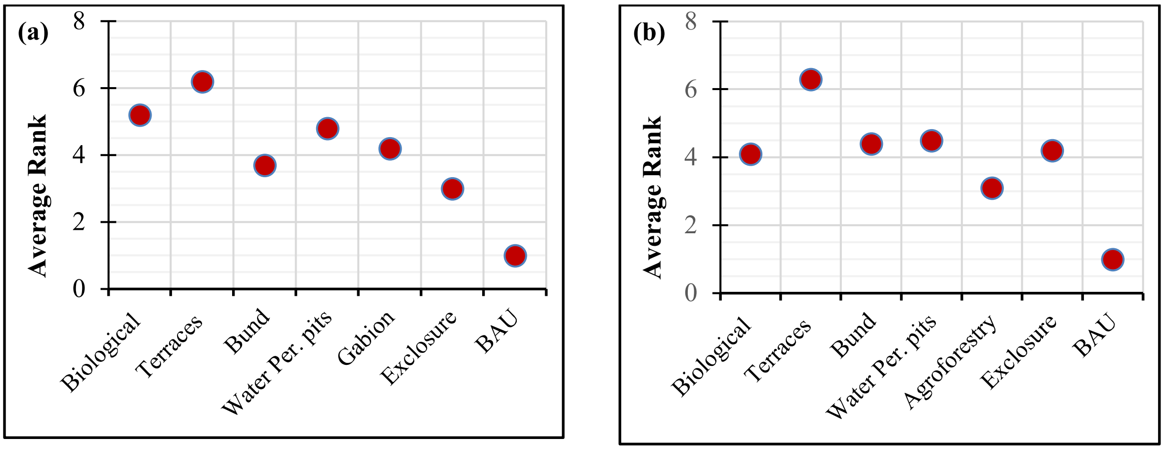

Figure 7. Land management practices as preferred by farmers in Basona-Worena (a) and Doyo-Gena (b) woreda.

Conclusions

Throughout the past fifty years, Ethiopia has undertaken numerous large-scale land restoration projects. However, not all land restoration technologies have been adopted equally by local farmers. This research examined farmers' propensity to employ sustainable land management technologies, their selection of such technologies, their understanding of the advantages and disadvantages they offer, and the obstacles that impede the uptake of restoration methods. The study found that some land management technologies had relative disadvantages, such as higher costs and increased pest occurrence, which resulted in a slower adoption rate. Other constraints included inappropriate practices in certain areas and limited technical capacity to effectively use available technologies. Farmer experiences, exposure, institutional support, and access to basic infrastructures also influenced their preferences for specific practices. Despite these challenges, the study revealed that farmers in both study sites applied technologies that were appropriate to their local context, resulting in livelihoods, productivity, and ecosystem services improvement. However, it was noted that the benefits of land restoration options accrue over a long time, while most farmers prefer short-term benefits. Limited adoption could also be due to the technologies not meeting the farmers' requirements in terms of cost, benefits, complementarity, and labor demand. The results showed that the three most desired ecosystem services were increased food supply during critical periods of food scarcity, improved soil nutrient composition, and improved water availability. The next three services were protecting drought, generating income, and improving soil moisture. There were also slight differences among districts in the choice of restoration technologies. Gabion required higher input and cost for the Basona-Worena communities, while enclosures and agroforestry required higher input and cost in Doyo-Gena. In terms of disadvantages and risks, farmers indicated that bunds and terracing attracted termites, while agroforestry was considered a risky investment due to its long-term benefits that could not be realized quickly. The least preferred land restoration practices in Basona-Worena and Doyo-Gena woredas were exclosure and agroforestry, respectively. Terracing, followed by water percolation pits, were ranked as the best options considering their costs, challenges, and benefits. Terracing was the most widely used conservation measure in Ethiopia due to growing knowledge of the benefits of terracing and its widespread application since 1970. Water percolation pits were highly preferred for their immediate benefits in supplying water for drinking, irrigation, and moisture retention. To enhance technology uptake and mitigate side effects, tailored training is recommended for farmers on restoration technology choice, application, and risk mitigation. The extension system should place greater emphasis on scaling up technologies with high impact and performance. It is recommended to prioritize technology supply based on the specific needs of each district, as not all technologies are equally important in both areas. Additionally, efforts should be made to reduce pest incidences and severity through improved technological design and the introduction of biological control methods.

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