Towards sustainable watershed-based landscape restoration in degraded drylands: Perceived benefits and innovative pathways learnt from project-based interventions in Ethiopia

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Research article

Towards sustainable watershed-based landscape restoration in degraded drylands: Perceived benefits and innovative pathways learnt from project-based interventions in Ethiopia

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ABSTRACT

Land degradation is one of the contemporary environmental challenges affecting regions inhabited by over one-third of the global population. In response to land degradation, restoration of degraded landscapes through area closure has been implemented through government and bilateral organizations for the last three decades in Ethiopia. Objectives of this study were to: i) explore the effects of landscape restoration on vegetation cover; ii) identify the perceived benefits to local communities; and 3) synthesize the lessons learnt on communities' willingness to sustain the restored landscapes. The study was conducted in project-supported restoration areas including the Dimitu and Kelisa watersheds representing the central rift valley dry lands and the Gola Gagura watershed representing the eastern dry land areas around Dire Dawa. The temporal changes in land use and land cover due to area closure integrated with physical and biological soil and water conservation measures were detected using GIS/Remote sensing techniques. Moreover, eighty-eight rural households were interviewed. The results of the study revealed that landscape restoration activities such as area closure integrated with physical soil and water conservation, and planting of trees and shrubs contributed to the significant changes in land covers of the watersheds in 3–5 years. Hence, barren lands were reduced by 35–100% while there were significant increases in forest lands (15%), woody grasslands (247–785%), and bushlands (78–140%). More than 90% of the respondents in the Dimitu and Gola Gagura watersheds verified that the landscape restoration activities improved vegetation cover and ecosystem services, reduced erosion, and increased incomes. A great majority of farm households (63–100%) expressed their willingness to contribute to different forms of landscape restoration interventions. Encroachment of livestock to closed area, shortage of finance, and the growing number of wild animals in closed area were the perceived challenges. Proper planning and implementation of integrated interventions, creating local watershed user associations, ensuring appropriate benefit-sharing and implementing innovative pathways to reconcile the tradeoffs could be considered to scale up interventions and address potential conflicts of interest.

1. Introduction

Land degradation is one of the priority contemporary global challenges affecting about one-quarter of the terrestrial area and regions inhabited by over one-third of the global population (Stanturf, 2021). Land degradation is a severe problem in Sub-Saharan Africa affecting food security (Nkonya et al., 2016). Severe soil erosion and fertility decline due to poor land use and land cover management practices have affected more than 60% of the land in Sub-Saharan Africa (Zingore et al., 2015). Socio-economic and biophysical interactions increased land degradation and its effects in low-income Sub-Saharan Africa (Barbier and Hochard, 2018).

In Ethiopia, a country with 80% of the population living in the rural area and relying on natural resources for livelihoods, varying levels of landscape degradation have been observed (Abera et al., 2019). Landscape degradation has affected about 45% of the nation's cultivated

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land, and about 23% of the land mass is severely degraded (Gebreselassie et al., 2016; Pistorius et al., 2017). The country experiences an annual degradation rate of more than 14 million hectares, equivalent to the estimated economic cost of more than US$ 4.3 billion per year (Gebreselassie et al., 2016). High population density (144 persons km-2) and large number of livestock (160 tropical livestock unit km-2) that by far exceed the optimum carrying capacity of the land have increased pressure on land, leading to widespread land degradation (Sonneveld and Keyzer, 2003; FAO, 2018). Feeding the country's 65 million cattle on the landscape and relying 95% of the energy demand on biomass could aggravate landscape degradation in Ethiopia (CSA, 2020; World Bank, 2020). Drivers including poverty, the undulating topographic nature of the cultivated highlands associated with intense rainfall, political instability, poor resource governance, weak land management practice, and expansion of cultivated land at the expense of natural vegetation could contribute to landscape degradation (Kassa et al., 2016). Arid and semi-arid areas are highly affected by land degradation causing water scarcity and associated problems.

In 2013, in Ethiopia, about 125 people obtain a living from a 1 km^2 area of land, which is expected to become 270 people per km2 by 2050 (Tongul and Hobson, 2013), which proves the need for restoration of degraded landscape. In response to the alarming increase in degraded landscapes, forests, and cultivated landscapes restorations have become a high priority on the government's agenda over the last half a century. Land restoration, as part of the natural resource and agricultural development plan, has begun in the early 1970s following the great famines, for example, in arid and semi-arid Wollo and Tigray areas (Adimassu et al., 2018; Abera et al., 2019). Since then, there have been several high-level programs and projects initiated and implemented by the government and non-governmental organizations and free labor public campaign works. Some of the projects had limited success due to its top-down approach particularly in the 1970s and 1980s, poor technical guide, land ownership issues and discontinued financial support (Abera et al., 2019). The landscape restoration activities of Ethiopia focused on farmland management (construction of bunds and *Fanya juu*, agroforestry, forage legumes, and grass), hillside treatment (area closure, constructing hillside terraces, trenches, micro-basins, tree planting), gully erosion control and restoration (check dams) and afforestation of degraded forested areas.

More recently, the government has widely implemented a community-based integrated watershed management program and community-based forest restoration activities to address the historical bottlenecks of landscape rehabilitation. In this revised approach, which focus on a more integrated institutional, social and technological innovations, attention was given to community participation, organizing the watershed users' association, and planning at a small scale (Wolka, 2015; Abera et al., 2019). Each year, millions of farmers are organized in local watershed-based organizations (watershed development teams or watershed committees) and being mobilized to work in the rehabilitation of degraded lands free of payments (Woldearegay et al., 2018). The paid and unpaid investment on soil and water conservation measures estimated to be 25 billion birr per year (Adimassu et al., 2018). Benin and Yu (2013) reported that Ethiopia is one of the six African countries that reached the Maputo Declaration target of spending 10% or more of the annual government budget on agriculture and Sustainable Land Management. Under the Bonn Challenge and AFR100 (Africa's commitment to Bonn Challenge), Ethiopia has committed the largest target to restore 15 million hectares by 2030. From 2010 to 2015, landscape restoration measures including area closure have been introduced in more than 3000 watersheds and more than 12 million hectares of land have been reported as rehabilitated (Lemenih and Kassa, 2014). Close to three million hectares of the degraded area have been under area closure and plantations are widely practiced through a green legacy (Lemenih and Kassa, 2014; Kibru et al., 2020). Adimassu et al. (2018) reported that a total of about six hundred thousand hectares of land have been under area closure every year between 2004 and 2015 in Amhara, Oromia, and Southern regions. About 14 million hectares of forest management and restoration of the degraded lands planned to achieve by 2030, showing huge investment on landscape restoration (Pistorius et al., 2017; Abera et al., 2019).

The Catholic Relief Service (CRS) has been highly supporting the landscape restoration activities in dry areas of Amhara, Oromia, and Tigray regions and Dire Dawa city administration in Ethiopia (CRS, 2008; Hebert et al., 2010; Tefera et al., 2020). The major landscape restoration activities of CRS can be categorized as i) physical soil and water conservation such as soil and stone bunds, *Fanya juu* terraces, hillside terraces, check dams, trenches and micro basins, and ii) area closure, tree planting, and grassland improvement. In most cases, interventions have been implemented by applying integrated watershed management principles, combining different suitable restoration activities in the forest, grass, and cultivated lands. The CRS attempted to restore degraded steep slopes through area closures, where construction of moisture-retaining structures and planting of tree/shrub seedlings are carried out. Bunds and *Fanya juu* are constructed on cultivated lands. In Dimitu and Kelisa watersheds of the Oromia region and Gola Gagura watersheds of Dire Dawa, the CRS has introduced a modified approach, where farmers organized in association to manage and utilize the products from closed areas in communal lands. The efforts of the CRS in landscape restoration and sustainable food security have focused on dry and dry sub-humid degraded landscapes.

The effects of landscape restoration through area closure on reducing surface runoff, conserving soil moisture, and maintaining soil fertility have been studied (Damene et al., 2013; Mekuria, 2013; YimerAlemu and Abdelkadir, 2015; Abera et al., 2021). Moreover, the effects of area closure on improving vegetation cover, biomass and biodiversity have also been reported (Mekuria and Veldkamp, 2012; Alem and Habrova, 2020; Habtamu and Elias, 2021). However, there has been limited information on the effects of area closure-based approach to landscape restoration. Limited information is available on the effects of watershed-based landscape restoration activities that involve physical, biological, and economic interventions in drought-prone and food-insecure areas. The objectives of this study were: i) to assess the landscape restoration effects on land cover/land use change in three agricultural watersheds that were rehabilitated by applying community-organizations based participatory integrated watershed management approach in semi-arid areas; ii) to identify the socio-economic benefits of landscape restoration to the rural community; and iii) to assess challenges of landscape restoration and compile lessons about community willingness to sustain the restored landscapes. The study assessed the effects of restoration activities in three drought-affected and food insecure rural watersheds of Ethiopia.

2. Material and methods

2.1. Descriptions of the case study sites

The study was conducted in three watersheds: Dimitu, Kelisa, and Gola Gagura (Fig. 1). Dimitu and Kelisa watersheds are in the rift valley dry lands while the Gola Garura is located in the eastern highlands of Ethiopia. Dimitu watershed is in Dimitu Raratii kebele (lowest administrative unit) of Ziway Dugda district, Arsi zone of Oromia regional state, at about 160 km south of Addis Ababa. It is at average elevation of 1796 m above sea level, and the annual rainfall of the area is about 780 mm (Adugna et al., 2020). Kelisa watershed, situated 280 km south of Addis Ababa, is found in Shalla Kobo kebele of Shala district in West Arsi zone, Oromia region. Kelisa area is characterized by erratic rainfall, recurrent drought, and food insecurity problems. The mean annual rainfall of the Kelisa area is about 1000 mm and the elevation is 1780 m above sea level (Dube et al., 2018). Gola Gagura watershed is near Dire Dawa town, about 500 km far from Addis Ababa in eastern Ethiopia. In the Dire Dawa, rainfall is irregular, with an annual rainfall of about 680 mm and temperature varies from 14.5 °C to 34.6 °C (Kasso and Bekele,

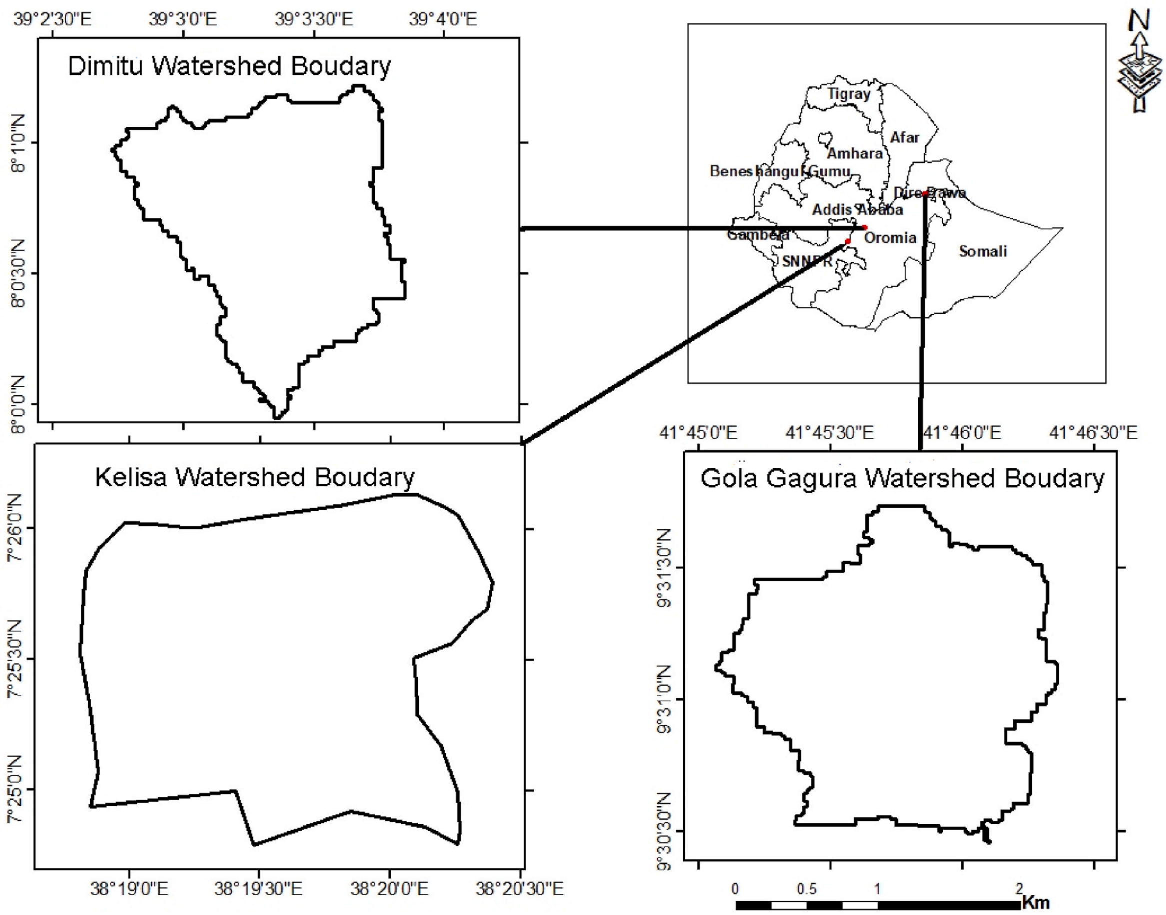

Fig. 1. Location map of Dimitu, Kelisa and Gola Gagura watersheds in Ethiopia.

2016). In all these watersheds, the local communities rely on subsistence crop and livestock farming. The areas are affected by recurrent drought. In all the three watersheds, the landscape has been deforested and currently, only scattered trees and shrubs grow on the farmlands and marginal areas. In Dimitu watershed, small lakes and rivers are available but, even though drought conditions are prevalent, community members are not using them for irrigation perhaps due to a shortage of financial capital. In Gola Gagura and Kelisa watersheds, water shortage is a challenge even for livestock and domestic use. In the watersheds, landscape restoration activities such as area closure in communal lands, construction of physical soil and water conservation measures, and tree plantings were carried out to rehabilitate deforested and degraded landscape.

2.2. Methods

2.2.1. Sampling technique and data collection

Three intervention watersheds were purposively selected as successive projects by CRS undertook integrated landscape restoration over the last five years. These watersheds were Dimitu at the central rift valley, Kelisa in the southern rift valley, and Gola Gagura around Dire Dawa representing the eastern part of the country. These watersheds had experienced severe land degradation problems and later improved through the government and CRS interventions, as claimed. The period and types of interventions were identified from CRS staff, focus group discussions, and key informant interviews.

2.2.2. Land cover/land use analysis

GIS and remote sensing techniques were applied to detect changes in the vegetation cover during landscape restoration periods. The Sentinel satellite image of two different time series data was accessed from USGS (http://earthexplorer.usgs.gov/) and pre-processed by open-source software QGIS 3.18. Hence, radiometric and geometric calibrations were undertaken for pre-processing. Radiometrically, haze and noise effects were removed from images. Furthermore, the imagery was enhanced for better classification accuracy. At the outset, the unsupervised classification method was used and classified the signature into 10 different classes. These classification results were used to estimate the total available land covers in the study area. After the field verification of land use and land cover types in the area in June 2021, training samples were created. By using training samples of the area, a supervised classification technique was implemented through a maximum likelihood algorithm.

To identify the land use/land cover changes of the area, multi-date maps were used. The prepared raster land use/land cover maps were converted to vector format to generate the change matrix. After the conversion of raster data to vector, the area for each land cover class was generated. The derived land use and land cover maps attribute was used to categorize each land-use class, to show the change of two different periods of land use/land cover maps. To identify the land cover change that occurred between the period 2016–2021 in Kelisa and Gola Gagura watersheds, the land use/land cover of 2016 and 2019 were compared with a land cover of the year 2021, independently. In Dimitu watershed, the land cover changes between 2019 and 2021 were analysed, as defined in Table 1.

To derive the change, a matrix from-to the post-classification approach was followed for each watershed. The cross-tabulation technique was used to determine the quantitative conversion from a

Table 1
Major land use/land cover types and their description at Dimitu, Kelisa and Gola Gagura watersheds in Ethiopia.

No.	Land use/cover classes	Description of each land use/cover class
1	Cultivated land	Refer to those covered by annual and perennial crops. This class includes also the scattered rural settlements which are commonly surrounded by cultivated home gardens or annual crops.
2	Forest	Areas covered by trees forming closed or nearly closed canopies and cover more than 0.5 ha and height higher than 5 m.
3	Wooded grassland (either woodland or savanna grassland)	10–40% tree cover, and continuous ground cover of grasses or other undergrowth
4	Bush/shrubland	Small woody plants are present together with dense herbaceous vegetation filling the space between patches, fragmented shrubs or bushes/herbaceous
5	Barren land	Land of limited ability to support life and in which less than one-third of the area has vegetation or other cover.
6	Grassland	Represents mainly of dense stands of medium length and tall grasses

particular land cover category to another land cover. It resulted in new thematic maps. Thus, new thematic maps were produced from the two-period maps, containing different combinations of ‘‘from–to’’ change classes.

2.2.3. Household survey, focus group discussion, and key informant interview

2.2.3.1. Household survey. In two (Dimitu and Gola Gagura) of the purposively selected watersheds, farm households were randomly selected. Accordingly, 48 and 40 rural households were selected in Dimitu and Gola Gagura watersheds, respectively, representing 15–20% of the households in the intervention watersheds. In the Kelisa watershed, the household interview was not conducted as almost all interventions were carried out on communal lands, instead, focus group discussions and key informant interviews were conducted. In Dimitu and Gola Gagura watersheds, the heads of the households allowed to respond to the structured questionnaire. Detailed information about their socio-economic characteristics and the perception on the historical land degradation and landscape restoration was assessed. The key issues that household heads responded to include socio-economic characteristics, land degradation problem and its effect, history of landscape restoration, types of major interventions (area closures, tree/fodder planting, soil and water conservation structures, water harvesting techniques, etc.), forms of stakeholders support to the intervention, decision-making processes, benefits (to livelihood and environment) and challenges of the restoration interventions, and plan to ensure the sustainability of the promising interventions.

2.2.3.2. Focus group discussion. In each of the Dimitu, Kelisa, and Gola Gagura watershed, focus group discussants representing different categories of the community (elderly men, elderly women, and youth group) were selected in collaboration with local administrators and agricultural development experts. In Dimitu, Kelisa and Gola Gagura watersheds, three, four and two focus group discussions (FGDs) were conducted, respectively, with 7–14 discussants. The semi-structured questions that used in the FGD could guide the facilitator and allowed participants to explain the land degradation, landscape restoration, activities practiced in the restoration project, the roles of different stakeholders, and decision-making processes. Moreover, the discussants commented on the observed benefits and impacts of the restoration activities, ownership and their involvements in the management and utilization of communal resources, by-laws, and legal frameworks. The discussants explained history of land degradation, opportunity and challenge, perception of adaptability and sustainability of the intervention, and modifications to the project activities.

2.2.3.3. Key informant interviews. Key informants at project sites encompass kebele and district-level administrators and experts in agriculture and natural resources at the target district. Experts and coordinators of natural resources, and coordinators of community watershed management at watershed or kebele level were interviewed. In Dimitu, Kelisa, and Gola Gagura watersheds, 4, 6, and 6 key informants were interviewed, respectively. The issues addressed during key informant interviews encompass the roles of the different stakeholders, project achievements, and challenges of the project, exit strategies, sustainability measures, and perceived pathways to improve future planning and implementations.

2.2.4. Field observation

Two transect observations were undertaken in each watershed. The transect walk and observation helped to explore the status of rehabilitation, biomass gains, the erosion features, and soil recovery. In the intervention area, the status of area closure, tree planting, cut and carry system, physical soil and water conservation measures, and challenges were assessed with transect walk-based field observations. Moreover, ground control points were taken using a GPS to collect relevant data for training and triangulation of GIS/remote sensing analyses.

2.3. Data analysis

The changes in land cover due to landscape restoration were detected by time-series image differences using remote sensing/GIS. Percentage of change in land covers at the Dimitu, Kelisa and Gola Gagura were assessed. In Dimitu and Gola Gagura watersheds, farm households' response to their socio-economic characteristics, farmers' participation in restoration activities, impacts of landscape restoration, and challenges to sustaining the interventions were summarized descriptively using the mean and percentages of respondents. Responses of key informants and focus group discussions were summarized, synthesized, and presented textually.

3. Results and discussion

3.1. Socio-economic characteristics of the respondents

The mean land holding size by smallholder farmers was 1 ha in Dimitu and 0.29 ha in Gola Gagura watersheds, respectively, (Table 2). The landholding size in Gola Gagura was lower than the mean

Table 2
Socio-economic characteristics of respondent households in the Dimitu (Rift Valley area of Ethiopia) and Gola Gagura (Dire Dawa, eastern Ethiopia) watersheds.

Attributes	Dimitu watershed, n = 48	Gola Gagura watershed n = 40
Average age of respondent, year	42.8	40.45
Sex Male, %	64.6	60.0
Female, %	35.4	40.0
Family size, number	5.4	5.7
Total land holding per household, ha	1.2	0.29
Cropland per household, ha	1.0	0.29
Individually owned grazing land, ha	0.2	0.0
Number of cattle per household	5.1	7.7

landholding size in the other dry land areas of Ethiopia (CSA, 2013; Adimassu and Kessler, 2016), indicating that the local households may tend to encroach on the neighboring communal lands (if available) in search of more land for their mixed crop-livestock farming. Despite the small land size, the size of cattle holding was higher in Gola Gagura, for which integrated landscape management is highly important as it could enable the supply of fodder on communal and private lands. Grazing on communal lands, cut and carry practices from closed area as well as crop residues support the livestock feeding as the private land holding is small. The family size was 5.4 and 5.7 persons per household in Dimitu and Gola Gagura watersheds, respectively, which is slightly greater than the national average (5.1) for the rural areas (CSA, 2016).

3.2. Farmers perceptions on landscape restoration

The focus group discussants and key informants in the Dimitu watershed agreed that the introduced landscape restoration practices are important to restore the degraded landscapes (Table 3). According to the local community, e.g., in the Dimtu watershed, the landscape was severely degraded due to the loss of natural vegetation in the upstream areas and improper land management in the cultivated hill slopes for the last 25 years. Before the implementation of the restoration activities, in Dimitu and Kelisa watersheds, the landscape was severely degraded to the extent that bedrocks were exposed on sloping lands leading to severe surface runoff and downstream flooding, thus, causing severe damages to the cultivated, grazing, and settlement areas.

Landscape restoration activities such as area closure, and physical soil and water conservation (trenches/deep trenches, micro-basins, soil, and stone bunds) were among the widely implemented physical and biological practices (Table 3). Area closure could reduce human and livestock pressure on the landscape for enhanced regeneration of different plant species. Mekuria et al. (2016) and Alem and Habrova (2020) reported area closure as an important component for rehabilitating degraded landscape. As perceived by farmers and observed in the field, the soil and water conservation measures were widely introduced. These practices could control surface runoff and improve soil water storage and enhance plant growth in degraded semi-arid areas. Soil and water conservation-based landscape restoration enhances the natural regeneration of plant species, thus, as result majority of households realized natural vegetation regenerations. In addition, planting indigenous and introduced woody species was carried out in the landscape restoration efforts. Implementation of water harvesting measures, exotic tree species planting, and growing legumes were more practiced in Gola Gagura than Dimitu due to water scarcity and associated challenges (Table 3).

Table 3
Farmers' responses on the landscape restoration activities in the Dimitu (Rift Valley area of Ethiopia) and Gola Gagura (Dire Dawa, eastern Ethiopia) watersheds.

Questions responded by the farmers	Percent of respondents who responded 'yes' in the study sites	
	Dimitu watershed, n = 48	Gola Gagura watershed n = 40
Area closure implemented	100.0	100.0
Physical SWC implemented	100.0	100.0
Grass and trees regenerated after area closure	100.0	95.0
New and indigenous species of grasses introduced to area closure	100.0	92.5
Exotic trees and bushes introduced and planted	16.7	62.5
Water harvesting structures (micro basins, ponds, trenches, etc.) introduced	16.7	100
Legume species introduced	0.0	92.5

In Dimitu and Gola Gagura watersheds, about 80% of households did not make financial contributions during the landscape restoration (Table 4). The project sponsored by the CRS covered the direct payments for skilled labor and purchase of materials such as farm tools, metal meshes for rehabilitation of large gullies, and purchase of planting materials. The focus group discussants and key informants in the Dimitu and Kelisa watersheds also confirmed that the CRS project has provided financial support for capacity-building events such as training, and purchase of farm tools and tree seedlings. The government also provided farm tools, tree seedlings and grass cuttings through the district office of agriculture and natural resources. After seeing the short-term effects of the landscape restoration efforts, the communities in Dimitu and Gola Gagura watersheds were willing to contribute labor, money, and materials for landscape restoration, implying a positive view of the community perhaps due to the observed positive effects and benefits of recent interventions (Table 4). The focus group discussants in Dimitu, Kelisa and Gola Gagura watersheds indicated that the local community contributed free labor, as part of the government-initiated campaign work for tree planting and construction of physical soil and water conservation measures such as bunds, trenches, and micro-basins. In the studied watersheds, restoration of the degraded landscape is initiated and driven by government-led campaign and NGO-supported projects/programs. Lemenih and Kassa (2014) reported that most landscape restoration activities in Ethiopia are driven mainly by aid agencies, at the beginning, communities have little or no involvement in investment and decision-making. This implies that communities are reluctant to participate and contribute unless they witness benefits generated out of the interventions and thus essential to design incentive strategies at early stage of the restoration interventions.

Many respondents in Dimitu and Gola Gagura recommended that communities should continue protecting the landscape restoration activities after the projects are phased out (Table 4). To sustain the interventions and ensure ownership of shared resources, a great majority of respondents in Dimitu and Gola Gagura watersheds recommended participation in decision making, labor contribution, and availing farm

Table 4
The participation and contribution of local communities to the landscape restoration activities at the Dimitu and Gola Gagura watersheds in 2021, Ethiopia.

Questions responded by the farmers	Percent of respondents who responded 'yes' in the study sites	
	Dimitu watershed, n = 48	Gola Gagura watershed n = 40
Contributed money to the landscape restoration works	18.8	17.5
Participated in repairing of the constructed physical structures	12.5	100
Participated in the protection of the restored areas from destruction by animals/humans	14.6	100
Protection and benefit sharing of closure has challenge	33.3	72.5
Local communities should have decision role	100.0	92.5
Local communities should contribute labor during the implementations	100.0	95
Local communities should contribute in kind for the implementations of landscape restoration practices	100.0	72.5
Local communities should contribute in money for the implementations of landscape restorations	100.0	62.5
Local communities should participate better in the management and prevention of the restored landscapes	100.0	97.5
Local communities should benefit better from the restored landscapes	100.0	95

tools for landscape restoration. This is a great opportunity to scale up landscape restoration as degradation has been a widespread problem in the country. Most respondents in Dimitu watershed believed that they did not strive sufficiently to protect the landscape restoration activities such as area closure and bunds from damage, e.g., by livestock. This could be associated with benefit sharing issue as major interventions are in the communal lands. For instance, many households within the watershed have participated in landscape restoration activities, but only watershed users' association members, who are mainly the poor households that supposed to benefit from the scheme of Safety Net Program and associated activities, were directly benefitting from the selling grass that grew on communal lands. Although the local communities who are not members in the watershed associations were buying fodder in a relatively lower price than the price set for communities coming from outside the watershed, they were not satisfied as they did not participate in setting the price. This kind of non-inclusive decision-making arrangement affects the perception and interest of communities to play roles and ensure sustainability of restored landscapes. The majority of the respondents (>90%) also indicated that they should have a decision role in landscape restoration including the identification of interventions and benefit-sharing gained from restored communal lands. Given the fact that area closure prohibits direct collection of grasses and fuel woods from the restored communal lands, resource-sharing modalities should be undertaken upon real community participation through negotiations to reduce conflict of interest between community members.

3.3. *Short-term effects of landscape restoration on land use/land cover changes*

The results of land use/cover analyses revealed that barren lands could be covered by vegetation in 3–5 years after the restoration of the degraded dry lands (Table 5; Fig. S1). In Dimitu watershed, with a classification accuracy of 81%, the watershed was categorized into four classes viz., barren, cultivated land, bush, and wooded grassland in 2019 (Table 5; Fig. 2). The cultivated land had the largest coverage, 71%, as it is widely practiced in upstream and downstream of the watershed (Fig. S1). The coverage of cultivated lands increased by 7% between 2019 and 2021 that was mainly gained from the bush and barren lands that rehabilitated after soil and water conservation activities. Three years after the restoration of the watershed in Dimitu, all the barren lands have been covered with vegetation (Table 5). The main increases (785.8% increment) was observed in wooded grasslands (Table 5) which is a promising change due to the increased availability of fodder for livestock which supported the livelihoods of the community. This is essential to support fodder supply through cut-carry practice particularly in areas where the private land holding is too small to allocate for grazing (Table 2). Restoration brings change in the grazing practice, shifting from free grazing to cut and carry practice with equitable benefits. The barren lands that have been in upslope areas are protected from human and animal interventions through area closure and implementations of water conservation structures such as micro-basins and trenches that support increasing water availability for both natural regenerations and growth of plants (Figs. S1a and S1b). The intervention could recognizably restore soils and vegetation of the landscape within three to five years. Mekuria et al. (2016) also reported improvement of vegetation and soil in 1–7 years area closure of the semi-arid northern Ethiopia.

In Kelisa watershed, the land cover classification was done with an accuracy of 85%. The watershed was classified into five different land cover/land use classes: viz., cultivated land, grassland, bush land, barren, and forest (Table 5). Cultivated land covered about 65% of the watershed in 2016. In this watershed, bush and forest lands increased by 140% and 15%, respectively, while barren land reduced by 37% between 2016 and 2021. The barren land has been converted mainly into a better vegetation cover including forest lands (Table 6). The decrease in grassland could be due to ecological succession that changed it to relatively woody species dominating land cover types such as bushland, particularly on communal upslope areas where area closure and soil and water conservation structures were widely implemented (Table 6). The observed decrease in herb and grass species under closed area through time due to increased woody species could have negative implication on feed availability for cattle, which would require adjusting management practice. A research by Mekuria and Veldkamp (2012) also reported increased area coverage of woody vegetation with the increasing age of the area closure in northern Ethiopia.

In Gola Gagura watershed, restoration interventions resulted in a 35% reduction of barren lands and increased the wooded grassland and bushland by 247% and 78%, respectively, in five years. When the restoration started in 2016, the largest area of the landscape was covered under barren land, which was more than half of the total area of the watershed (Table 5). After five years, the restored landscape had grassland as a new type of land cover mainly due to conversion from barren lands and cultivated lands (Fig. S1).

The land cover change analysis over years result dictated that the possibility of converting non-productive landscapes such as barren lands in the dry lands to productive form through appropriate landscape restoration interventions in 3–5 years. The trend of land cover changes is common across the study sites mainly in the semi-arid areas where woodlands and bushes are best adapted land use types after landscape restoration. Generally, the restoration efforts demonstrated that there is an increase in natural vegetation and a decrease in degraded or barren lands as well as a decreased rate of conversion of natural vegetation land uses to cultivated lands. A similar study on restoration interventions at Aba Gerima watershed around Bahir Dar, northwest Ethiopia, have also indicated that restoration of barren lands contributed to the increase in natural vegetation and a declining rate of increase of cultivated lands (Gumma et al., 2021). This restoration intervention would benefit the local community through resource availability and improved environmental quality for production as the land cover changes can have many ecosystem effects (Mekuria et al. (2021). Studies in dry lands of eastern Africa reported the positive benefits of landscape restoration on ecosystem including vegetation and soil (Nyberg et al., 2015; Mekuria et al., 2016; Winowiecki et al., 2018). Restoration studies also reported

Table 5
Land use/land cover change in Dimitu (2019–2021), Kelisa (2016–2021) and Gola Gagura (2016–2021) watersheds, Ethiopia.

NO.	Land use/cover classes	Dimitu			Kelisa			Gola Gagura		
		2019, ha	2021, ha	Change, %	2016, ha	2021, ha	Change, %	2016, ha	2021, ha	Change, %
1	Cultivated land	1914.8	2047.6	6.9	359.4	354.7	−1.3	94.7	53.4	−43.6
2	Grassland	0	0	0	40.5	0	−100	0	7.4	
3	Wooded grassland	40.3	357	785.8	0	0	0	19.9	69.2	247.7
3	Bushland	526.4	285	−45.8	45.4	109.4	140.9	64.8	115.7	78.6
4	Barren land	208.1	0	−100	64.7	40.8	−36.9	189.9	123.6	−34.9
5	Forest	0	0	0	34.7	40.0	15.3	0	0	0
	Total	2689.6	2689.6		544.7	544.7		369.4	369.4	

Note: The negative sign in change (%), implies in a land use/cover decrease when compared with baseline.

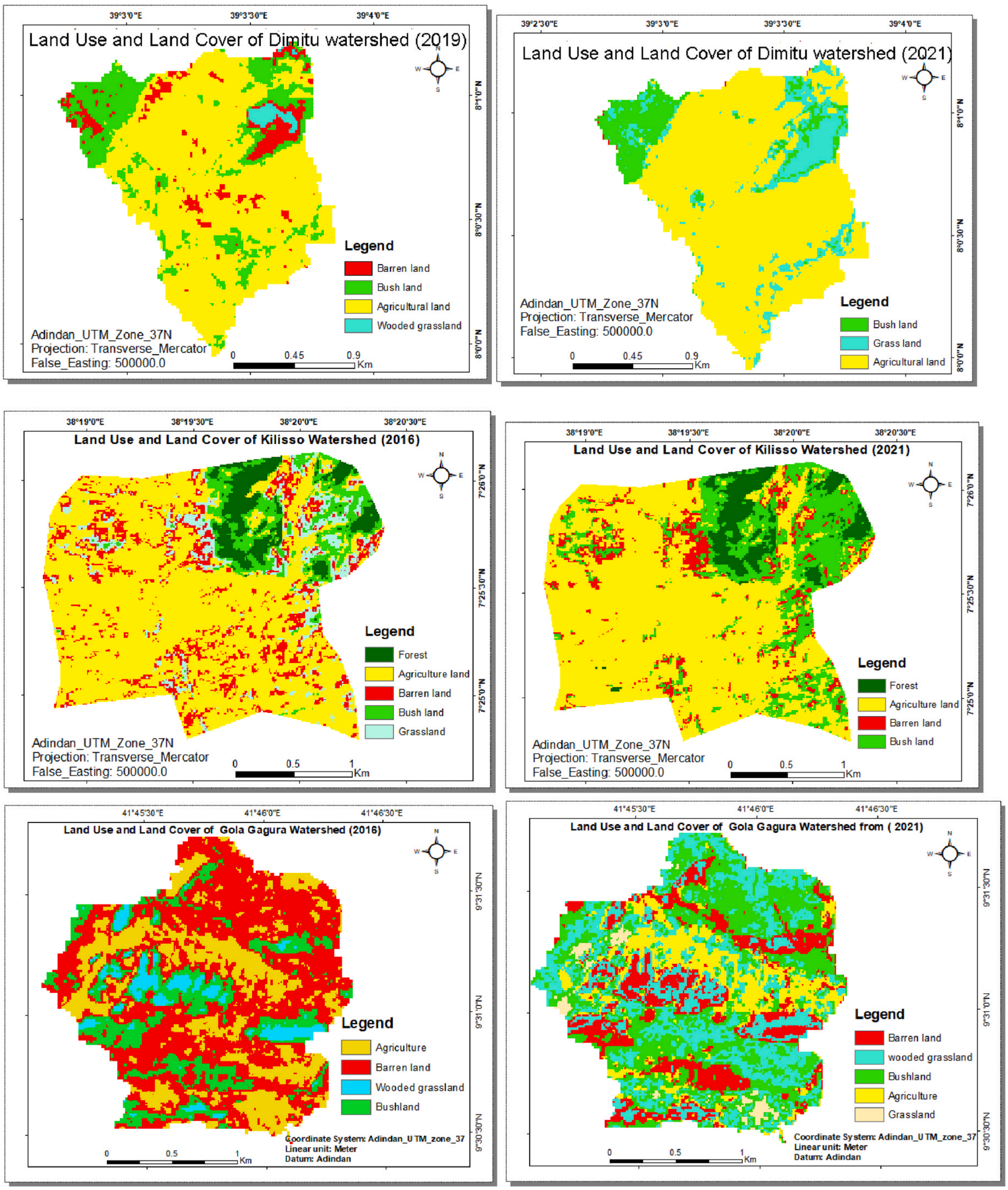

Fig. 2. Land use land cover of Dimitu watershed 2019 (top left) and 2021 (top right), Kelisa watershed 2016 (middle left) and 2021 (middle right), and Gola Gagura watershed 2016 (bottom left) and 2021 (bottom right).

an increase of bushlands and decrease of barren lands (Husien, 2009; Alem and Habrova, 2020; Gumma et al., 2021). A landscape restoration study in southern parts of the Ethiopian rift valley area reported that area closure combined with moisture-retaining structures improve vegetation performance in degraded lands (Alem and Habrova, 2020). Mekuria and Aynekulu (2011) and Tekle and Hedlund (2000) reported a decline in bare lands due to land restoration interventions in Kalu area of north central Ethiopia. A study that assessed the impact of restoration efforts of the Sustainable Land Management project in Ethiopia on drought resilience found that the gross primary production in treated locations increased by 13.5% in drought affected areas and by 3.1% in non-drought areas over a five-year restoration period (Constenla-Villoslada et al., 2022).

Overall, if there were no restoration interventions in Dimitu watershed, the land conversion trends over years shows that bush and barren lands could be converted to cultivated lands at an alarming rate that might be even abandoned due to severe degradation. However, the success of restoration interventions in the increase of natural vegetation cover was impeded after phased out of the projects. Thus, without ensuring community participation and an equitable sharing of the benefits from restoration and inclusive arrangements as well as without placing and enforcing resource governance and protection rules with the consent of the community, the sustainable use of benefits generated from restored barren lands would be at risk of encroachment by

Table 6
Land use land cover change-transition matrix of Dimitu, Kelisa and Gola Gagura watersheds, Ethiopia.

From	To	Area changed (ha)
Dimitu watershed, 2019–2021rowhead		
Cultivated land	Bushland	0.3
	Wooded grassland	8.9
Barren land	Cultivated land	8.5
	Bushland	3.2
	Wooded grassland	8.4
Bush land	Cultivated land	12.5
	Wooded grassland	14.9
Wooded grassland	Cultivated land	0.9
	Bushland	0.7
Kelisa watershed, 2016–2021rowhead		
Cultivated land	Barren land	3.7
	Bushland	34.6
	Forest	1.0
Barren land	Cultivated land	32.9
	Forest	4.8
Forest	Cultivated land	0.0
	Bushland	0.5
Grassland	Cultivated land	0.8
	Barren land	7.0
	Bushland	32.6
	Forest	0.0
Gola Gagura watershed, 2016–2021rowhead		
Cultivated land	Barren land	32.6
	Bushland	39.7
Barren land	Cultivated land	34.4
	Bushland	45.6
	Wooded grassland	24.5
Bushland	Wooded grassland	31.2
Wooded grassland	Barren land	0.0
	Bushland	7.6

expansion of cultivated lands.

3.4. *Perceived impacts of landscape restoration on ecosystem and agricultural yields*

The local communities around the restored landscapes had perceived positive environmental impacts in terms of increasing vegetation cover and regaining lost wild life. More than 90% of respondents in Dimitu and Gola Gagura watersheds reported that grass and woody plants cover have been improved due to landscape restoration, with a greater majority of them rating the level of increase as 'high' in Dimitu and 'moderate' in Gola Gagura watersheds (Table 7). The focus group discussants agreed that the diversity of plant species increased at both Dimitu and Gola Gagura watersheds due to planting in the home gardens and regeneration in the closed area (Table 3). A previous study reported that area closure of degraded landscapes enabled plant regeneration from soil seed banks due to reduced disturbances and improvement in soil and water conditions in Lake Hawassa watershed of Ethiopia (Alem and Habrova, 2020). Both plant regeneration and conservation structures, in turn, reduce the loss of soil and seeds. The flood and sedimentation problems of Dimitu and Kelisa watersheds have been reduced due to water retention in the rehabilitated upslope because of increased vegetation cover and physical soil and water conservation structures, as focus group discussants explained. Sedimentation in the downstream farmlands has reduced substantially following the restoration interventions at both Dimitu and Gola Gagura watersheds (Table 7). Farmers in a focus group discussion and key informants at Dimitu and Kelisa watersheds further explained that they did not expect such a quick rehabilitation of the severely degraded areas. Studies in different areas, e.g., in northern Botswana and Ethiopia reported an increase in vegetation cover and diversity following area closure (Teketay et al., 2018; Gebregerg et al., 2021). According to the focus group discussants

Table 7
Household heads' response on the impact of landscape restoration activities at Dimitu and Gola Gagura watersheds.

Questions responded by farmers	Response	Percent response	
		Dimitu watershed, n = 48	Gola Gagura watershed n = 40
Soil erosion reduced	Yes, %	100.0	100
Level of erosion reduced	high, %	72.9	20.5
	Medium, %	27.1	79.5
	low, %	0.0	0.0
Grass cover improved	Yes, %	100.0	92.5
Level of grass cover improved	High,%	89.6	
	Moderate, %	10.4	83.8
Forest and bush cover improved	Yes, %	100.0	87.5
Level of improvement in forest and bush cover,	High,%	75.0	2.8
	Moderate, %	25.0	71.4
	Little, %	0.0	2.8
Vegetation diversity increased	Yes, %	100.0	97.5
Availability of streams during the dry season increased	Yes, %	72.9	75
Was the flow of existing streams improved?	Yes, %	77.1	95
Quality of water improved due to less erosion/ sedimentation	Yes, %	93.8	100
Access to irrigation improved	Yes, %	0.0	97.5
The yield of major crops increased	Yes, %	91.7	100
The level of major crop yield improvement	High,%	2.3	2.5
	Moderate, %	79.1	97.5
	Little, %	18.6	0
Livestock feed increased	Yes, %	87.5	100
Level of livestock feed improvement	High,%	0	22.5
	Moderate, %	76.9	77.5
	Little, %	23.1	0
Productivity of livestock (cattle, small ruminants) improved due to better access to feed	Yes, %	79.2	100
Level of livestock productivity improved	High,%	0.0	2.5
	Moderate, %	42.9	97.5
	Little, %	57.1	
Food diversity improved	Yes, %	37.5	100
Access to food/food security status improved	Yes, %	93.8	100
Level of improved food security	High,%	0.0	2.5
	Moderate, %	82.2	95
	Little, %	13.3	2.5
Income improved due to landscape restoration	Yes, %	22.9	97.5
Job opportunity improved/ increased due to landscape restoration	Yes, %	20.8	62.5

Note: the farmers who responded 'yes' to a question have been further asked to respond on the level of improvement on the same issue.

in Dimitu watershed, the recovery of the natural vegetation and its impacts on reducing flood and sedimentation was observed in a few years after restoration. The study indicated that landscape restoration is a non-replaceable remedy to prevent watershed degradation and its effects on terrestrial and aquatic ecosystems (Alem and Habrova, 2019; Desta et al., 2017; DestaFetene, 2020).

All respondents in Dimitu and Gola Gagura watersheds perceived that soil erosion was reduced due to restoration activities, and many of them estimated the level of reduction is medium to high (Table 7). Landscape restoration activities could retain surface runoff and increase the chance for infiltration, which could have importance in regulating stream/river flow. In the studied watersheds, farmers perceived that stream flow improved after the landscape restoration. The positive effect of area closure and associated land management effect on moisture availability was also reported in China (Chen et al., 2010).

Greater than 90% of the farmers in Dimitu and Gola Gagura watersheds perceived that, after landscape restoration, crop yield has substantially increased (Table 7), which mainly could be due to reduced erosion by the runoff coming from the degraded upstream, or increased moisture availability due to improved soil and water management. Damages of floods on farmlands and houses have been under control in the Kelisa watershed, implying social benefit to the community. In the same watershed, in 2006, a large gully, as deep as 30 m was formed, this becomes a physical barrier hindering connection between communities. After the implementation of landscape rehabilitation interventions, it reduced further gully formation and partially stabilized the existing gully as observed in the field. Supporting our results, a study in Borkena watershed, northeast dry lands of Ethiopia, reported significant reduction of erosion and a positive change in soil fertility after landscape restoration (Ayele, 2019). The majority of the farmers also perceived that feed supply and livestock productivity improved moderately after landscape restoration, which could be mainly due to the increased biomass production both on closed communal land and conserved private fields. The effect of landscape management on soil fertility and moisture retention might have contributed to better productivity. A study in China reported that area closure could highly restore soils and vegetation in degraded lands (Rong et al., 2014).

3.5. Socio-economic impacts

The results revealed that 98% of the respondents in the Gola Gagura watershed and 23% of the respondents in the Dimitu watershed agreed that their income improved due to landscape restoration (Table 7). The income improvement could be associated with selling of, fodder mainly of grasses by watershed users, paid jobs for rehabilitation activities, improvement of crop production due to soil and water management, and increased livestock productivity due to better access to fodder as perceived in Dimtu watershed. Moreover, 21% of respondents in Dimitu and 63% in Gola Gagura watersheds indicated that employment opportunity was improved because of landscape restoration. The employment opportunities created by the landscape restoration included casual labor for the project-based activities such as the construction of check dams and bunds and guarding the closed areas. On the other hand, the reduced degradation of farmland due to landscape restoration reduces the risk of migration in searching for off-farm activities and helps farmers remain in their locality and improve livelihood and social integration.

Due to landscape rehabilitation, farmers in Dimitu could get grasses nearby for grass-thatched houses and livestock feed, otherwise, they should travel far distances. The members of the watershed users' associations have benefited by selling grass harvest from area closures. Indirectly, the local communities, who are not members of the watershed users' association, can access the grasses at reasonable prices. The availability of grass to the community in their vicinity also saved time, labor, and money. In the Kelisa watershed, the female focus group discussants indicated that the rehabilitated upslope is better than the previous bare land to get some woods and grasses even illegally. In area closure, woody species gradually expected to replace grasses due to ecological succession and thus, grass availability for different purposes would decrease. Woody plants such as Acacia spp, *Olea africana*, *Podocarpus falcatus*, *Balanites aegyptiaca*, *Dodonaea angustifolia*, *Euphorbia abyssinica,* and 'muka buna', 'kararu', 'digita' *Entada abyssinica*, etc have been mentioned by the focus group discussants as naturally regenerated on closed areas in the Dimitu and Kelisa watersheds. *Dodonaea angustifolia* and *Acacia saligna* were among the planted species to improve vegetation cover on dry lands where tree seedlings survival is a challenge. Currently, majority of farmers in Dimitu and Gola Gagura perceived that due to landscape restoration and increased availability of grasses and shrubs, availability of livestock feed and livestock productivity improved (Table 7). The contribution of naturally regenerated species for livestock feed and ecosystem services could be more as the survival of planted species is challenge in dry land areas. In general, resource availability resulted in positive implication to the local community. Demissie et al. (2019) reported a positive economic role of landscape restoration in drylands due to improved ecosystem services in South Gondar area of Ethiopia. The positive role of landscape restoration on agriculture was reported for the dry lands of Kenya (Kizito et al., 2021).

Focus group participants perceived that the diversity in food items increased after landscape restoration in Dimitu and Gola Gagura watersheds, which could be due to improved income and job opportunities. The increased crop and livestock yield could improve food diversity and availability for the majority of the local communities (Table 7). Since there are beneficiaries of the Productive Safety Net Programme and other project incentives following participation in partially/fully paid labor works, the income of some farmers could be improved due to landscape restoration activities, which in turn could increase access to food. A previous study on CRS intervention sites also reported that the watershed management projects improved food availability due to better production, and income resulting from soil and water conservation and irrigation schemes (Hebert et al., 2010).

The natural regeneration after landscape restoration could also provide additional benefits through access to medicinal plants. One of the key informants at Dimitu watershed reported that some of the disappeared medicinal plants could regenerate after interventions. When needed, otherwise, people would travel a far distance to obtain a piece of such plant species for medicinal use. A study in the South Gondar, Ethiopia, also reported that the landscape restoration has increased access to medicinal herbs (Demissie et al., 2019). The focus group discussants at both Dimitu and Kelisa watersheds perceived that rehabilitation of the landscape improved landscape appearance and increased recreational value as the youth group indicated in the FGD, which is another social benefit of restoration.

3.6. The lessons and food for thought

It was learned that in the studied watersheds, the highly degraded landscape has been reasonably restored in three to five years, which failed many times in earlier attempts. This changed the perception of the community and shown the possibility of rehabilitating highly degraded land. Through participatory processes and continuous deliberations with the local community, it was possible to increase the technical knowledge and skills of farmers on landscape restoration practices. This witnesses the effectiveness of CRS-supported restoration interventions and adaptive project management approaches.

Key informants and focus group discussants uncovered the main challenges related to equitable benefit sharing mechanisms. For example, in Dimitu watershed, the discussants mentioned that the benefits from the closure area are utilized only by the members of watershed users' association. Others such as youths were excluded, and they suggested that Safety Net Programs that recruit poor households should also consider jobless young people in the area so that they can work on landscape restoration activities and could share the benefits. Non-inclusive approach leads to conflicts over resource use and benefit-sharing and in the long term it reduces community ownership and affects sustainability of interventions. The entitlement of area closure benefits only to safety net beneficiaries need to be negotiated and agreed among the community members for equitable benefit sharing.

The wild animals inhabiting the rehabilitated upslope (area closure) raid agricultural crops as well as predate livestock, which appeared to be a serious problem both in Dimitu and Kelisa watersheds. The focus group discussants in Dimitu watershed reiterated that they lost many cattle by hyenas and other wild animals. This implies that designing alternative options is essential by considering habitats and corridors for wild animals. On the other hand, even though the area closure is strictly protected, owners of adjacent farms slightly encroach to the closed areas as explained by focus group discussants. Few people harvest firewood illegally from the restored landscape, for which devising solutions could contribute for sustainability of interventions.

Key informants expressed that protection should go with sustainable utilization as prohibiting access to generated benefits from area closures may not lead to sustainability. To reduce adjacent farmers' encroachment to the closed area, growing trees and grass on private land as alternative feed sources should be encouraged. A study by Meaza et al. (2016) reported that integrated management of the degraded lands improved livelihood of the community. Furthermore, increasing the income of households by applying different livelihood components, e.g., fattening of animals, poultry, and beekeeping as observed in other projects could help to sustain the landscape restoration. In general, this calls for integrated land use planning across different systems (for example, protected areas and agriculture) and delineating buffer areas to address conflicts between wildlife and agricultural land uses and tradeoffs.

Fencing of the area closures and putting buffer from the cultivated lands were suggested strategies to protect and control wild animals' from attacking crops and livestock. The feasibility of this was argued, particularly in Kelisa and Dimitu, as it is difficult to fence large area closures and ensuring sustainability is under question. The option explained by officials includes relocating wild animals from area closure to national parks in the country, which may require further studies. Under such contexts, introducing and promoting nature conservation approaches is essential so that communities could benefit, for example, from eco-tourism of the habitats.

3.7. Innovative pathways for ensuring sustainable landscape restoration practices

The suggested pathways based the lessons on current practices in the case study watersheds at implementation level and the national and global experiences of landscape restoration. It was also assumed that there is no severe change in droughts and shocks that limit the adaptation capacity of communities; and policy incentives influencing land use regulations and protection of restored resources will remain unchanged. Two contextualized pathway options including institutionalizing community led processes and governance and integrated planning of land uses could have a potential role to enhance the restoration efforts at scale. The two options are taken since the institutional arrangements for inclusive benefit sharing and resource governance as well as the operational planning of interventions between land use systems are the determining factors for the effectiveness of the restoration works. This is because of the reason that governance and use of restored resources of communal lands have been reported as main challenges of landscape restoration at national and global levels (Cronkleton et al., 2017; Djenontin et al., 2018; Gumma et al., 2021; Schweizer et al., 2021).

To replicate the achievements made in the case study watersheds and ensure a sustainable restoration practice, contextualization of the restoration interventions with the local biophysical and socio-economic settings are essential. The practices need to be locally owned and actionable by in placing community led innovation processes and strategies. Participatory actions at early stage of the interventions can ensure benefit driven landscape interventions (Child et al., 2021). Landscape restorations are vital when socio-economic benefits are rapidly realized thereby resulting in motivating land users to invest their time. Such integration leads to adaptable and sustainable practices and approaches including land management practices, crop-livestock production intensification, livelihood options and locally relevant service delivery approaches. These could be effective when bottom-up planning and visioning, coordination, managing land resources and land use regulations, and joint monitoring and evaluation are enabled through an efficient community led participatory processes and landscape governance structures at local level (Child et al., 2021; Gumma et al., 2021).

In the case study watersheds, one of the emerging challenges after restoration is the conflict between crop and livestock use and wildlife habitat. This conflict happened because of lack of participatory and integrated land use planning at the initiation stage of project interventions. To govern conflicts between land uses, integrated land use should be used as a planning approach by considering key interventions such as demarcating buffer zones, regulating the expansion of agricultural lands to natural land use systems, and issuing tenure security to communal lands. In this regard, conflict of uses between protected areas/area closures and agricultural lands shall be given priority. Revisiting the existing land uses and the operational plan should be considered to reverse unsustainable land uses and environmental damages.

4. Conclusion

Restoration of degraded landscapes using area closure integrated with physical soil and water conservation measures enabled the conversion of barren lands to vegetation cover through natural regeneration within 3–5 years in the studied dry land areas. Apart from less participation of communities in the planning and decision-making processes, the communities in the study watersheds agreed that the restored landscapes had resulted in positive environmental and socio-economic benefits pursuant to sustainability. As perceived by households, landscape restoration improved the livelihoods of the local community through reduced surface runoff and erosion that could affect agricultural production in the downstream areas of degraded lands, regulated water flow in springs, and improved crop and livestock production. The fast regeneration of grasses and shrubs on barren lands after the restoration improved farmers' access to fodder for their livestock which is an important means of livelihood in dry land areas. Landscape restoration has an important social role including job opportunities in the form of incentives, income change, availing resources in the vicinity, and reducing potential migration. Sustainable utilization and management of landscape restorations require setting solutions, particularly for challenges on the communal land including benefit-sharing, land-use conflicts, reducing wild animal damage to crops and livestock, and reducing encroachments. The landscape restoration and management approach implemented in the studied watersheds, particularly the integration of interventions as well as creating local associations and institutions for communal resources, are scalable in areas having landscape degradation problems. Innovative pathways that could create the integration of practices and technologies (e.g., water harvesting, agroforestry, rangeland management, natural regeneration, and area closure) and increase synergy between landscape restoration and economic development should be implemented to reconcile the tradeoffs between the encouraging acceptances of restoration interventions and potential conflicts of interest among community members. Sustainability of restored landscapes could be achieved through strengthening watershed cooperatives and community participation, institutionalizing community lead processes and resource governance for the implementation of landscape restoration and integrated land use plan.

Author credit

Kebede Wolka has participated in proposal writing and designing the research. He participated in field data collection on focus group discussion, household interview, key informant interview and field observation. He produced the draft manuscript and improved the manuscript after comments. Birhanu Biazin contributed in proposal writing and designing the research. He participated in field data collection on focus group discussion, key informant interview and field observation. He commented on the draft and revised manuscripts. Fikadu Getachew has contributed in proposal writing and designing the research. He participated in field data collection on focus group discussion, key informant interview and field observation. He commented on the draft manuscript. Firehiwot Girma participated in field data collection on focus group discussion, and field observation. He did land use land cover analysis using remote sensing data and GIS software. Gizaw Desta has repeatedly commented on the draft and revised manuscripts.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2023.117499.

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