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Sustainability Science for Meeting Africa's Challenges

Indigenous resource management practices in the Gamo Highland of Ethiopia: challenges and prospects for sustainable resource management

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Abstract Deforestation and soil degradation are serious sustainability challenges in many countries of Sub-Sahara Africa such as Ethiopia. Rapid socioeconomic change is a key underlying factor for the unsustainable use and management of natural resources. However, there is a number of well-established resource management systems and a wealth of local experience in maintaining and managing natural resources. This study explores the indigenous and local knowledge (ILK) practices for managing soil, forestland, grazing land, and farmland at the Gamo Highland of southwestern Ethiopia. Field observation, household surveys, focus groups discussions, and expert interviews were conducted to identify the different indigenous practices for managing natural resources in the area. Primary and secondary data were used to identify various relevant ILK practices such as terraces, intensive cultivation systems using drought tolerant species, soil management practices (e.g., manuring and fallowing), and a series of social norms and regulations to preserve sacred forest and manage grasslands. All these practices reflect the cumulative application of ILK over long periods of time, for the effective use and management of natural resources. However, the implementation of such ILK practices has been declining recently due to various factors such as land scarcity, labour shortages, shifts in rural livelihood options, and government policies. However, such indigenous management practices should be preserved and promoted through the integration of ILK with scientific approaches to ensure the design and implementation of socially acceptable resource management systems to ensure the long-term sustainability of the Gamo Highland.

Keywords Sustainable agriculture · Indigenous knowledge · Terrace · Sacred forest · Gamo Highland · Ethiopia

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Introduction

Ethiopia faces many sustainability challenges related to unsustainable natural resource use such as extensive soil erosion, soil fertility decline, deforestation, overgrazing, water depletion, and fuelwood scarcity that affect adversely most of the population (NPC 2015; Haregeweyn et al. 2015; Meshesha et al. 2012).

For example, following the long-term monitoring of agroecosystems in the highlands of Ethiopia, Hurni (2007) indicates that soil loss from cultivated land can be more than 40 t/ha/year. This rate of soil loss is more than four times the average tolerable limit of soil erosion (Hurni 1993), and can result in nutrient loss of 80 kg N, P, K ha^{-1} per year, or greater. Earlier sources have also documented that approximately half of the area of the Ethiopian highlands is moderately to severely eroded (FAO 1986; Hurni 1993; Pender et al. 2001; Lemenih et al. 2005). In a sense, soil erosion has become one of the major constraints of agricultural production and food security in Ethiopia (Hurni 1993; Tekle 1999; Tadesse 2001; Sonneveld 2002).

Deforestation (a major sustainability challenge in itself) is one of the main causes of soil erosion in the country. Deforestation is an old phenomenon and has been associated with the long history of human settlement and agricultural activity in Ethiopia (Butzer 1981; Hurni 1993). Unprecedented deforestation, however, has been occurring since the beginning of the 20th century, owing to the demographic, political, economic, and social dynamics. At the turn of the 20th century, approximately 40% of Ethiopia was under forest (of various types and densities), but forest cover was reduced to 16% of the total land area in the 1950s, and shrank further to 2.7% in the 1990s (EFAP 1993). The decline/shrinkage of the genetic pool associated with deforestation can be another serious threat to the sustainability of natural resource use in Ethiopia (Sahilu 2003).

The deforestation-driven loss of genetic pool, severe soil erosion, and the associated declines in agricultural productivity are major interlinked challenges for the livelihoods of most of the (ever-increasing) population in the country. As a result, the government of Ethiopia has laid out plans to reduce land degradation, improve productivity of natural resources, and enhance food security by 2020 (NPC 2015).

For example, there is a general consensus in the government of Ethiopia that the 1970s famine event was associated with deforestation and soil degradation (Admassie 2000). As a response (and with the assistance of international organizations), massive soil and water conservation activities were undertaken across the country to mitigate land degradation. Between 1975 and 1989, terraces were constructed on 1,188,000 ha, and about 310,000 ha were re-vegetated (Admassie 2000). This has probably been the largest effort of physical reclamation of eroded land in Africa (FAO 1990; NCS 1990). However, in some cases, afforestation was unpopular, with local communities destroying indigenous terraces (Admassie 2000; Alemneh 2003). This unpopularity of physical reclamation efforts was partly attributed to the failure of the soil and water conservation program to meaningfully involve local communities due to its top–down approach (Admassie 2000; Alemneh 2003; Bewket 2007). This approach excluded to a large extent local farmers from planning and implementing soil conservation activities (Admassie 2000).

However, farmers in Ethiopia have long been using their indigenous local knowledge (ILK) to manage natural resource systems. For example, they have devised a wide range of soil management practices that include structural, agronomic, and biological measures, to halt soil erosion and to limit land degradation (Westphal 1975; Asrat et al. 1996; Krüger et al. 1996; Million 1996; Reij et al. 1996; Herweg and Ludi 1999; Osman and Sauerborn 2001; Besha 2003; Mitiku et al. 2006). Moreover, there are well-managed and preserved forests across the country as for example extensive areas owned by the Orthodox Church (Wassie et al. 2005).

Several scholars have pointed that environmental management should be socially inclusive and adopt a social-ecological system approach if it is to tackle effectively such intertwined sustainability challenges (Gasparatos et al. 2016; Mitiku et al. 2006). ILK practices such as the ones discussed above are increasingly recognized for their contribution to the effective development and implementation of policies, strategies, and management approaches to enhance sustainability (e.g., Agrawal 1995; Parsons et al. 2017; IPCC 2014; Löfmarck and Lidskog 2017; Tengö et al. 2017). For example, ILK practices can contribute to climate change adaptation (IPCC 2017), water resource management (Parsons et al. 2017), biodiversity conservation (Kok et al. 2017), and soil management (Guzman et al. 2017). In doing so, ILK systems can add value to national efforts to achieve the Sustainable Development Goals and enhance community resilience (Parsons et al. 2017).

Sustainability science can lead academic scholarship on the theory and practice of integrating ILK and modern science for the effective design and implementation of resource management systems (Johnson et al. 2016; Scoones 2017; Emeagwali and Dei 2014; Eyong 2007). However, while sustainability scholars and practitioners have highlighted the relevance of ILK in Africa in general, and in Ethiopia in particular (e.g., Emeagwali and Dei 2014; Eyong 2007; Mitiku et al. 2006; Reij et al. 1996), it still remains a relatively under-researched topic.

Towards this end, the major aim of this study is to identify key ILK practices used in Ethiopia to manage soil, forests, grazing lands, and farmlands, and understand what drives changes in the use of such practices. The paper focuses on ILK practices in the Gamo Highland of south Ethiopia and seeks to examine the sustainability implications of these ILK practices in the region and beyond. The paper starts by introducing the characteristics of the Gamo Highland and outlines the main methodological approach for identifying the different ILK practices used for the management of agricultural land, forest, grazing land, and soil. It then discusses the main drivers that threaten the long-term application of such practices in the region, and makes the case that there is a need to link better ILK and modern science to improve the sustainability of resource use in the country and beyond.

Methodology

Study Site

The Gamo highland is located in the Gamo Gofa Zone of Southern Nations, Nationalities, and People's Regional State, about 480 km southwest of Addis Ababa (Fig. 1). The topography is characterised by high plateaus, which are topped by hills and mountains. It has an area of 373.52 km^2 with altitude ranging from 1200 to 3250 m above sea level (a.s.l.). According to the traditional agro-climate classification system, which only considers altitude, the study area lies within a *kola* zone (elevation of below 1500 m a.s.l.), a *weinadega* zone (elevation of 1500–2300 m a.s.l.), and a *dega* zone (elevation above 2300 m a.s.l.) (see Fig. S1, Supplementary Electronic Material).

The mean annual rainfall of the study area was about 1392 mm, based on meteorological records from Chencha, a part of Gamo highlands between 1970 and 2008. The rainfall distribution is bimodal, occurring from April to October, with the highest monthly rainfall occurring in April (185.4 mm on average). The main soil types in the study area are Fluvisols, Leptosols, Cambisols, Acrisols, and Alisols. Acrisols and Alisols are the dominant soil types in the Chencha area (Assefa 2002).

The main land uses of the Gamo highland include cultivated land (61%), grassland (19%), woodland (9%), and forest (7%) (Fig. 2). Cultivated land in the Chencha area (focus area of this investigation) has increased 39% between 1973 and 2006 (Assefa 2012). Eucalyptus trees are common around the homesteads and on community woodlots. The main economic activity is subsistence crop production and livestock rearing. People mainly cultivate barley, wheat, and enset, and, to a lesser extent, peas, beans, potatoes, and tree cabbage. Enset is the staple food in the area and central to the subsistence agriculture.

Farming is marked by small-scale agriculture entirely dependent on rainfall. The two methods of tillage used in the area are conducted with hoe plough and ox plough, with the former being dominant. Only very few people are engaged in off-farm activities as additional sources of income. Weaving is one such important economic activity, especially for the Dorze people of the Gamo Highland.

Chencha is the main study area with an estimated total population of 134,371 (61,846 men and 72,525 women), of which 14,230 (11.19% of the total population) are urban dwellers in 2012 (CSA 2012). Population density in the study area is quite high, estimated at 359.7 people per km^2. High population density in the Gamo Highland has been traditionally high (300–400 persons per km^2) with average land holding per household being less than 0.5 ha in the 1960s, which has been surpassed by the carrying capacity (i.e., the amount of agricultural production per unit land that supports a given population) since then (Rahmato 2009).

In particular, we focused this study on three kebeles (Belle, Meshe, Gule), which are the smallest administrative

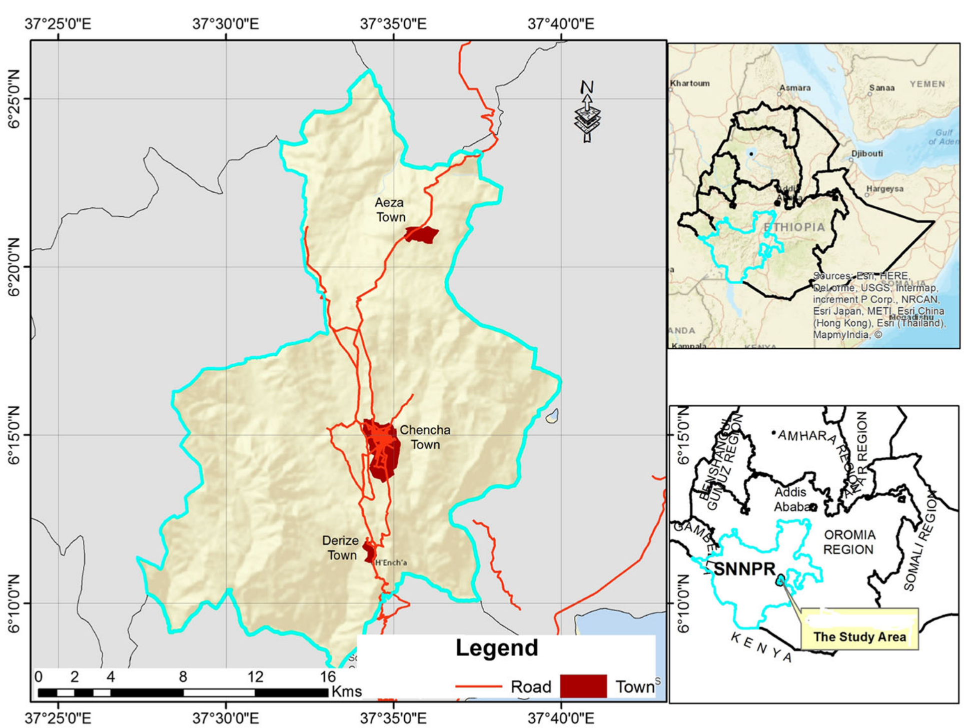
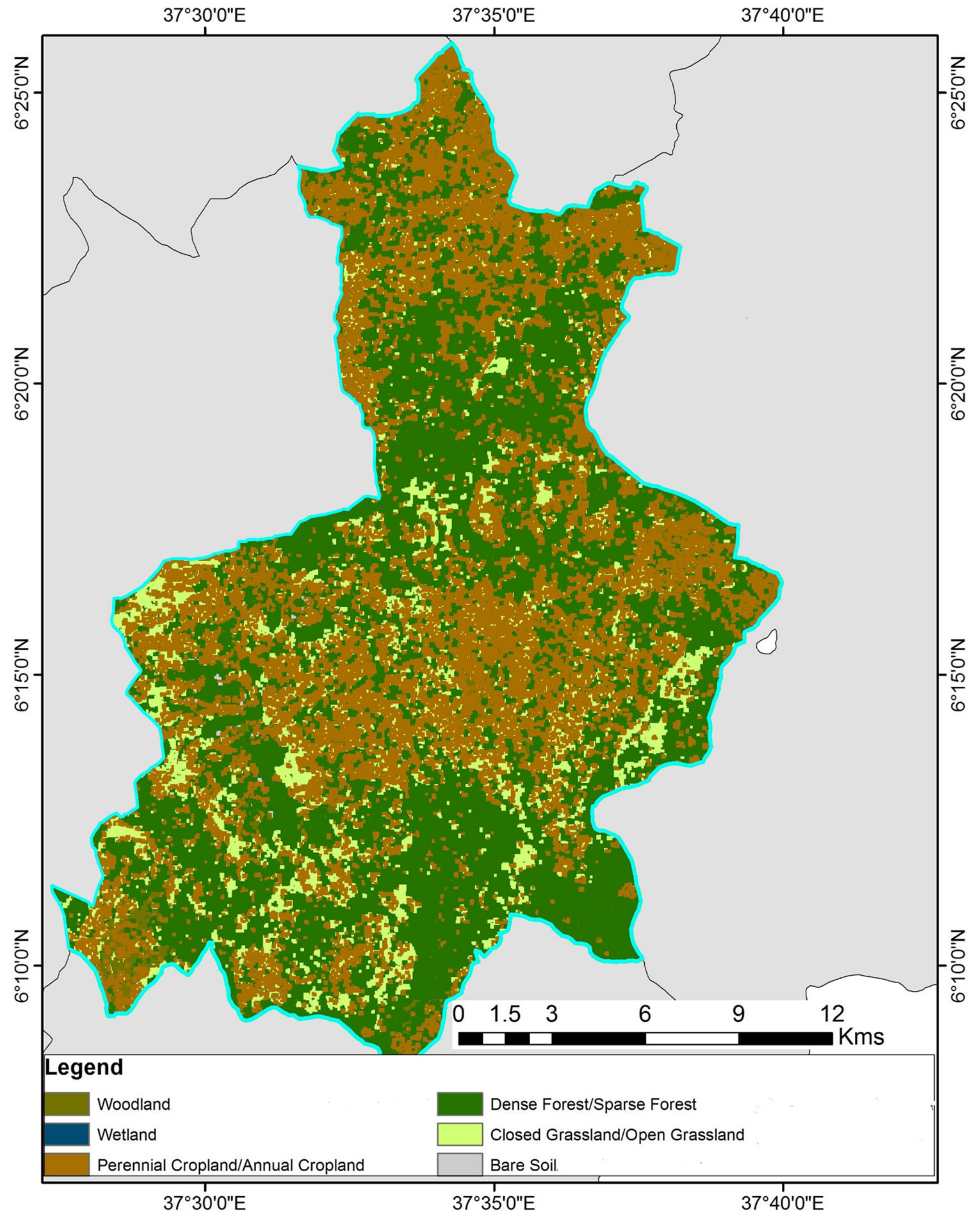


Fig. 1 Location of the study area

Fig. 2 Land use and cover in the study area



unit in the region (see Fig. S2, Supplementary Electronic Material). These kebeles were chosen as they widely use various land resource management practices.

Gamo Highland is known for ILK related to forest and soil management. Large parts of the Gamo highland are covered by a series of traditional terraces and bunds made of stones that have converted the slopes to a series of steps.[1] As a survival strategy considering the steep mountainous topography prone to resource scarcity, along with terracing, farmers also practice manuring (application of manure), crop rotation, fallowing, and tree planting on farm fields. Local traditional systems have also played a pivotal role in helping to maintain and manage forests. This is manifested by remarkable natural forest on the summits of the highlands, with trees being in the centre of the agricultural and social system in the area. Drought tolerant plants such as Enset (*Ensete ventricosum*) are extensively used, which make the area one of the least affected by the recurrent droughts in Ethiopia (Rahmato 2009).

Data collection and analysis

This study is a part of the broader study project that aimed at investigating land use systems, land cover, and landscape structure in the Gamo Highland through a multidisciplinary and interdisciplinary research approach (Assefa 2012; Assefa and Bork 2014a, b).

[1] The area is considered to be megalithic due its ancient stone-walled terraces (Jackson 1972; Jackson et al. 1969).

Initially, a transect walk, as a reconnaissance survey, was undertaken to understand the study area before designing and undertaking the detailed data collection through household surveys and group discussions. Such a survey is useful for observing and becoming familiarized with the different features of land use systems and land management practices.

A household survey was undertaken to collect various information about ILK practices related to land management and intensive farming systems. The household questionnaires had both close and open-ended questions that tried to capture the farmers' knowledge and experiences on the use and management of land (e.g., forest and grazing land) and natural resources such as soil. Questions also tried to elicit the local or indigenous strategies and approaches to respond to the demographic and other pressures that affect the sustainability of the agricultural landscape in the study areas.

A total of 120 households were randomly selected from lists of resident households in three kebeles (Belle, Meshe, Gule) (see Table S1; Fig. S2, Supplementary Electronic Material). The interviews were carried out with the help of college graduate assistants that knew the local languages. Interviews were conducted by going to the individual households in the morning and during the afternoons, which are usually appropriate times for farmers, since they are neither times for agricultural activity or other activities in which the household head is likely to be involved. Interviews were also held outdoors as long as the respondents were willing to answer questions. If the informant was unwilling to disclose information, then she/he was asked to propose someone who would be willing to be interviewed.

Key informant interviews were conducted with 15 elders and rituals leaders (Table S2, Supplementary Electronic Material). These interviews were semi-structured and mainly focused on what had changed in the study areas, how changes had occurred, and why changes in the farming system, and indigenous land management practices had taken place. Moreover, there were some different types of questions pertaining to oral history, which referred to situations in the time of their fathers.

Group discussions were used to check and refine the data collected from household surveys and key informant interviews. Three group discussions were conducted, one per kebele. Each group was composed of ten participants of both sexes, who were mainly elders over 50 years of age, and could remember and convey past events of agriculture land use and land management practices. Discussions were carried out based on checklists and consisted of open-ended questions.

Results

Household characteristics

Average household size was 6.6. The overwhelming majority of household members were young, with those below the age of 15 and above the age of 65 years being 58 and 11% of the total, respectively. The literacy rate, as elsewhere in rural Ethiopia, was very low. Over half of the total respondents (55%) were illiterate, 18.3% could read and write, 15.7% had primary-level education, and the remaining 11% had secondary education.

Table 1 Fraction of landholding sizes of sampled households (in %)

Land size (ha)	Belle	Meshe	Gule
<0.1	8.1	9.5	9.1
0.1–0.5	62.2	55.8	59.2
0.51–1.0	20.4	22.4	22.0
1.01–1.5	8.1	9.8	6.0
1.51–2.0	1.2	2.5	3.7

The average size of land holding varied, but about two-thirds of the interviewed households owned land holdings smaller than 0.5 ha (Table 1). Household land holdings of cultivated land have decreased over time despite the increase of agricultural land uses in the area. About 30% of interviewed households pointed out that their land holdings had decreased by 75% when compared to the *derg* regime period (1974–1989), whereas 45% mentioned a decrease of 50%. Only 15% of the respondents stated that their land holdings had not changed.

At present, the main way to gain access to land in the study area is through inheritance, rent (low rates of close to 10%), and share-cropping, while there was also a redistribution of grassland to farmers to provide land to those who were landless. Share-cropping rates are about 20% for the study sample. The scarcity of cultivated land mostly relates to demographic pressure, which was exacerbated by government policy, land tenure, and the nature of subsistence agriculture.

Crop production is the major source of income (82%) for the interviewed households. Barley had the largest share in the total household income with the contribution of livestock also being significant. For instance, the sale of livestock and livestock products contributed to 13% of the total income in 2015. Table 2 summarises the amount and types of livestock in the investigation area. The average level of livestock holdings per surveyed household amounted to 2.59 TLU,[2] with an average TLU per household in Meshe was (1.6), in Bele (2.2), and Gule (2.5). Livestock is dominated by cattle (46.3%), but also include sheep (36.7%), goats (11.6%), donkeys (2.2%), mules (1.5%), and horses (1.7%).

[2] One Tropical Livestock Unit (TLU) is equal to 250 kg. The TLU values for different species of animals are: 0.7 for cattle; 0.8 for horse or mule; 0.5 for donkey; 0.1 for goat or sheep.

Table 2 Total livestock ownership (in TLUs)

	Belle (TLU)	Meshe (TLU)	Gule (TLU)
Cattle	62.0	35.0	74.0
Sheep	4.2	19.2	12.7
Goat	3.8	0.4	0.5
Donkey	4.0	1.6	3.2
Mule	3.2	5.6	2.1
Horse	2.4	7.2	5.4
Total	79.6	69.0	97.9

Most respondents (82%) reported that crop production is declining in the area as compared to the last 40 years, whereas 11% responded that it is increasing and 7% said that there is no change. With regard to the rate of decline of crop production, about 45% responded that there is a high rate of decline, 10% reported a medium decline, and 27% a low rate of decline. The remaining interviewees (18%) could not trace the rate of decline due to trend irregularities.

Finally, respondents identified multiple factors that affect agricultural productivity in the area such as scarcity of cultivated land (97%), soil fertility decline (87%), grazing land shortage (86%), soil erosion (81%), low fertilizer input (56%), erratic rainfall (57%), lack of improved seed (53%), pests and diseases (17%), and inadequate extension services (23%).

Description of ILK practices

Intensive farming systems

Growing several varieties of food crops (crop diversification) has been one of the salient features of agricultural practices in the study area over a long period of time. In one of the earliest studies, Jackson et al. (1969) identified that the crops that grow across the Gamo Highland include grains (barley, wheat, and emmer wheat), starch crops (taro, enset, potato, and kolto), spices (fenugreek), oilseed plants (linseed), pulses (beans, peas, lentils, and lupine), vegetables (shallot, garlic, and tree cabbage), and stimulants (tobacco). In the surrounding lowlands and at middle altitudes, Belachew (2002) identified about 133 different plant species, 48 of which are used as food for humans. There are also a large number of different crop varieties. For instance, Samberg et al. (2010) recognized about 65 varieties of barley, with some local farmers reporting that some of the varieties of barley were locally domesticated. Olmstead (1975) observed about 34 varieties of enset, whose cultivation is a key farming activity in the Gamo highland due to its economic and ecological importance (Cartledge 1995). For example, enset is its drought resistant and provides a higher amount of food per unit area than most other cereals in the area (Rahmato 2009).

In the study area, the principal cultivated crops in terms of area and importance to local diets are barley, enset, and wheat (Table 3). Clearing and ploughing of land start before the beginning of the rainy season, early March, with sowing taking place sometimes in April following the rain.

Intercropping, i.e., cultivation of different crops on the same field in the same season, and intensified agriculture is one of the most prevalent agricultural practices in the area (see Fig. S3, in Supplementary Electronic Material). The most common crop rotation schemes in the Gamo Highland entail the rotation of barley (2–3 years), wheat (2–3 years), and then bean (1 year) and peas (1 year). They also grow enset with taro, coffee, and cabbage. Intercropping has been practiced in the area due to the various advantages compared to mono-cropping in small farms, and especially the fact that it increases that potential to achieve food self-sufficiency. Moreover, it also reduces the risks associated with erratic climatic conditions and pests, as some crops are more resistant to drought (e.g., enset), while others are less susceptible to pests and crops diseases (e.g., wheat).

Farmers also have long-term experience in the efficient use of the garden areas close to their homesteads (Belachew 2002). Except for a small field in front of a house, which is barren (or covered by grass in some cases), all other lands are used to grow crops. Enset is the main crop grown close to homesteads, while it is common to find enset groves surrounding houses (Fig. S3, in Supplementary Electronic Material). Other crops such as peppers, cabbages, onions, garlic, taro, tobacco, pumpkins, and kale are also grown in the home gardens, usually grown during the early stages of enset cultivation. Sometimes trees (e.g., apple trees) are grown close to homesteads. In the surrounding lowlands, people used to grow bananas, vegetables, mangos, and papayas around their homes.

Intercropping in gardens has various advantages for using the available agricultural resources efficiently as well as for harvesting, processing, and transporting the products. Moreover, by growing different types of trees, the farmers can benefit from various advantages of tree cultivation such as improving fertility, obtaining additional food and fodder, gaining shade, sourcing wood household uses, reducing soil erosion, and conserving water. It is also not uncommon to find trees in the middle of farms in some areas of Ethiopia (Zewde 1998).

Livestock tending is an integral part of the local agricultural system in the Gamo Highland (Table 2). Livestock is the main source of income for paying taxes, buying clothes, and meeting other major household expenses. Livestock also serves as a type of insurance during crop

Table 3 Cropping calendars of the main crops in the Gamo Highland

	Barley	Wheat	Teff	Potato	Bean	Peas	Enset
Clearing	May	May	June	July	March	March	
Ploughing	June	June	June	July	April	April	
Sowing	July	July or August	August	Sep.	June	June	April
Weeding	–	–	–	–	–	–	–
Harvesting	Dec.	Dec.	Dec.	Dec.	Dec.	Dec.	2 years

failures, when farmers can sell animals and use the money to buy food. More importantly, livestock is the major source of manure for the local farming systems described above. Finally horses and donkeys are very important in the highlands for transportation.

Grazing land management

Grazing land management practices have evolved over a long time owing to the economic and spiritual significances of cattle in the area. In the past, local communities irrigated grazing land, which indicates a high level of resource management skills (Jackson et al. 1969). However, this practice has been abandoned as a lot of these grazing lands were shifted to cultivation to support the growing population.

Common grazing land is mainly situated on mountain summits and on the top of ridges and is the principal source of cattle feed (see Fig. S4, Supplementary Electronic Material). The use and management of this grazing land is directed by social rules and norms know as *benne waga*, which are enforced by elected and hereditary elders. Among others, the rules include planting of trees in grazing areas, house building at the fringes, and prohibition of fires on grazing land.

When the grass is too short, usually at the end of the dry season, the elected elders decree the closing of grazing land. Grazing land is also closed at the end of the main rainy season (end of August). During the closed period, cutting grass for cattle and direct grazing are strictly forbidden. To implement the rules, watchmen (known as *kalomura*) are elected by the community, and placed in charge of controlling and observing the rules. The communities are also ethically responsible for the protection of (and cooperation with) the watchmen. Violating these rules and regulations is considered a serious breach of the traditional law and is taboo to the community. If the rules are violated, local communities believe that crop failure, epidemics, and other calamities will follow as a consequence. Hence, the punishment for those who violate the rules extends as far as to cast them out from the society and accept sanctions against involvement in any social activities. However, these breaches of bylaws are rare, particularly in the recent past as expert interviews and focus groups have suggested.

The grazing land is then reopened during the *Mesqal* time at the end of September, a local annual festivity in relation to the celebration of the founding of the True Cross. This closing period allows for the re-growth of a sufficient amount of grass and protects the grazing land against deterioration. This system has been identified as efficient in managing the common property resources in the area (Cartledge 1995; Ogato 2006).

Forest and woodland management

Despite the growing human population and the shrinking forests in the Gamo Highland, ILK practices related to forest management and preservation have played an immense role in the conservation of forests and trees. These include relics of natural sacred forest, trees in the fields close villages, and trees on farmlands and around homesteads (Assefa and Bork 2014b).

Sacred forests are patchy remains of old montane forests in the highlands of the study area (see Fig. S5, Supplementary Electronic Material). Informants could not trace the origin and age of these forests, as they have existed since time immemorial. The remains of a church found inside a sacred forest by ethno-archaeological investigations give some hints about the age of sacred forests (informal discussion with John Arthur, Associate Professor of Anthropology, University of South Florida; Head of the investigation team). This church was among those deserted by people from the northern part of Ethiopia during the war that took place in the sixteenth Century. This suggests that these forests already existed in the area before the 16th century. At present, sacred forests are found in eight different locations within the investigation area, with a total area of about 29 ha as estimated by local people (see Fig. S5, Supplementary Electronic Material). Sacred forests are situated in different topographic positions, but mostly on mountain summits and on ridge plateaus.

In sacred forests, the ritual offering of animals takes place. The main purpose of these sacrifices is to have a productive season with fertile land that can bear many crops, higher yields, good and regular precipitation, and women to have babies. Sacred forests are, to a limited extent, also a source of fuelwood and construction materials. However, there is variation in the degree of accessibility to the different sacred forests for obtaining wood.

Sacred forests have several ecological significances. About 23 tree species were identified in the sacred forests, the most common being: *Juniperus procera*, *Euphorbia* spp., *Olea Africana*, *Ficus spp*, *Cordia africana, Sterculia africana*, and *Acacia abyssinica* (Assefa and Bork 2014b). These forested areas are the most important refuge of natural resources in the Gamo Highland, and sources for seeds of the various indigenous tree species. Remaining pockets of natural forest in different parts of Ethiopia are also common, preserved by older generations (e.g., Zewde 1998; Tekle and Hedlund 2000; Bewket 2003).

Similar to sacred forests, local people have also kept stands of old trees, which are often situated in large grass areas in the highlands of the study area. They are locally known as *Dabush* and are commonly used for gatherings of the local people that deal with their affairs. Government officials also use these stands as meeting points with local communities. *Dabush* are also used for annual festivals and celebrations such as the *Mesqel* (New Year), which takes place at the end of September. They are also areas for mourning, which has a significant social role for local communities. Finally, stands of these trees can also provide fodder for the livestock.

Finally, private woodland and tree plantations are at the centre of agricultural practices in the area. Tree products are important for daily diets (e.g., moringa from the surrounding lowlands), cash crop production (e.g., provide shading for coffee), and for beekeeping (apiculture). Trees are also a source of fuelwood that can provide income during crop failures, acting as insurance. Tree products can also be used for fodder and trees can serve as shade for livestock during grazing periods. Furthermore, trees have a high religious significance, as they are considered to be places of dwelling spirit and used to offer sacrifice (Cartledge 1995). For example, juniper is very important for rituals and wooden statues.

Thus tree planting has been a widespread practice for most farmers over a long period of time (see Fig. S6, Supplementary Electronic Material). Local communities acknowledge the possession of large areas of tree as prestigious. Trees, mainly eucalyptus, are mostly planted on small tracts of land designated for plantations, in the farm fields, and around homesteads. These lands are usually found on degraded steep slopes, which are marked by poorer soil quality. These lands are usually unfit for cultivation. Farmers also plant trees inside/along gullies as well as to mark boundaries along the borders of paths and roads, and at the limits of properties and farmland or grazing land. Trees of old age are also common within the farm and around homesteads, showing that trees are not only grown on abandoned farmland. Farmers in the area have been using the woodland as a source of fuelwood since the 1960s (Jackson et al. 1969). In addition, they plant trees to protect their land from soil erosion and flooding.

Soil conservation and soil fertility management

Farmers in the Gamo Highland have long been aware of the negative effects of soil erosion due to agricultural activities. As a response to soil erosion and runoff, and to increase the productivity of agricultural land, local communities have devised and adopted various indigenous soil and water conservation measures such as terracing for agricultural production (Assefa and Bork 2014b) (see Fig. S7, Supplementary Electronic Material).

The height of terraces varies between 0.5 and 2 m, depending on the gradient of the slope. Terrace height declines in accordance with the slope, with terrace height increasing along steep slopes to retain higher amounts of runoff. Local communities tend to construct a series of shorter terrace walls along a contour, rather than a single long wall. The upper sides of the walls are commonly used to grow grass and trees. Water outlets are built on the side of the walls to divert water flows. Distances between terraces vary from 3 to 15 m depending on the slope. Longer distances between terraces are observed at lower slope segments, whereas short distances are common on steep slope segments. Thus, terraces with higher walls and shorter spacing mark steep slope segments to protect better against runoff and soil erosion.

Due to terracing, the original steepness of the slope is reduced drastically allowing for the demarcation of land for cultivation. To further minimize the effects of the slight soil erosion, the eroded soil accumulated at lower parts of the terrace is brought back to the upper part of the terrace. This activity is usually carried out during the ploughing period when terrace maintenance takes place.[3] The soils of the terrace fields are well managed and used to grow various crops and to plant trees.

Radiocarbon dating of terraces in the Chenca–Dorze Belle area found that they are probably some of the oldest relics of agricultural activity in the region (Assefa 2012). These terraces were most likely established in the late 12th Century or the first half of the 13th Century.[4] Group

[3] Indigenous terraces are very strong and can last for long periods of time. They usually can last more than 8 years without maintenance. Sometimes, farmers have to maintain the terraces if they are partly damaged (or sometimes washed down) by high amounts of runoff that usually occur in April and October or cattle damage due to grazing on terrace fields after harvest.

[4] Archaeological studies have concluded that the area has been settled in since at least approximately 3360 years before present age, and that indigenous crops such as enset were grown for at least 2000 years (Arthur et al. 2010; Cartledge 1995).

discussions with elders in Chencha–Dorze Belle area about the history of terraces and land use systems suggested that the terraces are possibly as old as the agricultural activity in the area. Elders were also well aware of the cultural landscape and its cultural significance to local communities.

Apart from constructing and maintaining terraces, local farmers also use various other traditional soil fertility management techniques to conserve soil and enhance soil fertility. Some of these include (a) manuring, (b) cultivating grass and trees along strips, and (c) fallowing. Manure mainly consists of dung and urine of cattle, sheep, and horses, household refuse, and crop residues. Females collect and carry the manure at sites close to their houses and on their farmland during 1 to 2 months each year. The manure is then spread on agricultural fields and turned in through digging by males. Channeling cattle urine from houses to adjacent enset grove is also practiced. Leaf litter from trees is also used to maintain soil fertility, most commonly coming from trees such as *Erythrina abyssinica, Hagenia abyssinica,* and *Croton macrostachyus.*[5] Finally, when land productivity decreases following continuous cultivation, the intensively used farmland rested to regenerate. During the fallowing period, grass is grown on the formerly cultivated land as animal feed. Traditionally, cereals were grown during the first 3 years of the crop rotation cycle discussed above, followed by a 3 year fallowing period. In other areas of Ethiopia, the land would fallow for 1 year following 8 years of barley cultivation (Jackson et al. 1969).

Drivers of change in ILK practices

Soil conservation and fertility management

The indigenous natural resource management and intensive farming systems have undergone changes in the Gamo Highland. Farmers reported different drivers for these changes with the most frequently cited are: scarcity of cultivated land (98% of the respondents), livestock shortage (92% of respondents), introduction of ox plough (85% respondents), labour shortages (84% of respondents), and government policies (75% of respondents) (Table 4).

The introduction of the ox plough at the beginning of the 12th century has resulted in the deliberate removal and dislocation of terraces. In the past, the dominant cultivation instrument was the hoe and terraces in the study area were fixed. As the ox plough requires a wider space to operate (including for turning the oxen), the local farmers ended up demolishing some terraces and expanding the fields between the former terraces. In addition, farmers sometimes dislocate terraces when soil is accumulated above the wall of the terraces. They often construct new terraces by removing the old ones and extending the space of farm fields between the terraces. Moreover, farmers displace terraces when they construct new houses, while they often construct terraces at the sides of the new houses. These terraces have higher walls to protect the houses from the runoff from upslope. Once terraces are dislocated, the accumulated soils are spread on their farm fields.

The lower part of the study area is marked by gentle slopes and flat segments, and was not covered with indigenous terraces in the past. However, the governmental local bureau of agriculture, which is responsible for implementing/promoting soil and water management practices, has forced farmers to build newly introduced terraces. While local farmers receive food aid and financial incentives to construct new terraces, they can have negative impacts on indigenous terraces. For example, as farmers do not receive any assistance by constructing or maintaining the traditional terraces, they may wish to demolish old terraces to construct new ones as a means of receiving food aid and money. In addition, this situation may also create the perception among the farmers that indigenous terraces are not appreciated and valued by the government.

Labour shortages are also a recent constraint for the construction and maintenance of the indigenous stone-walled terraces. This labour shortage can be attributed to the migration of young people to towns for economic reasons. Furthermore, the recent transformation and assimilation of cultures and religions as well as urbanization processes have also exacerbated problems related to land management. For example, local residents who migrated to urban areas and worked in off-farm jobs, they had a little interest in the construction and maintenance of terraces upon their return to rural areas. Elders rightly stated that their parents were more skilled at constructing and maintaining the terraces than themselves, with the current younger generation being even less skilled.

Manuring, crop rotation, and fallowing practices have all undergone significant changes during the last decades. Local farmers have used manuring over generations to maintain soil fertility. Nevertheless, the application of manure to gardens and fields is declining since the 1960s. About 90% of respondents suggested that the decline in manuring is significant, while only 8% perceived a moderate decline. In the past, manure was applied extensively on cultivated land, and especially for the cultivation of enset. However, presently manure use occurs only selectively due to the manure shortages, which prohibits its application at the same intensity across all farmland. Manure shortages can be mainly attributed to the shortage of livestock.

[5] Leaves and branches of these trees are also used for animal feed and fuelwood.

Table 4 Drivers of change in soil management systems

Driver	Belle (% of respondents)	Meshe (% of respondents)	Gule (% of respondents)
Scarcity of cultivated land	97	99	98
Livestock shortage	96	90	90
Introduction of ox plough	91	85	80
Labour shortages	91	78	82
Government policies	65	76	83

Percentage does not add up to 100 due to multiple responses

The frequency of using crop rotation practices has decreases in the past years due to farmland scarcity. Farmers increasingly prefer to grow solely staple food crops such as barley, wheat, and enset. Furthermore, they aim to maximize the return on land investment by growing cash crops such as apples. Similarly, fallowing practices have declined significantly as only roughly 15% of the surveyed households employed fallowing, with the majority of farmers cultivating land without any interruption till the land is abandoned due to a significant decline in the crop yields.

Grazing land management

Despite the various sources of cattle feed, most respondents (87%) stated that cattle feed shortages are the main causes for the decreasing number of cattle. Fodder shortage is mainly caused by the conversion of large grassland areas into farmland. Satellite image analysis in the area has revealed that about 37% of grassland areas in the highlands have been converted to cultivated land between 1973 and 2006 (Assefa 2012). However, extensive grassland areas were already converted into cultivated land in the 1960s (Jackson et al. 1969). In particular, private grazing land, which was an important source of cattle pasture, was also almost completely replaced by cultivated land as reported by most of the surveyed households. Subsequently, a major part of the communal grazing land was converted to cultivated land. Currently, grazing practices such as forest grazing and the using enset leaves as feed are also declining. This is an outcome of the decline in enset cultivation and the dominance of eucalyptus trees on steep forestland that hinders grass growth. Finally, the irrigation of grazing land has entirely ceased when grasslands were converted to arable farmland (Jackson et al. 1969).

Forest and woodland management

The indigenous forest management practices have also underwent radical change as reported by a large proportion of interviewed farmers (57%). Interviews with elders further identified endangered tree species such as *Cordia africana* and *Aeschynomene elaphroxylon*. The decline of scared forest cover is a result of significant changes in farming practices and farmland expansion (97% of the respondents) along with increasing fuelwood demand (83% of the respondents).

Sacred forests have been highly affected by human activity in the recent past. A major threat to forests has been the informal felling and collection of wood for fuel, building materials and for sale. In most cases, trees with high market value are selectively logged, as for example the Hagenia tree, which is one of the most exploited tree species and currently on the verge of disappearance from the forests. Large numbers of sacred forest trees were felled during the government upheaval in the 1990s. Moreover, while the land surrounding sacred forests was used for grazing in the past, in the last decade, most of this grassland has been converted to cultivated land due food shortages. Respondents expressed fears that forests could be further encroached upon in the near future.

Grazing a large number of cattle within (or along) the borders of sacred forests can also affect the forest itself. As already mentioned, above the shortage of grassland means that cattle grazing inside sacred forests becomes increasingly popular among local communities. Intensive grazing adversely affects the regeneration of trees and other plants, while soil compaction is caused along footpaths inside (and along) forest edges due to cattle movement.

Intensive farming system

Common farming practices in the Gamo Highlands such as cultivating different crop types on one field (multiple cropping) and intercropping can spread risk of crop failure and maximize return on land investment. However, several of the interviewed farmers are abandoning such traditional practices and are shifting towards mono-cropping. Furthermore, this shift towards mono-cropping entails the replacement of indigenous crop varieties that can have important ramifications to the indigenous farming systems, including the decline of the genetic pool of crops (agricultural biodiversity).

For example the black variety of barley has disappeared from the area due to its low output and the introduction of barley types that give higher yields. Other barley varieties, as well as varieties of enset, maize, and potato have also decreased significantly,[6] including from the adjacent lowland areas (Belachew 2002). The main reasons for these important changes to the traditional farming systems can be attributed to younger inhabitants returning from urban areas to rural areas, where they start growing new crop varieties, including cash crops (Belachew 2002). Some of the highland farmers that moved to lowland areas of the Rift Valley also adopted different crops types and varieties. Finally, the transportation and increasing economic significance of cash crops for rural livelihoods are also important factors for the loss of indigenous crops.

Discussion

ILK is receiving growing attention in international academic discourse. For example, the ongoing work programme of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has demonstrated the significance and relevance of ILK systems for the sustainable use and management of biological resources (Diaz et al. 2015; Löfmarck and Lidskog 2017; Tengö et al. 2017; Kok et al. 2017; Pascual et al. 2017). ILK is also receiving attention within the sustainability science community as discussed in a recent special issue in Sustainability Science (Johnson et al. 2016), but it still remains an under-researched topic in Africa. A first step towards merging insights from ILK and modern science is to document the existing ILK resource management systems in Africa, such as those of the Gamo Highland, and understand what factors drive their change.

As already mentioned, the Gamo Highland is characterised by high population density and small land holdings (see the previous sections). The area has possibly surpassed its carrying capacity since the 1960s (Rahmato 2009). Land scarcity is becoming even more acute considering that the existing land parcels have to be further divided and shared to children in each generation. Moreover, the lack of off-farm employment opportunities keeps local communities heavily reliant to the cultivation of family farmlands. These factors contribute to the enormous pressure on land observed the Gamo Highlands.

To cope with this land scarcity (and the factors that exacerbate it), local farmers have developed ILK systems to manage efficiently land and other resources. This includes the development of highly intensified cultivation systems, the use of drought tolerant plants such as enset (as well of other local crop varieties), and crop rotation and intercropping (Table 5). Of key importance for ensuring sustained levels of agricultural production in the area are ILK practices related to soil conservation and fertility such as the development of indigenous terraces,[7] tree cultivation, and various cultivation techniques such as manuring, use of leaf litter, composting, and fallowing. These ILK practices are used in various ways and extents, depending on the severity of soil fertility decline, the topography, and the economic significance of the crops (Tegene 2002; Eyasu 2002; Moges and Holden 2008). It is highly possible that if such ILK practices had not been implemented in the area over centuries, local communities would not have survived (Rahmato 2009).

Social organization and commitment are other factors that have contributed to the long-term success of the indigenous land management practices. In particular, the unique social organization has played a significant role in successfully constructing and maintaining the indigenous terraces. The link between people and land has been very strong, with local communities putting tremendous effort to take the best care of their land. Indigenous terraces are embedded in the local culture and are a testimony of Gamo Highland hard-working culture. Some social norms dictate that if persons do not maintain or construct terraces on their farmland, they are considered to be lazy farmers. In addition, the community may also for such reasons fine or cast out from social interaction community members, which further implies communities' appreciation towards agricultural work and the value placed on land.

Societal rules, regulations, and bylaws have also contributed significantly to the maintenance of sacred forests and grassland in the Gamo Highland.[8] Examples include the rules and regulations regarding access to (and use) of wood from sacred forests. For example, if someone is caught violating the rules by cutting or collecting wood, he or she has to pay a sheep as punishment that will be sacrificed inside the sacred forest. To implement communal

[6] It is worth mentioning that some crops such as sisal (*Agave sisalana*) and rice that were introduced later into the area (e.g., sisal was introduced by Italians during the occupation period from 1938 to 1943) were abandoned soon after.

[7] Terracing is also practiced and in other parts of Ethiopia such as Konso (southern Ethiopia) where the local terraces have been designated a UNESCO world heritage site, south Shewa (central Ethiopia), and the Hararghe plateau (eastern Ethiopia) (Westphal 1975; Asrat et al. 1996; Krüger et al. 1996; Besha 2003; Watson 2009).

[8] Such community bylaws are prevalent and in other parts of Ethiopia. For example, Yami et al, (2013) discuss such bylaws for the community management of exclosure forestland in Tigray, northern Ethiopia.

Table 5 Characteristics of ILK practices in the Gamo Highland

ILK practices	Practitioners	Purpose	Approach and outcome
Intensive farming systems	Family farmers	Ensure household food security and livelihoods through the efficient use of land	Maximize agricultural production per unit of land
Crop diversification			Reduce crop production failure by growing multiple crop varieties on the same plot
Intercropping crop rotation			Cope with drought by cultivating drought resistant crops
			Diversify income by tending livestock
Grazing land management	Local community and locally elected people (watchman)	Ensure economic sustained benefits for the entire community by reducing grazing land degradation	Ensure that cattle feed is available at regular periods of time through the periodic prohibition of grazing
			Implement various social rules and norms to manage the communal grazing land
			Steep social consequences for those that breach the rules and norms
			Reduction of grazing land degradation and enhancement of social cohesiveness
Forest/tree management	Local community and individual farmers	Protect forest habitats and tress of economic and social significance	Protected sacred forests are found scattered throughout the Gamo Highland
Sacred forest			Cultivation of tree species with a high economic value (e.g., apples) in farm borders and slopes
Old and newly planted trees close to village a			Tree cover reduces soil erosion and enhances soil fertility in sacred forest and farmland
Old trees on farmlands			Income diversification by beekeeping and selling timber
			Maintain biological diversity and traditional values (e.g., rituals) based on trees
Soil management	Groups of local residents	Conserve soil and maintain its fertility through the use of various agricultural technique	Build terraces as a means of reducing soil erosion and allowing the cultivation of slopes
Terracing	Neighbors		manuring and fallowing practices to preserve soil fertility in agricultural areas
Manuring	Farmer families		Decreased soil erosion and runoff/flooding down slope
Fallowing	Females (particularly for manuring)		
Cultivate grass and trees along strips			

rules in grasslands, the local communities elect watchmen (known as kalomura). Local communities are ethically responsible to cooperate with the watchmen in observing the local rules, whose violation is a serious breach of the traditional law and a taboo to the community. It is believed that breaking the rules will precipitate crop failure, epidemics, and other calamities, so the punishment for those who violate the rules extends as far as to cast them out of the society. However, it is rare to find these breaches of bylaws, particularly in the recent past, as grazing land is common property used by every farmer without any discrimination.

Another reason for the long-term success of ILK practices, and especially terracing, is the farmers' own psychological makeup. Terrace design is based on farmers' perception of the pertinent local problems that affect directly their livelihoods such as soil erosion, and the scarcity of land, material, and labour. Such problems have shaped extensively the design, planning, and construction of terraces, and have massive psychological significance to enhance self-reliance and feelings of empowerment.

However, such ILK practices in the Gamo Highland have been experiencing unprecedented change, especially since the 1970s. Several local resource management systems have been modified, changed, and/or abandoned (Table 6). Such an example is the decline (and on occasion total abandonment) of fallowing practices, the modification of crop rotation, and the almost complete abandonment of manuring as a soil management practice. The traditional terraces have also experienced neglect, with most existing terraces lacking maintenance, and only few sporadic attempts to construct new terraces. Sacred forests and communal grazing land are

Table 6 Drivers and outcomes of environmental and socioeconomic change related to ILK practices in the Gamo Highland

Drivers	Mechanisms	Outcomes
Population pressure	High scarcity of cultivated land, as land is currently shared and distributed to the children	About two-thirds of the interviewed farmers own land parcels smaller than 0.5 ha per household
	Shortage of grazing land, because large area of grazing land (particularly privately owned) is converted to cultivated land	About 37% of grassland in the highland areas have been converted to cultivated land between 1973 and 2006
		Cattle grazing inside sacred forests
		Decline and abandonment of fallowing practices
		Reduction of manure availability (and manuring)
Economic drivers	Lack of off-farm employment keeps the local communities heavily reliant on the cultivation of their farmland (further contributing to the enormous pressure on land)	Illegal logging of sacred forests and timber sales to surrounding towns
Lack of off-farm employment		Dominance of eucalyptus trees which prohibits the growth of grass
Insufficient income		Cattle grazing inside sacred forests
Expansion of cash crop cultivation		decline and disappearance of some forest species
		Mono-cropping (especially of cash crops)
		Disappearance of some local crops species and varieties
		Replacement of enset cultivation by cash crops
Social dynamics and cultural changes	Modification and violation of local rules and regulations related to resource use	Changes in forest management and use regimes established and practiced by society in the past
	Introduction of ox ploughs	Demolition of terraces and field expansion between former terraces to allow the use of ox ploughs that require wider spaces
	Migration of youth to the nearby town	Lack of terrace maintenance due to its labour-demanding nature
Land tenure and government policy	Lack of incentives for ILK practitioners as only those that practice newly introduced soil and water conservation practices receive support from the government	Farmers are reluctant to invest on the long-term conservation of soil and water as they fear losing access to their land
	Policies have banned the selling and buying of land since 1974.	ILK practices are not considered valuable by policy-makers
	Top-down soil and water conservation approaches that lack appreciation for ILK practices	

also at risk of misuse and deterioration. The latter have been converted to cultivated land, with grazing land irrigation almost entirely discontinued upon conversion to farmland. The dominance of exotic trees on forestland and steep slopes such as eucalyptus prohibits the growth of grass, which further exacerbates the scarcity and subsequent deterioration of grazing land.

These changes can be attributed to various factors, and especially the shifts in the dominant livelihood activities towards cash crops (see the previous sections). However, the prevailing land tenure systems and the agricultural policy of the government that has banned the sales and purchases of land have further aggravated the loss of ILK practices. Currently, the only way to gain access to land is by share-cropping and leasing as all land has been state property since 1974. As a result, farmers are reluctant to invest in long-term soil conservation measures, as the land might be taken by the government and redistributed to others.

Conclusions

Farmers and local communities in the Gamo Highland have developed a wide range of local practices to manage effectively farmland, forests, grazing land, and soil. These practices are based on ILK that has entailed the investment of the skills, labour, energy, and knowledge of local communities over generations in. These ILK practices include, among others, the construction of terraces to manage local agro-ecosystems, and the conservation of forests and grazing land. However, the significance of these practices based on ILK accumulated over generations goes beyond their contribution to land productivity and rural livelihoods. They are an integral part of the identity and the sense of place of local communities contributing manifold to the resilience of the local socio-ecological systems. This ILK has been ingrained in the traditions of local communities and is a major part of the cultural landscape, not only for the region and Ethiopia, but also for Sub-Sahara Africa.

It is important to preserve and promote such management practices through the productive cross-fertilisation of ILK with modern science. In this respect, by identifying key ILK practices in the Gamo Highland (and their driver of change), this study can provide valuable information for decision-makers and land use planners on how to enhance the sustainability of resource management systems by integrating elements informed by ILK.

Land use planners and environmental managers should not only consider land rehabilitation but also consider how the attributes of local ILK management systems have raised agricultural productivity and have contributed to the survival of local communities for hundreds of years under adverse environmental and socioeconomic conditions. Most importantly, the design and implementation of sustainable land management and farming systems should be entail the participation of local communities and recognize and protect ILK practices.

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