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Research Article

Evaluating farmers' perception on soil erosion and management of physical soil and water conservation measures in southwest Ethiopia

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Article Info

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Abstract

Land degradation is one of the major challenges affecting soil quality and food security. To control erosion, soil and water conservation (SWC) measures such as bunds are implemented. However, farmers' perception of erosion and management of introduced SWC measures are poorly documented. Therefore, this study is aimed to assess the farmers´ perception, adoption, and management of physical SWC in the Fanta watershed, southwest Ethiopia. Data were collected by interviewing 128 randomly selected households from three kebeles (lowest administration unit), which were beneficiaries of the Productive Safety Net program that incentivizes SWC activities in the region. In addition, focus group discussions were carried out. Results showed that 75% of farmers categorized soil erosion on their farmland as severe, and 40% of farmers experienced gullies. As a result, the majority of the farmers (87%) believe that there is a decline in soil fertility. Farmers (66%) practice traditional techniques such as short fallowing and diversion ditch to control erosion. After the construction of government-supported physical SWC measures such as soil bunds, in the past ten years, 66% of the farmers observed a decrease in soil erosion, and 93% of the farmers perceived improvement in soil fertility. However, 38% of the farmers do not repair the constructed SWC measures expecting external incentives. Age of farmers had a negative association, while education level, the slope of the field, training, and extension service had a positive effect on the adoption and management of physical SWC conservation measures. Without soil bunds, soil fertility decreases, but the adoption and management of conservation measures are under incentive syndrome. In the study watershed, continued awareness creation activities could enhance farmers' participation and commitment to the adoption and repairing of physical SWC measures. **Keywords:** crop yield; Productive safety net program; sustainability; incentive; repairing conservation structure; soil bunds

1 Introduction

Ensuring and sustaining global food security and environmental safety rely on soil quality. The mismanagement of physical land resources could adversely affect soil quality. Soil erosion has been among the major processes challenging soil quality. Soil erosion removes 36–75 billion tons of soil every year across the world (Pimentel & Burgess, 2013; Borrelli et al., 2017). About 80% of the global soil erosion is due to agricultural activities (Pimentel, 2006). The removal of soil organic carbon and nutrient-rich topsoil by erosion affects soil quality and land productivity, implying adverse effects on food security. Deposition of sediment in aquatic ecosystems and flood plains could have negative effects on the functioning of dams, water quality, and ecosystem (Wolancho, 2012). The agricultural activities of Sub- Saharan Africa (SSA) have been affected by severe soil degradation due to erosion, which on average removes 35–75 t of soil ha-1 yr-1 (Tamene and Le 2015). In countries such as Rwanda soil loss of up to 420 t ha-1 yr-1 was reported in cropland (Karamage et al., 2016). Conventional agriculture in the sloping highlands of Ethiopia, where the majority of the population inhabits, caused severe soil erosion that removes about 2 billion tons of soil every year (Bewket, 2007; FAO, 2019). In Ethiopia, about 10 million people are food insecure, e.g., in 2020 (IPC, 2020), for which soil degradation through erosion and nutrient depletion is one of the important contributing factors. About 50% of the total soil loss in Ethiopia originates from cropland, in which more than 30 t ha^{-1} yr^{-1} of soil eroded (Hurni, 1993; Haregeweyn et al., 2015; FAO, 2019).

On cultivated lands, scientists and farmers developed, tested, and practiced soil and water conservation techniques such as fallowing, crop rotation, and soil and stone bunds (Critchely et al., 1994; Giller et al., 2009; Wolka et al., 2018). Many countries in SSA have practiced combinations of soil and water conservation measures in erosion-prone as well as water-scarce areas. In Ethiopia, indigenous soil and water conservation measures such as fallowing, crop rotation, traditional diversion ditches, agroforestry, and stone bunds have been implemented for centuries (Ali & Surur, 2012; Mushir & Kedru, 2012; Dotterweich, 2013; Mulat, 2013). Institutionalized soil and water conservation measures, particularly bunds, were implemented in the past five decades following the severe soil degradation and drought as well as food insecurity concerns (Abera et al., 2019). Recognizing the positive effects of earlier interventions and the need for wider implementation, since 2011, the government of Ethiopia implemented a new approach, national physical soil and water conservation campaign that run for about two months (January and February) every year throughout the country. The campaign is aimed to mobilize the community to construct expert-recommended soil and water conservation measures following the principles of watershed management. This was coordinated by the local development committee. Some studies claimed that this approach contributed considerably to the rehabilitation of the agricultural landscape despite some technical and management weaknesses as work annually focuses on building new structures with little attention to monitoring the previous works (Meshesha & Birhanu, 2015; Wolancho, 2015; Assefa et al, 2018, 2021).

The physical SWC measures are considered as an investment for which significant benefits are expected later and for years to come. The short-term effects of physical soil and water conservation measures such as bunds and Fanya juu are reduction of slope length and surface runoff. The progressive deposition of sediment above the physical measures could reduce inter-bund slope and form bench terraces over a long time. Previous studies indicated that bunds reduce more than 50% of soil loss (Adimassu et al., 2014; Wolka et al., 2018). Bunds have various effects on crop yield, ranging from no effect to a positive role on the yield (Herweg & Ludi, 1999; Adgo et al., 2013; Adimassu et al., 2014).

The adoption and management of improved physical SWC technologies in developing countries have attracted much attention from scientists and policymakers mainly because land degradation is a key problem for agricultural production (De Graaff et al., 2008). Adoption and management are processes expected to pass steps including acceptance, implementation, and continuous management including repairing, which is highly linked to farmers' perception. Farmers may wait for visible evidence such as gullies, the severe form of erosion, to accept soil and water conservations. Teshome et al. (2016) reported that farmers are aware of the negative consequences of soil erosion and the need for conservation, particularly when erosion creates visible features such as rills and gullies. Adoption and management of introduced soil and water conservation measures are affected,

for example, by the socio-economic status of farm households, topography, and institutional arrangements. Farmers' decision to adopt soil conservation measures is influenced by their perception of erosion hazards and types of structures and their attributes (Bewket, 2007). In Zimbabwe, the management of dead level contour for soil and water conservation is influenced by resource ownership of the household (Munamati and Nyagumbo, 2010). Amsalu and De Graaff (2007) reported that farmers' age, land area owned, and the slope of cultivated land are among the factors influencing conservation structures adoption and management in the Beressa watershed of central Ethiopian highlands. Education, extension service, training, and age of farmers affect the adoption of physical soil and water conservation measures in the south Wollo zone of Ethiopia (Asfaw & Neka, 2017). In southwest Ethiopia, land area, age, household labor, and education affect the adoption and management of soil and water conservation measures (Anley et al., 2007). Mekuriaw et al. (2018) reported that government-based incentives had a positive effect on adopting soil and water conservation measures. In general, farmers' adoption and management of soil and water conservation measures vary geographically due to socio- economic, environmental, and institutional circumstances (De Graaff et al., 2008; Teshome et al., 2016), and thus results in farmers' perception, and adoption remain inclusive.

In the Fanta watershed of southwest Ethiopia, physical soil and water conservation measures were introduced to food insecure areas in 2005 through the Productive Safety Net Program (PSNP). Soil degradation and drought affect the food security of the rural households of this watershed. To reduce the effect of erosion and soil degradation, the PSNP has implemented incentivized physical soil and water conservation measures such as soil and stone bunds, Fanya juu, and cutoff drain. The public campaign works also constructed conservation measures in this watershed. However, some farmers do not manage the constructed conservation measures sufficiently, and thus, the measures could not

serve effectively in controlling erosion. Farmers rarely construct conservation measures by investing their family labor, instead, wait for incentive-based government projects or public campaigns. In the region, the farmers' perception of soil erosion and adoption and management of introduced physical soil and water conservation are not well documented. Therefore, this study aimed to assess the farmers´ perception, adoption, and management of physical soil and water conservation technologies that were introduced to the mountainous food insecure Fanta watershed.

2 Materials and methods

2.1 Description of the study area

The study was conducted in the Fanta watershed, Omo-Gibe River basin, southwest Ethiopia. Geographically, the watershed is situated at 7°17'30"–7°20'30"N latitude and 37°17'10"–37°19'40"E longitude (Figure 1). The watershed drains to Gibe III hydro-electric dam on Omo River, Dawuro zone. The Omo-Gibe River basin, on the Omo River, has three hydroelectric dams and the fourth, the Koyisha dam, is under construction implying the economic, environmental, and political importance of the area. Fanta watershed covers about 4230 ha and is characterized by steep slopes, mountains, valleys, and a small plateau with an altitudinal range of 1000–2860 m above sea level. The mean annual minimum and maximum temperatures are 15.1°C and 27.5°C. The mean annual rainfall is about 1400 mm. In the area, soil types such as Nitisols and Leptosol are dominant (SNNPRS-BOFED, 2004). Subsistence crop-livestock farming of the area relies on rainfall, which is commonly in between March and September with a short break in May/June. Crops such as maize (Zea mays), teff (Eragrostis tef), sorghum (Sorghum bicolor), and barley (Hordeum vulgare) are cultivated, while enset (Ensete ventricosum), a staple food in the region, grows together with other perennials, e.g., tree, coffee and fruit tree at home garden. Cattle (Bos taurus) and goats (Capra aegagrus hircus) are common livestock. Livestock production is an essential part of the farming system as nearly all seedbed preparations are done with oxen-driven plows.

2.2 Sampling and data collection

Farmers' perception of soil erosion as well as adoption and management of physical soil and water conservation measures were assessed using household interviews and focus group discussions. The Fanta watershed was chosen due to the reasonable years (15 years) of experience in the introduced physical soil and water conservation measures in the region, which have been supported by the Productive Safety Net Program. For the interview, 128 (95 adopters and 33 non-adopters of the introduced representing ˜8% of the total households, were randomly selected from three kebeles (lower government administration unit), viz. Beza Shota, Bodola Mamado, and Mela Galda (Table 1). Those kebeles of the Fanta watershed were purposively selected considering accessibility, soil erosion features, and implementation of the introduced physical soil and water conservation measures. Heads of the household responded to face-to-face interviews based on a structured questionnaire. The questionnaire included socio- economic characteristics (e.g., age, farm size, family size, livestock owned) of the household, physical SWC measures households, challenges in agricultural land management perceived severity of soil erosion on the farmland, implemented land management practices and technologies to prevent soil erosion, effects and limitation of the soil and water conservation measures, and challenges in adopting and repairing physical soil and water conservation measures. Furthermore, three focus group discussions, one in each kebele, were carried out. In each focus group, 8–12 heads of household, representing different villages and experiences in managing soil and water conservation techniques, were participated. The discussion was focused on soil erosion severity, mitigating erosion, benefits of the introduced soil and water conservation measures, adoption of physical soil and water conservation measures, factors determining adoption of physical soil and water conservation measures, and challenges in repairing the constructed conservation structures.

2.3 Data analysis

Quantitative data were analyzed using a statistical package for social sciences (SPSS) computer software (version 20). Descriptive statistics were used to assess the socio-economic characteristics of respondents as well as erosion impacts on the livelihood of subsistence farming. Implementation of erosion mitigation measures and effects of conservation measures on soil and crop yield were evaluated using mean and percentage values. A binary logistic regression model was applied to evaluate factors affecting farmers' adoption of the physical soil and water conservation measures. In the binary logistic model, two categories, viz. adopter and non- adopter, and selected independent parameters including sex, age, education level, family size, number of farm plots, farmland area, the slope of farmland, livestock, extension service, and training were tested. Odd ratio, Wald statistics, and significance level of $p<0.05$ were used for data interpretation.

3 Results and discussion

3.1 Socio-economic characteristics of the households

Ninety-five percent of the respondents were from male-headed households. About 95% of the household heads were below 65 years old (Table 1), implying many of the farm heads can engage in tasks requiring intensive labor such as soil bund construction. The majority of the respondents, about 60%, have a family size of 3– 7. Among the residents of the Fanta watershed, 41% are illiterate, which indicates the considerable proportion of farmers having limited access to information including literature and radio in different languages. This could have a negative effect to understand technological options including the soil and water conservation measures and their management and performance.

More than 75% of the farmers own farmland of less than ˜1 ha, indicating farmland scarcity that could result in continuous cultivation of the land to sustain subsistence crop-livestock mixed livelihood. The results showed that the livestock, on average about 2 livestock per household, mainly feed on cultivated fields (35.9%) during the off-cropping season, and on community grazing land (31.3%). The grazing of livestock on cultivated land would remove residue and thus, degrade the land. Livestock tramples and damages the constructed bunds of the cultivated lands. The result indicated that 90% of the respondents had access to agriculture and natural resource extension services. In the study area, the extension service is a major means to provide agriculture and natural resource information, with

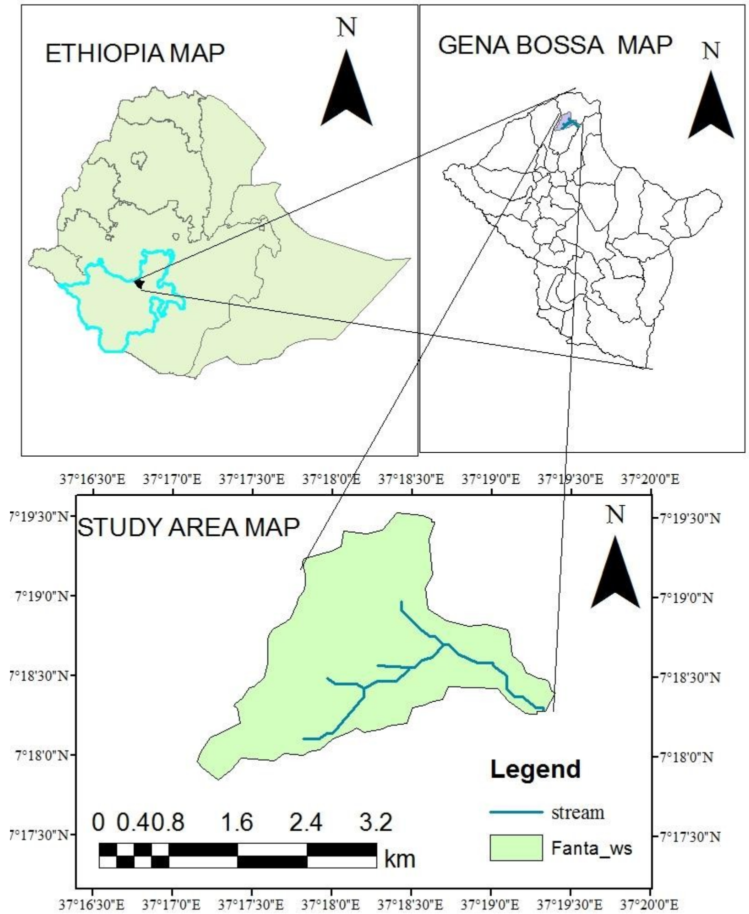

Figure 1: Map of the Fanta watershed in the Omo-Gibe river basin

basic principles and demonstrations of agricultural inputs application, forest development, soil and water conservation, and livestock production. This could be the main information source for illiterate farmers.

3.2 Soil erosion and effect

In Beza Shota, Bodola Mamado, and Mela Galda kebeles 90%, 93%, and 80% of the farmers have cultivated land on moderate to steep slopes, respectively, implying susceptibility to soil erosion by water. In the area, soil erosion happens, at least to a certain extent, on all farmers' cultivated land as perceived by the majority of the respondents (Table 2). About 75% of farmers had severe soil erosion that forms visible features such as rills and gullies, where soil erosion formed gullies on plots of 40% of the farmers. About 87% of the farmers experienced soil fertility decline due to soil erosion, adversely affecting crop yields and food security. Focus group discussants explained that, three decades ago, croplands were more fertile and productive than their present condition, and currently their lands do not give sufficient yield unless inorganic fertilizer is added. This indicated that soil erosion is a problem in the area. Studies in the Omo-Gibe basin, and Lake Awassa watershed reported that farmers recognize soil erosion based on visible erosion features and a significant decline in crop yield (Moges and Holden; Betela and Wolka, 2021). Farmers who replied soil erosion as a major problem in the farming system were asked to explain the main causes of erosion, and about 80% replied overgrazing and cultivation of steep slopes, while 61% perceived deforestation. In the study area, cattle graze freely after crop harvest, which could increase soil erosion due to the removal of residue cover and compacting of the soil. Livestock damages constructed physical soil and water conservation measures. Cultivation of sloping land becomes common practice due to the nature of topography in the area and increasing demand for land and production. Lack of alternative livelihood to agriculture, low awareness, and poor land use policy has contributed to plowing on steep slopes, which without appropriate soil and water conservation measure could result in severe soil erosion. Conventional cultivation on steep slopes is widespread in the region and in the country (Asfaw and Neka, 2017; Wolka et al., 2018), which requires awareness creation and land use policy implementation.

About 95% of farmers reported that soil erosion reduces soil fertility, while 60% perceived yield decline, and 32% of the farmers abandoned their land due to severe erosion such as gully formation and severe removal of topsoil. The yield decline and abandoning of cultivable plots negatively affect production and food security. The effect of soil erosion on soil fertility and yield is expected to be higher than perceived by the farmers as farmers could sense only the visible features of erosion and a considerable decline in crop yield.

Table 1: Socio-economic characteristics of respondent households in the Beza Shota, Bodola Mamado and Mela Galda kebeles of the Fanta watershed, Omo-Gibe river basin of southwest Ethiopia.

Respondents socio-economic characteristics	Kebeles			Total (n=128)
	Beza Shota (n=43)	Bodola Mamado (n=42)	Mela Galda (n=43)	
	%	%	%	%
Age, year				
<25	9.3	7.1	11.6	9.4
25-35	9.3	14.3	18.6	14.1
35-45	18.6	26.2	30.2	25.0
45-65	60.5	45.2	34.9	46.9
>65	2.3	7.1	4.7	4.7
Family size, number				
1-3	16.3	21.4	14.0	17.2
3-7	67.4	50.0	55.8	57.8
8-10	14.0	21.4	25.6	20.3
≥11	2.3	7.1	4.7	4.7
Formal education level, grade				
Illiterate	39.5	47.6	37.2	41.4
Primary (1-4)	27.9	35.7	32.6	32.0
Secondary (5-8)	23.3	14.3	18.6	18.8
Above secondary	4.7	2.4	11.6	7.8
Land size, ha				
<0.25	14.0	7.1	4.7	8.6
0.25-0.5	32.6	19.0	16.3	22.7
0.5-1	39.5	47.6	51.2	46.1
1.0-5.0	11.6	19.0	23.3	18.0
>5	2.3	7.1	4.7	4.7

4 Soil and water conservation in Fanta watershed

In the study area, to limit the effect of soil erosion on croplands, many farmers practice traditional land management practices such as fallowing (42%), crop rotation (76%), cutoff

drain (83%), contour cultivation (55%) and mixed cropping (78%). Similarly, a study in the Chencha area of southern Ethiopia reported that farmers have experiences in characterizing the severity of soil erosion and practice indigenous conservation measures to mitigate the effect of erosion on land degradation (Engdawork and Bork, 2014).

Traditional cut-off drains, a small ditch constructed on cultivated fields using oxen- driven plow, are the widely used erosion controlling practice in the Fanta watershed. Traditional cut-off drains are constructed to allow excess water to drain out of cultivated land and are also practiced in other parts of the country (Ali & Surur, 2012; Mulat, 2013). The majority of adopter farmers implemented soil bunds (92%). Other physical SWC measures such as stone bunds (48%), check dams (35%), cut-off drain (39%), and *Fanya juu* (12%) were implemented in the area by a considerable proportion of farmers. Physical SWC measures, which were built on farms and rangelands for soil and water conservation, could reduce surface runoff and increase infiltration (Desta et al., 2005). As result, 66% of the farmers, in our study area, observed less soil erosion by water on plots with soil bunds, and 93% of the farmers perceived improvement in soil fertility. Thus, due to soil bunds, 71% of the farmers perceived an increase in crop yield. Furthermore, focus group discussants explained the positive effects of physical soil and water conservation measures

in reducing soil erosion and improving soil fertility and crop yield. Related studies by Wolka et al., (2018) also reported that implementation of physical soil and water conservation such as soil and stone bunds and Fanya juu increased soil fertility and consequently improved crop yield in the west and south Ethiopia. Abdallah et al. (2014) reported that SWC measures increase maize yield in Ghana. The positive effect of SWC measures in the present study area could be associated with surface runoff and soil loss protecting the ability of the physical conservation measures.

5 Sustainability of physical SWC measures

Farmers (100%) and focus group discussants reported the damage to constructed SWC measures (Table 3). Soil erosion preventing capacities of soil and water conservation measures, e.g. soil bunds, depend on their potential to retain surface runoff. The soil and water conservation structures can be damaged due to sedimentation, trampling of freely grazing livestock, and planned removal by landowners as reported by 71%, 94%, and 20% of respondents, respectively. In the study area, cultivated land is exposed for intensive

Table 2: Perceived soil erosion severity in the Beza Shota, Bodola Mamado and Mela Galda kebeles of the Fanta watershed of Omo-Gibe river basin, southwest Ethiopia.

Perceived soil erosion problem and conservation effect	Kebeles			Total
	Beza Shota (n=43) %	Bodola Mamado (n=42) %	Mela Galda (n=43) %	(n=128) %
Have you experienced soil erosion on any of your plot?				
Yes	100	100	100	100
No	0.0	0.0	0.0	0.0
What is the extent of soil erosion problem?				
Severe	74.4	83.3	67.4	75
Moderate	23.3	16.7	27.9	22.7
Slight	2.3	0.0	4.7	2.3
What effects do soil erosion have?				
Reduce soil depth	81.4	61.9	90.7	78.1
Difficulty during plowing	30.2	40.5	20.9	30.5
Soil fertility decline	95.3	88.1	76.7	86.7
Gully formation	53.5	45.2	27.9	42.2
Abandon the land	34.9	47.6	14	32
Yield decline	67.4	54.8	62.8	61.7
To what extent soil erosion occur after constructing conservation structures?				
Severe	7.0	11.9	7.0	8.6
Moderate	34.9	45.2	37.2	39.1
Low	58.1	42.9	55.8	52.3

grazing during the off- cropping season, which could damage the constructed structures. In addition, focus group discussants indicated that cultivation activities such as cultivating close to the structures, in inter-bund areas could damage the constructed SWC measures. Few farmers remove some of the structures in order to use the fertile sediment retained above bunds, which challenges the sustainability of the built structure. To sustain the erosion-controlling role of physical soil and water conservation measures, periodic repairing is essential. About 62% of the respondents

expressed their commitment to repairing the destroyed parts of constructed physical soil and water conservation measures through sediment excavation and managing riser of bunds (Table 3), but 38% stated that they did not maintain the bunds. Within group discussions, farmers acknowledged the introduced physical SWC measures and widely accepted their effectiveness and the potential to improve land productivity. Nonetheless, sustainability of the already constructed structures and adoption of new conservation measures at the farm level appeared below expected, which is due to the farmers' expectation of incentives to repair the constructed conservation structures. Focus group discussants also debated on this issue and agreed that farmers wait for incentives, e.g., from PSNP to repair and construct physical soil and water conservation measures. The other weakness is that the government and development partners are more focused on constructing new physical SWC measures than repairing the previously constructed measures,

implying poor monitoring, evaluation, and enforcing or encouraging sustainable management and use. Furthermore, without the government supported-incentive, many farmers did not construct physical soil and water conservation measures including soil bunds, indicating that adoption of physical SWC is incentive-driven. More than 80% of the farmers mentioned reasons for not sufficiently repairing the constructed SWC measures including lack of awareness, measures occupying cultivable land, labor shortage, and inconvenience of the structures for cultivation practices. This suggests the need for revisiting the approach. To sustain the productivity of the land, farmers should invest, e.g., by controlling erosion and other processes of degradation. The incentive-based conservation can be considered as a step to demonstrate technologies, otherwise, expecting incentives for construction and repairing could not help for realizing sustainable land management.

6 Farmers' adoption of physical SWC measures

Most of the local farmers acknowledged the introduced physical SWC technologies as effective measures in controlling soil erosion and improving land productivity. However, many farmers did not show interest to repair the constructed measures. In addition, the non- adopted farmers did not initiate constructing, e.g., bunds by themselves, implying little chance for farmer-to-farmer diffusion. Rather many farmers rejected newly introduced physical SWC mea-

Table 3: Farmers' response on repairing the constructed physical soil and water conservation measures in the Beza Shota, Bodola Mamado and Mela Galda kebeles of the Fanta watershed, Omo-gibe river basin of southwest Ethiopia.

Respondents characteristics	Beza Shota		Bodola Mamado		Mela Galda		Total	
	n	%	n	%	n	%	n	%
Is there any destroyed soil bunds?								
Yes	34	100	29	100	32	100	95	100
No	0	0.0	0	0.0	0	0.0	0	0.0
If "Yes", what destroys it?								
Planned removal by cultivation	7	20.6	9	31.0	3	9.4	19	20.0
High rainfall	29	85.3	21	72.4	18	56.3	68	71.6
Livestock	32	94.1	28	96.6	29	90.6	89	93.7
Do you repair the bunds?								
Yes	25	73.5	17	58.6	17	53.1	59	62.1
No	9	26.5	12	41.4	15	46.9	36	37.9
If yes, how do you repair it?								
Excavating sediment	3	12.0	1	2.9	4	23.5	12	20.3
Planting vegetation on bund	8	24.0	9	52.9	3	17.6	18	30.5
Stabilizing by leaving the riser slope with grass cover	6	32.0	4	23.5	7	41.2	19	32.2
Increasing bund height	19	76.0	16	94.1	14	82.4	49	83.1
Stabilizing the damaged bunds with stone and soil	23	92.0	17	100	17	100	57	96.6
If not repair, why?								
Erosion is minimal	0	0.0	0	0.0	0	0.0	0	0.0
Difficulty for ploughing	8	88.9	9	75.0	12	80.0	29	80.6
Labor shortage	8	88.9	10	83.3	13	86.7	31	86.1
Structures occupy plot area	9	100	8	66.7	15	100	32	88.9
Lack of awareness	9	100	12	100	14	93.3	35	97.2

Note: n= number of respondents

sures even though they were aware that adoption of the conservation technology improves the productivity of their lands. These could be associated with socioeconomic and institutional factors in the implementation of the technology as part of the agricultural production systems.

The binary logistic regression model showed that sex, family size, number of farm plots, and land size showed no significant association with the adoption of introduced physical SWC measures. Whereas, age of the household head, education level, slope of the land, frequency of contact with extension workers, and access to training opportunities had significant ($p<0.05$) effects on the adoption of physical soil and water conservation measures (Table 4). The age of the household head showed a significant ($p<0.05$) negative influence on the adoption of physical SWC measures. The result of Wald statistics (4.404) and odds ratio also revealed that young farmers more adopted the introduced physical SWC measures than old aged counterparts. This could be because younger farmers are often educated and aware of the new technologies, while older farmers may be inclined to maintain their traditional farm management experiences. The older farmers would lack labor to construct and repair physical soil and water conservation measures as some of their sons/daughters leave. Our result supports earlier findings by Shiferaw & Holden (1999). Contrary to this, Chomba (2004) reported that the age of the household head had a positive relationship with the adoption of physical soil and water conservation measures.

The odds ratio revealed that farmers with educated household heads adopted the introduced physical soil and water conservation measures by a factor of 16 compared to illiterate household heads. The level of formal education showed a positive significant ($p<0.05$) effect on the adoption and management of the introduced physical SWC measures. Educated farmers would be more interested in the newly introduced physical soil and water conservation measures to improve the productivity of croplands. Educated farmers who are eager for positive changes have options to access information and the ability to analyze improved technologies. This agreed with the results reported by Asfaw & Neka (2017) and Sileshi et al. (2019), who reported a positive association between formal education and the adoption of physical SWC measures in northern and eastern Ethiopia. Earlier, a similar finding was also reported by Tenge et al. (2004) in the West Usambara highlands of Tanzania. Sometimes, educated farmers would prefer off-farm activities and employment opportunities that require less labor than traditional farming. However, that was not the case in our study area where educated farmers were motivated to implement soil and water conservation technologies to improve cropland productivity.

The slope of farmland influences the adoption and use of physical soil and water conservation measures significantly ($p<0.05$) and positively. About 44% and 38% of respondents have farmland on steep and medium slopes, respectively, which are susceptible to soil erosion by water. The effect of slope gradient on soil erosion by water has been well documented (Morgan, 2005; Zhao et al., 2015). The increasing erosion and soil degradation on cultivated sloping

Table 4: Binary logistic regression results of factors influencing adoption of soil and water conservation measures in the Fanta watershed, Omo-Gibe river basin of southwest Ethiopia.

Socio-economic characteristics	Coefficient (B)	Error	Wald	p-value	Exp(B)
Sex	3.448	2.807	1.509	0.219	31.430
Age	-3.118	1.486	4.404	0.036*	0.044
Education level	2.779	1.290	4.642	0.031*	16.106
Family size	-0.729	0.538	1.836	0.175	0.482
Plot number	-1.487	0.988	2.263	0.132	0.226
Land size	-0.587	0.518	1.288	0.256	0.556
Slope of the land	0.575	0.630	0.833	0.036*	1.778
Contact with extension	1.807	0.636	8.087	0.004*	6.095
Access to training	2.995	1.202	6.207	0.013*	19.991
Livestock number	-0.927	0.668	1.926	0.165	0.396

* Statistically significant ($p<0.05$)

farmlands could motivate farmers to undertake control measures. Thus, farmers owning land on steep slopes have a greater interest to accept physical SWC measures. Our study supports the findings of Bekele & Drake (2003) and Sileshi et al. (2019), who reported that slope affects farmers' decision to adopt conservation structures positively in eastern Ethiopia.

Farmers' contact with extension service providers and participation in training opportunities showed a significant ($p<0.05$) positive effect on the adoption of physical SWC measures. Agriculture and natural resource extension workers could provide information to farmers and increase willingness to implement new physical SWC measures and maintain the existing practices. Asfaw & Neka (2017) and Sileshi et al. (2019) reported that extension service had a positive association with the adoption of physical soil and water conservation measures in northern Ethiopia. Sometimes, extension service providers participate in multiple tasks and thus, the frequency of their contact with farmers would have limited importance on the adoption and management of physical soil and water conservation measures, which was not the case in our study area. Training of farmers on soil erosion and conservation had a significant ($p<0.05$) and positive effect on the adoption of physical SWC measures. The Wald statistics (1.20) indicated a significant association and the odds ratio of farmers who had access to training was greater by a factor of 19.99 than non-trained farmers to the adoption of introduced physical SWC measures. Less awareness of the functions and technical requirements of the physical SWC measures, as well as a lack of awareness of agricultural knowledge and physical SWC measures, could be major challenges. Previous studies reported better perception and knowledge of farmers about conservation could contribute significantly to the sustainable use of introduced soil and water conservation measures in Tanzania (Tenge et al., 2004) and Uganda Turinawe et al. (2015).

7 Conclusions

Soil erosion by water can adversely affect soil fertility and food security. Farmers believe that PSNP-supported physical SWC measures such as soil bunds improved soil fertility and crop yield. The sustainability of constructed physical SWC measures is a challenge as many farmers did not repair the structures on their farmland despite their observation of better soil fertility on fields with bunds than without bunds. Farmers expect government-based money or grain incentives for repairing the constructed physical soil and water conservation measures, mentioning labor shortage and unsuitability of the measures for oxen-driven plowing practice. Without an incentive, the construction of introduced physical SWC measures including soil bunds was not common. Age of the household head, education level, slope of the land, frequency of contact with extension workers, and access to training opportunities were found to influence the adoption of erosion- mitigating technologies such as bunds. We conclude that, without soil conservation measures, soil erosion was severe enough to reduce soil fertility, but the adoption and management of conservation technologies are under incentive syndrome. Continued awareness creation activities could enhance farmers' participation and commitment to the adoption and repairing of physical SWC measures.

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Competing interests

The authors declare that they have no competing interests.

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