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Research Article

Effects of integrated use of grass strip and soil bund on soil properties, Southern Ethiopia

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Abstract: Soil degradation is the major environmental and agricultural production problem in the highlands of Ethiopia. The objectives of the study were to examine farmers' use of grass strip and soil bund to minimize soil degradation, and effects of grass strip and soil bund on basic soil properties. Structured questionnaire survey and field observations were conducted to collect data on farmers' use of grass strips and soil bund to minimize soil erosion, improve soil fertility and crop productivity. Simultaneously, composite soil samples were collected from croplands treated with both grass strip and soil bund, and the adjacent lands treated with soil bund only. The statistical result indicates respondents sex, marital status, educational level, erosion degree, access to conservation information, contact with extension workers, and trainings were significantly ($P < 0.05$) and positively affect the use of grass strips while livestock and land holding sizes were significantly ($P < 0.05$) and negatively affect farmers use of grass strip. The interaction of land management practices (grass strip and soil bund) and slope positions was significantly ($P < 0.05$) affects soil clay fractions and moisture, the highest amounts was observed at lands managed with grass strip situate at lower slope position. Similarly, soil organic matter, total nitrogen, available phosphorus, and cation exchange capacity were significantly ($P < 0.05$) influenced by the combined effects of land management practices and slope positions, highest quantity of these properties were observed lands managed with a grass strip and soil bund in lower slope position. Hence, integrated use of soil bund with grass strip has a meaningful contribution for selected soil property improvement that enhances soil fertility and crop productivity.

Keywords: *grass strip, land management, soil conservation practice, soil degradation, soil erosion*

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Introduction

Water erosion induced soil degradation is one of the most destructive and widespread phenomena and realized as the key issue affecting food security. Of the total areas affected by soil degradation global, water erosion occupies 56% (Oldeman et al., 1991) and affects 80% of agricultural lands (Angima et al., 2003). Global assessment of human-induced soil degradation (GLASOD) reported, about 36% of farmlands are degraded at rates of 5-6 million ha per annum (Scherr, 1999). The problem is severe in developing countries (like Africa and Asia), most of the lands in Africa are vulnerable to soil and environmental degradation (Vlek et al., 2008). Erosion-induced soil degradation, aggravate the problems of low agricultural productivity, food insecurity and rural poverty in Ethiopia (Smith 2010). In the highlands of Ethiopia (i.e., above 1500 m.a.s.l) erosion remove over 1.5 billion tons of top fertile soils annually (Taddese, 2001). Undulated terrain conditions and erosive rainfalls in the highlands of Ethiopia coupled with detrimental farming practices worsen the problems of land degradation and make the soils more fragile. However, Ethiopian highlands hold greatest agricultural potentials and settlements; it accommodates over 88% of the human and 77% of the livestock populations of the country (Teklu, 2005). Because of this, water erosion is a serious threat to the development (e.g., economic, social, environmental) of Ethiopia (Tefera and Sterk, 2010; Amsalu and de Graaff, 2007; Pender et al., 2001; Shiferaw and Holden, 1999).

Since 1970's in collaboration with international partners, Ethiopia has made substantial efforts to introduce soil and water conservation technologies to reduce the risks of soil erosion and associated problems (Kebede, 2014). In Ethiopia the main challenges of soil and water conservation include, focus on initial construction of physical structures (e.g., terraces, bund, etc.), implement uniform technologies for all conditions (e.g., agro-ecological), fail to integrate physical structures with biological practices, top-down extension approach, and provide little attention to indigenous knowledge (Mitiku et al., 2006; Bekele et al., 2018). Because of this bottleneck, soil and water conservation efforts are less successful in the nation. Lately, the government has realized the cause failures in soil and water conservation efforts and give due attention to integrate physical structures with biological practices, enhance community engagement at various stages, and promote untapped indigenous soil conservation practices. Accordingly, in 2007 Ministry of Agriculture and Rural Development has adopted the framework of WOCAT (World Overview of Conservation Approaches and Technologies) to implement Sustainable Land Management (SLM) Program. As WOCAT framework focus on locally tried and tested techniques, the public and private partners use desho grass (*P. pedicellatum*) across the escarpment in densely populated highland for sustainable land management program (Smith, 2010).

Desho grass belongs to the family of Poaceae and native to tropical countries (Welle et al., 2006; Smith, 2010). This grass has an extensive root system and produces high biomass per unit area (Ramirez et al., 2010). In Ethiopia, the grass is discovered in 1991 at Chenecha District Southern region (Welle et al., 2006), and well adopted in different agroecology (Leta et al., 2013). This grass had been used as grass strip to protect croplands from soil erosion and degradations in highlands of Ethiopia (Welle et al., 2006; Yakob et al., 2015), to rehabilitate degraded land (Smith 2010), and to improve grazing land and livestock feeding (Welle et al., 2006; Danano, 2007). As compared to other grasses (e.g., elephant *P. purpureum*, vetiver *V. zizanioides*) used for land management practices in Ethiopia, desho grass is among the most desirable one to control erosion and rehabilitate degraded land (Yakob et al., 2015). Based on the grass's character (e.g., root system) and diverse roles (erosion control, land rehabilitation, feed for cattle), desho grass is probably widely distributed and used for land management practices in Ethiopian highlands and others countries with similar agroecology. However, farmer's use of desho grass as grass strip to protect cropland from erosion, rehabilitate degraded land and livestock feeding is uneven among farmers. Farmers' use of land management practices are affected by institutional, technological, and socioeconomic factors (Kebede, 2014). In the study area, very limited information is available on farmers' use of desho grass as grass strip, and the effects of desho grass strip and soil bund at different slopes category on soil properties. Therefore, this study aims to assess farmers' use of desho grass as grass strip to minimize soil erosion and degradation, and examine the effects of grass strip and soil bund on selected soil properties at different slopes positions.

Materials and Methods

Description of the study area

This study area is located near to Analemmo District town Fonka Hadiya Zone, Southern Nation Nationalities and Peoples Regional State of Ethiopia. It is situated between 7.54- 7.70 latitude and 37.89 - 38.06 longitudes. Analemmo is 210 km away from Addis Ababa, the capital city of Ethiopia, and bounded with Silte Zone in North, Lemo District in South, Shashogo District in East, and Misha District in West direction (Figure 1). The study area receives mean annual rainfall between 1001-1200 mm and temperature within the ranges of 15-20^{o}C. The rainfall distribution is characterized as bimodal; the small rains from March to April and the main (heavy) rain from June to October (AWOARD, 2013 unpublished). Most parts of Southern Ethiopia is dominated by schists, gneisses, granites and slates which are exposed in areas where geological erosion has been great (FAO 1986). The dominant soils of southern Ethiopia including of the study areas are Vitric and Nitisol (FAO/UNDP, 1984), Luvisols, Regosols and Cambisols (Adbacho, 1991). The average rate of population growth in South Ethiopia is 2.9% per annum with an average population density of 127 per sq.km. While in Hadiya Zone, the population density is

346 per sq.km, which is to be overpopulated and higher than the regional average (SNNPRSO, 2006). Mixed agriculture (integration of crop and livestock) is livelihood base of the community.

Methodological approach

To understand the effects of desho grass used as grass strip to stabilize soil bund at different slope positions on soil properties, composite soil samples were collected from croplands situated at upper and lower slope positions treated with both grass strip and soil bund, and adjacent cropland managed with soil bund alone (Figure 2). The sample plots were used for wheat production with uniform agronomic practices such as nutrient management and weed control practices. As presented in Table 1, total 16 composite soil samples were collected 30 cm sampling depths using an auger for chemical property and nutrient content analysis. At the same time, 16 undisturbed soil samples were collected for bulk density and moisture content determination. Past studies on farmer's participation and use of land management practices, provide lists of variables that influence farmers decision (Ervin, 1982; Tadesse and Belay, 2005). Based on information obtained from literatures, in this study, the following conceptual framework was adopted to capture variables influence grass strip use for land management practices in the study area (Figure 3).

A structured questionnaire survey was used to identify factors affecting farmers (households) use of grass strip as land management options. A simple random sampling technique was employed to choose respondent households for a face-to-face interview.

Table 1. Description of soil samples collected for laboratory analysis

Land management practices	Slope position	Replication
Soil bund alone	Upper	4
	Lower	4
Grass strip and soil bund	Upper	4
	Lower	4
Total composite soil sample		16

The farmer's list existing in village administrative centre (locally called Kebele-the smallest administrative unit of Ethiopia) has used as a sample frame for random sampling techniques. The respondent sample size was determined using Cochran (1977) formula provided for finite population (below 10000). Accordingly, 110 randomly selected respondent households were interviewed.

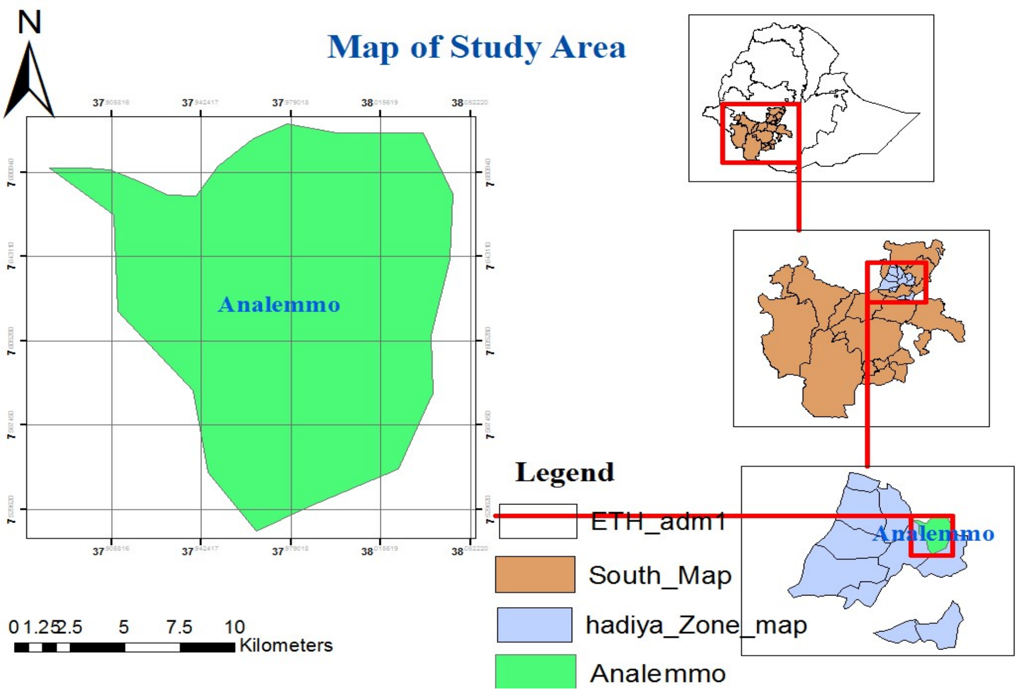

Figure 1. Geographical map of the study area

Figure 2. Partial views of bund stabilized with grass strip and bund alone

Independent variables

- Socioeconomic factors: education, age, family size
- Institutional factors: extension services, provide training
- Physical factors: landholding, livestock holding, erosion on cropland

→

Dependent variable

Utilization of desho grass for soil and water conservation

Figure 3. Conceptual framework

Soil laboratory analysis

The soil samples collected from the study area were transported to Jimma University College of Agriculture and Veterinary Medicine research and teaching soil laboratory. Before analyzing soil texture, pH, EC, CEC, OC, TN, and Av. P samples were air dried, grounded, and sieved with standard mash size. Soil particle size distribution was determined by Boycouse Hydrometer method (Houba et al., 1989) after organic matter was destroyed by addition of hydrogen peroxide (H_2O_2), disperse cementation with hexametaphosphate $(NaPO_3)_6$ and sodium carbonate (Na_2CO_3), and removes foam via amyl alcohol. Bulk density of undisturbed soil sample were determined by core method (FAO, 2007), using the ratio of solid mass to total volume when the sample was dried in an oven at 105°C for 24 hours. The gravimetric method was used to determine soil moisture content. Soil reaction (pH) was measured with pH meter glass electrodes in 1:2.5 (soil: water on a mass to volume basis) suspension after calibration of the pH meter with buffer solutions (pH 4, 7 and 10). Soil electrical conductivity (EC) was measured by conductivity meter 1:2.5 (soil: water on a mass to volume basis) suspension after the calibration of EC meter. Walkley and Black wet digestion method was used for organic carbon determination (Walkley and Black, 1934). Soil total nitrogen was determined by Kjeldahl digestion procedure (Bremmer, 1996). Bray II method was used to extract available phosphorus (Av. P) from soil (Van Reeuwisk, 1993), and the extracted Av. P was determined using spectrophotometer at a wavelength of 820 nm. While ammonium acetate method (1N NH_4OAc) at pH 7.0 was used to determine cation exchange capacity (CEC) of the soil (Houba et al., 1989).

Statistical analysis

Both laboratory and survey data were subjected SPSS (Statistical Package for Social Science, version 20 software). Soil laboratory data was statistically analyzed via two ways ANOVA, the main and interaction effects of land management practices (grass strip with soil bund, and soil bund alone) and slope positions (upper and lower) on soil properties, and significant means (P = 0.05) were separated using LSD. The t-test and chi-square were used to analyze continuous variables, and dummy variables gathered via survey, respectively.

Results and Discussion

Farmers use of grass strip to stabilize soil bunds

In the study area, soil bund was widely constructed on croplands to collect surface runoff, increase infiltration, and minimize soil erosion. About 70.9% of the respondent households use desho grass as grass strip on soil bunds while the rest 29.1% left the bund bare. The statistical result indicates household land and livestock holding sizes were significantly (P < 0.05) and negatively influence the use of desho grass strip to stabilize bunds (Table 2). As land and livestock holding size of the household gets larger, the probability to use grass strips to minimize erosion on croplands becomes lower. Perhaps this could be, farmers possessed large cropland requires huge bunches (bundles) of grass to establish grass strips on their croplands - which requires huge amount of money to buy grass. On the other hand, large livestock sizes can destroy the grass strip while grazing on the croplands after harvest. Because of this, smaller land and livestock holders use grass strips to stabilize soil bunds, minimize erosion and enhance soil productivity. This argues with the finding of Sinore et al. (2018), who stated that land and livestock holding size has a strong association with farmer's perception on the uses of biological land management practices such as grass strips to minimize land degradation problems and enhances land productivity. This disagreement is arising due to the use of similar land management practice for lands under different conditions: already degraded land for restoration and stable cropland for maintaining productivity. Accordingly, the current study deal with the use of grass strips (land management) to preserve stabile croplands for sustainable production, while the former study deal with the use of land management practices to restore degraded lands.

Table 2. Independent t-test on factors influence grass strip to stabilization soil bund

Dependant variables		**Mean**	**S.D**	**t-test**	**Sig.**
Livestock holding (TLU)	Grass strip user	2.97	1.02	-2.56	0.012
	Non- user	3.62	1.58		
Land holding size (ha)	Grass strip user	0.71	0.38	-3.39	0.001
	Non- user	1.03	0.58		
Farming experience (year)	Grass strip user	29.74	11.07	1.40	0.165
	Non- user	26.53	10.58		
Family size (number)	Grass strip user	1.67	0.77	0.12	0.900
	Non- user	1.69	0.86		

Furthermore, household head sex, marital status, educational level, cropland erosion status, information access, contact with extension workers, and trainings were significantly (P < 0.05) influence farmers use of grass strip for land management purpose (Table 3). Unlike married farmers, the unmarried have poor interest to invest in long-term land management practices (e.g. grass strip) and focus on short-term gains. In the society, married farmers carry more social, economic and environmental responsibility than the unmarried farmers did. Oakley and Garforth (1997) reported unmarried men in some communities are expected to work on his parent's farm, and only married are expected to start farming his own to feed his family members. The educated households tend to use grass strips to prevent soil erosion and improve soil productivity. Because the length of attending formal education enables farmers to easily realize extensions information and apply land management options to enhance crop production and productivity to realize household food security and generate sufficient income. This argues with the finding of Budry et al. (2006) who reported, more educated farmers place greater emphasis on finding jobs outside the community instead of managing soil conservation structures on their plots. As compared to Western construes, in Ethiopia getting a better off-farm job (e.g., government, non-government, and private sectors) is very difficult for farmers who graduated high school. Thus, most high school graduates mainly depend on agriculture to produce food for home consumption and generate incomes through properly managing lands.

Table 3. Chi-square test on the relationship between grass strip user and non-user farmers

Variables		User	Non-user	P-value
Sex	Male	61.8%	10.9%	0.000
	Female	9.1%	18.2%	
Age	Productive (> 18 < 65)	40.0%	13.6%	0.362
	Unproductive (< 18 > 65)	30.9%	15.5%	
Marital status	Married	61.8%	21.8%	0.019
	Single	0.9%	4.5%	
	Divorced	2.7%	1.8%	
	Widowed	5.5%	0.9%	
Educational status	Illiterate	5.5%	2.7%	0.012
	Primary	10.9%	11.8%	
	Secondary	54.5%	14.5%	
Cropland erosion degree	Sever	68.2%	2.7%	0.0001
	Moderate	2.7%	26.4%	
SWC information access	Development agents (DA)	47.3%	1.8%	0.001
	Family in neighbour	3.6%	8.2%	
	Media (FM radio)	13.6%	13.6%	
	NGOs	6.4%	5.5%	
Contact with DA	Once a week	14.5%	8.2%	0.051
	Twice a week	15.5%	11.8%	
	Once a month	40.9%	9.0%	
Attend SWC training	Yes	70.0%	0.9%	0.001
	No	0.9%	28.2%	

In the study area, farmers' access to extension information (e.g., media, training, extension workers) improves farmers understanding of land management options and facilitates their land management decisions. This coincides with previous studies, access to agricultural information improves farmers adoption soil conservation (Yishak, 2005; Batiwaritu and Mvena, 2009).

Effects of grass strip on selected soil physical properties

Statistical analysis of main effects revealed, clay fractions were soil significantly (P < 0.01) differ as function of land management practices (grass strip and soil bund, and soil bund alone) and slope positions, more amount was found at soil bunds stabilized with grass strip situated at lower slope positions (Table 4). Similarly, the interaction effects of land management practices and slope positions significantly (P< 0.05) influences clay fractions, the highest amount of clay was recorded at soil bunds stabilized with grass strips situated in lower slope positions. The low clay fraction at bunds treated with grass strip in the upper slope (42.0 ± 2.58) position was not an indicator the poor performance of grass strip to capture clay materials in the upper slope position. However, this confirms the effects of past water erosion events or topographic effects on clay fractions. The past erosion events caused the removal of clay fraction from the upper slope position, are transported and deposited into lower slope positions; consequently, more sand material is remained in upper slope positions. It was evidenced that at the upper slope positions soil bunds managed with grass strip had relatively better clay (42.0 ± 2.58) than soil bund alone (41.0 ± 2.23). This indicates that using grass strip as land management option at the upper and lower slope position could have similar soil protection effects. Other studies reported soil bunds stabilized with grass are contributes for high proportion of clay particles than the bund alone (Tadele, 2011) and fine materials are selectively removed from the upper slope and deposited at the lower slope (Tripathi and Singh, 2001). The main effect of both land management practices and slope position significantly (P< 0.05) contributed for soil moisture and bulk density improvement. However, the interaction effect shows land management practices and slope position significantly (P< 0.01) influences soil moisture. The highest soil moisture was recorded from soil bunds managed with grass strip situated at lower slope position (18.04 ± 0.54) while the lowest at upper slope position (15.13 ± 0.12). This could be due to the presence of high clay fraction in lower slope positions. Furthermore, root systems of the grass strips conserve moisture through minimizing erosion, evaporation, surface runoff and modifying soil microenvironment.

Table 4. Soil physical properties as influenced by integrated use grass strip and soil bunds at different slope position

Soil physical property	**Mean ± SD**	**P-value**	**Interaction of LMP x SP**	**Mean ± SD**	**P-value**
LMP					
Sand (%) SBG	20.75±3.19[b]	0.0001	Sand (%) SBG x upper	22.15±1.9[b]	0.012
Sand (%) SB	22.00±2.82[a]		Sand (%) SBG x lower	18.5± 1.09c	
Silt (%) SBG	33.25±2.76[a]	0.4421	Sand (%) SB x upper	23.5± 2.51[a]	
Silt (%) SB	34.25±2.81[a]		Sand (%) SB x lower	21±3.41[ab]	
Clay (%) SBG	44±3.85[a]	0.0005	Silt (%) SBG x upper	34.5±2.51[a]	0.337
Clay (%) SB	43 ±4.11[b]		Silt (%) SBG x lower	36.05±3.41[a]	
BD (g/cm^3) SBG	1.06±0.05[b]	0.0006	Silt (%) SB x upper	33.15± 3.40[a]	
BD (g/cm^3) SB	1.11±0.03[a]		Silt (%) SB x lower	35.25±2.51[a]	
MC (%) SBG	16.02±1.43[a]	0.0002	Clay (%) SBG x upper	42.0±2.58c	0.003
MC (%) SB	12.10±1.54[b]		Clay (%) SBG x lower	49.0± 1.63[a]	
Slope position (SP)			Clay (%) SB x upper	41.0± 2.23[ab]	
Sand (%) upper	23.00±2.13[a]	0.0004	Clay (%) SB x lower	45.0± 1.33[b]	
Sand (%) lower	19.75±2.91[b]		BD (g/cm3) SBG x upper	1.05±0.05[a]	0.061
Silt (%) upper	32.00±2.77[b]	0.0813	BD (g/cm3) SBG x lower	1.03± 0.03[a]	
Silt (%) lower	33.00±2.13[b]		BD (g/cm3) SB x upper	1.10± 0.016[a]	
Clay (%)upper	45.00±2.13[b]	0.0003	BD (g/cm3) SB x lower	1.11±0.08[a]	
Clay (%) lower	47.75±3.37[a]		MC (%) SBG x upper	15.13± 0.12[b]	0.001
BD (g/cm^3)upper	1.15±0.04[a]	0.0005	MC (%) SBG x lower	18.04±0.54 [a]	
BD (g/cm^3) lower	1.07±0.05[b]		MC (%) SB x upper	12.09± 0.82[ab]	
MC (%) upper	10.53±2.56[b]	0.0002	MC (%) SB x lower	14.17±0.46[c]	
MC (%) lower	11.58±1.65[a]				

LMP = land management practices; SBG = soil bund integrated with grass strip, SB= soil bund alone, in column two superscript followed with a same lower letter for the same soil parameters are not significantly different at P=0.05

This agrees with Danano (2007) who reported, the root system of desho grass holds soil particles, improves structure, and soil water retention.

Effect of grass strips on soil chemical properties

Statistical analysis shows main effects of land management practices (grass strip and soil bund, soil bund alone) and slope positions significantly ($P< 0.05$) influence soil pH, OC, N, C:N, Av. P, and CEC (Table 5). However, interaction effects of land management practices and slope positions significantly ($P < 0.05$) influence soil OC, TN, C:N, Av. P, and CEC. The highest amounts of soil OC, TN, C:N, Av. P, and CEC were observed at soil bunds managed with grass strips in lower slope position. This implies using grass strip as alternative land management options has a meaningful contribution for soil nutrient (e.g., Av. P), soil organic matter content (via above and below ground biomass addition), nutrient retention capacity (CEC), and organic matter decomposition. Other findings also witnessed about desho grass contribution for soil chemical property improvement through its extensive root system that anchors soil particles, high biomass production capacity and return organic matter to soil (Ramirez et al., 2010), minimize and control soil and nutrient loss (Welle et al., 2006; Yakob et al., 2015), and rehabilitate degraded area (Smith 2010). Moreover, other authors reported the presence of high nutrient in the accumulation zone (lower slope position) than the loss zone (upper slope position) (Kibret, 2008; Tadele et al., 2011). The highest amounts of OC, TN, C:N, Av. P, and CEC recorded in the lower slope position were not only due to the interaction effects of land management practices and slope position but also from past deposition events. For instance, when the quantity of soil properties (e.g., Av. P, C:N, CEC.) observed in soil bunds managed with a grass strip, and soil bunds alone at the upper slope positions, a better property was found at soil bunds managed with a grass strip.

Table 5. Effects of desho grass integration with bunds on at different slope position soil physical properties

Soil chemical property	Mean ± SD	P-value	Interaction (LMP x SP)	Mean ± SD	P-value
LMP					
pH-H2O SBG	5.69±0.26a	0.0001	pH-H2O SBG x upper	6.00± 0.00a	0.2732
pH-H2O SB	5.36±0.08b		pH-H2O SBG x Lower	5.50± 0.54a	
EC (ds/m) SBG	0.128±0.03a	0.0623	pH-H2O SB x upper	5.00± 0.05a	
EC (ds/m) SB	0.137±0.02a		pH-H2O SB x lower	5.44± 0.16a	
OC (%)SBG	2.33±0.44a	0.0010	EC (ds/m) SBG x upper	0.055±0.00a	0.1010
OC (%)SB	1.85±0.37b		EC (ds/m) SBG x Lower	0.115±0.02a	
TN (%)SBG	0.20±0.03a	0.0001	EC (ds/m) SB x upper	0.082±0.12a	
TN (%)SB	0.19±0.03b		EC (ds/m) SB x lower	0.142±0.02 a	
C: N SBG	11.65±0.02a	0.001	OC (%) SBG x upper	1.51±0.98ab	0.0001
C: N SB	9.73±0.01b		OC (%) SBG x Lower	2.48± 0.15a	
Av.P (ppm) SBG	6.12±0.78a	0.0001	OC (%) SB x upper	2.18±0.10b	
Av.P (ppm) SB	4.84±0.81b		OC (%) SB x lower	1.69± 0.13c	
CEC(cmol(+)/kg SBG	28.82±2.99a	0.0218	TN (%) SBG x upper	0.13±0.017ab	0.0310
CEC(cmol(+)/kg SB	26.92±2.17b		TN (%) SBG x Lower	0.22±0.01a	
Slope position(SP)			TN (%) SB x upper	0.18± 0.016b	
pH-H2O at upper	5.63±0.31a	0.0300	TN (%) SB x lower	0.16±0.02c	
pH-H2O at lower	5.41±0.11b		C:N SBG x upper	15.75±0.021b	0.0001
EC (ds/m) at upper	0.098±0.054a	0.9336	C:N SBG x Lower	17.2±0.021a	
EC (ds/m) at lower	0.097±0.028a		C:N SB x upper	12.11±0.062c	
OC (%) at upper	1.60±0.144b	0.0001	C:N SB x lower	10.56±0.06ab	
OC (%) at lower	2.00±0.202a		Av.P(ppm) SBG x upper	5.00± 0.00b	0.0001
TN (%) at upper	0.14±0.026b	0.0001	Av.P(ppm) SBG x Lower	6.50± 0.57a	
TN (%) at lower	0. 16±0.02a		Av.P (ppm) SB x upper	4.00± 0.00ab	
C:N at upper	11.65±0.02a	0.001	Av.P (ppm) SB x lower	4.09± 0.14c	
C:N at lower	9.73±0.01b		CEC(cmol(+)/kg SB x upper	30.00±2.30b	0.0048
Av.P (ppm) upper	6.12±0.78a	0.0001	CEC(cmol(+)/kg SBG x lower	31.50±1.29a	
Av.P (ppm) lower	4.84±0.81b		CEC(cmol(+)/kg SB x upper	25.75±0.95ab	
CEC(cmol(+)/kg upper	26.35±1.40b	0.0009	CEC(cmol(+)/kg SB x lower	27.25±0.95c	
CEC(cmol(+)/kg lower	30.39±1.74a				

LMP = land management practices; SBG = soil bund integrated with a grass strip, SB= soil bund alone, in column two superscript followed with a same lower letter for the same soil parameters are not significantly different at P=0.05

Conclusions

Integrating soil bund with grass strip as land management options play important roles in maintaining land productivity or restore degraded lands situated at different slope position. It has improved soil properties (like CEC, OC, Av. P) at croplands found in upper and lower slope positions. The difference observed in soil physical and chemical properties between slope positions (lower and lower) is not due to grass strip malfunction at slope positions but caused by past erosion events and topographic effects on soil property. Using desho grass strip could have relatively similar effects on soil properties at different slope positions. However, farmers' socio-economic status, cropland erosion, and access to information are affecting the use of desho grass strip to ensure sustainable land management practices. General, to scale-up desho grass strip as one of land management options in similar agro-ecological setting desho grass strip specific extension has to be provided to the community.

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