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Full-Length Research Article

Participatory Demonstration of *Pennisetum pedicelluatum* and Elephant grass *(Pennisetum purpureum)* Strip as Biological Soil and Water Conservation Measures for Erosion Control

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ABSTRACT

On three beneficiary farmer fields, prescaling up and participatory demonstration of biological soil conservation techniques using Desho (*Pennisetum pedicelluatum*) and Elephant grass (*Pennisetum purpureum*) were carried out in 2019/2020 in comparison with control (no grass) activities. Assessing the role of biological conservation techniques in reducing soil erosion and farmers' opinions of these techniques was the primary goal. A total of 132 m2 demonstration plots were used to collect and analyze the experimental data. Elephant grasses (134 tons/ha) and desho (61.1 tons/ha) differed significantly ($P < 0.05$) in the second year. Elephant grass provided an average soil loss of 6.6 tons/ha/yr-1, desho grass produced an average of 10.9 tons/ha/yr-1, and control provided an average of 13.4 tons/ha/yr.The elephant grass plots showed the least amount of nutrient loss, while the control plots showed the greatest amount.When compared to Desho grass, elephant grass has a higher potential to control soil loss due to its robust root system and to rebound quickly, even in the event of a severe drought.Furthermore, because elephant grass grows quickl y and has the largest freshweight biomass of any grass, farmers gave it more consideration in their assessments of grass strips than they did Desho grass.In order to improve acceptability and spread of the technology in dry land areas with a 5% slope for managing soil and nutrient losses, it is best to scale up elephant grass on a bigger scale. The highest nutrient loss was observed on the control plots and the least on the elephant grass plots. Based on the study results, elephant grass has a high potential to control soil loss through a strong root system and recovery immediately, even under severe drought conditions, compared with Desho grass. Additionally, farmers' evaluations of grass strips showed a higher attention to elephant grass than Desho grass due to the fast-growing nature of the grass and their highest freshweight biomass. Finally, it is better to scale up elephant grass on a larger scale to enhance acceptance and diffusion of the technology in dry land areas on a slope of 5% for controlling soil and nutrient losses.

Keywords: Biological soil and water conservation, Desho grass, soil and nutrient loss

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1. INTRODUCTION

Soil erosion is one of the most damaging and wide-spread occurrences and is recognized as a key issue for heartwarming food security. Of the total areas affected by soil degradation, global water erosion occupies 56% (Oldman *et al*., 1991) and affects 80% of agricultural land (Angima *et al*., 2003). Global assessment of human-influenced soil degradation informed us that about 36% of farmlands are degraded at rates of 5–6 million per ha per year (Scherr, 1999). The problem is severe in developing countries (like Africa and Asia); most of the lands in Africa are susceptible to soil and environmental degradation (Wim and El-Hadji, 2002).

Erosion convinced soil degradation to aggravate the problems of low agricultural productivity, food insecurity, and rural poverty in Ethiopia (Smith, 2010). In the highlands of Ethiopia above 1500 m.s.l., erosion removes over 1.5 billion tons of top soil fertile soil annually (Taddese, 2001). The rate of soil loss in Ethiopia was put in severity levels of very high (>100 t/ha/yr), high (50–100 t/ha/yr), moderate (10–50 t/ha/yr), low (1–10 t/ha/yr), and no erosion (<1 t/ha/yr) (Hurni, 1983).

In light of these problems, efforts to regulate the impacts of land degradation on soil productivity have been under way in various parts of the country. Major types of conservation methods introduced were structural, and of these, the most common were fanayajuu and soil bunds (Belay, 1992). For instance, soil bunds reduced soil loss by 39 percent in Tigray (Greegziabher *et al*., 2008) and by 50 percent in Anjeni (Herweg and Ludi, 1999). Besides; soil bunds promote rainwater infiltration (Crtichley *et al*., 1994). As WOCAT frame work focuses on locally tried and tested techniques, the public and private partners use Desho grass across the escarpment in densely populated highlands for a sustainable land management program (Smith, 2010). This grass had been used as a grass strip to protect crop land from soil erosion and degradation in the highlands of Ethiopia (Welle *et al*., 2006; Yacob *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 (*P. purpureum*, *Vetveria zizanoides*) used for land management practices in Ethiopia, In the study area, limited information is available on farmers' effects of grass strips on soil conservation. This study aimed to assess' farmers' perceptions of biological conservation and to demonstrate the contribution of desho and elephant grass to controlling soil erosion.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was conducted on Denba Gofa woreda, which is one of seven *woreda* in the Gofa zone, located 505 km from Addis Ababa and 275 km south-west of Hawassa. The study area lies at 6025'.208 N latitude and $37^0$02'.698" longitude. It has an altitude of 1200m a.s.l. Based on the 2007 population census of the Federal democratic republic of Ethiopia, the total population of the population of which 40,335 were male and 40,823 40,823 female (Federal Democratic Republic of Ethiopia Population Census Commission, 2008).

The *woreda* is bound by Zala woreda in the south and south-east, Uba Debretsehay Woreda in the south, Oyda and Geze Gofa in the west and north-west, the Omo River in the north, and Kucha *Woreda* in the east. The area that accounts for 75% (more than ¾) of the total land area is lowland, characterized by irregularities and deficiency of rainfall in the district, and it is relatively sparsely populated because of the prevalence of tropical diseases like malaria.

Based on the data from the Rural and Agricultural Office of the *woreda*, the land area measures 97,468.44 hectares, of which 48% is currently cultivated, 27% is employed for grazing, and 25% is under bush, shrubs, and forests. It has an optimal rainfall distribution that is favorable to a variety of crops: teff, maize, barely, pea, highland sorghum, avocado, bean, orange, chickpea, cabbage, enset, pineapple, onion, and potato. Coffee and korerima are the main cash crops.

2.2 Implementation Procedure

A field participatory demonstration work was examined on the effects of biological soil and water conservation methods on soil loss and maize production during cropping seasons in 2011 and

2012 E.C. at Denba Gofa Woreda with a plot size of 6x22 $^{m2.}$ The biological soil conservation measures used were Desho (*P. pedicelluatum*), Elephant (*P. pupureum*), and Control (without grass strip) on three farmers' fields (slope of 5). Planting of maize variety 540 was done during the main rainy season, from the beginning of March up to the end of April each season, at a spacing of 75cm by 25 cm. The spacing between the grass splitting of desho grass (30 cm) and elephant grass (40 cm).

2.3 Data Collection Methods

The collected data for the trial was grass strip biomass, soil moisture content, soil loss, soil nutrients, and farmer preferences.

2.3.1 Determining soil loss

The experimental field was built in February of 2011 on three farmers land on a slope of 5%. Each runoff field (catch pit) had a length of 5 m, a width of 1 m, and a 0.5m depth made from plastic sheet. The plots were set up, and the soil collected in the catch pit was measured after the end of the rain fall.

The plots were bounded by a corrugated iron sheet, buried to a depth of 20cm and protruding 10cm above the ground to prevent runoff water from outside the plots from entering the plots and that from runoff plots from flowing out unmonitored.

2.3.2 Grass biomass

The green biomass grass yield harvest of both Desho and Elephant was carried out after three months of planting, while the other harvest was done at a 15-day interval for elephant grass and a one-month interval for Desho grass.

2.3.3 Determining soil moisture content under treatments

Measuring soil moisture was conducted at three periods (initial, development, and mid-stage) to evaluate the amount of soil water during dry periods. A composite soil sample taken by an auger was used for soil sampling from a depth of 0–20 cm, and 20–40 cm was used as "x" around the field to collect soil from various places on the field. From each of the two depths, collect sub-samples of the auger sample and mix well in a plastic bucket. The weight of the wet soil samples was measured and put in an oven at 105°C for 24 hours, and then the weight of the dry samples was measured. The amount of soil water stored (%) in each 0.4-meter incremental depth was determined gravimetrically. It was then converted to water depth (mm) by multiplying by the specific bulk density values measured by the core sampler methods as described by Blake (1965).

2.3.4 Farmer's preference and perception

Data on farmers' observations towards the grass strip were collected using focus group discussions. Farmers were asked to list standards they would like to consider in their preference. Criteria defined after focus group discussion included reducing soil loss, drought resistance, animal preference, harvesting frequency, easy establishment, and fast growth. Farmers were asked to prioritize the grass strip by giving scores based on each criterion: 3 for excellent, 2 for very good, 1 for good, and 0 for not good.

2.4. Data analysis

One-way ANOVA in SPSS version 20 is used to examine farmers' opinions and preferences about plants in connection to biological water and soil conservation variables. Nevertheless, the randomized block design model was used in the analysis of the experimental data. The least significant difference procedure was followed by the mean separation. The block effects were determined to be insignificant ($P > 0.05$).

3. RESULTS AND DISCUSSION

3.1 Farmers Perceptions towards Grass Strips for Soil and Water Conservation

Results for the farmers' scores of the grass strip practices presented in Table 1. The values reflected the farmers' perceived degree of importance of each grass practice based on their evaluation criteria. Farmers gave scores based on their multipurpose nature. Accordingly, farmers gave the first rank to elephant grass except for palatability and the second rank to desho grass. The discussion with farmers showed that elephant grass is fast-growing, easy to establish, drought-resistant, reduces soil erosion, and has a higher harvesting frequency than Desho grass. The elephant grass was found to be extremely superior to the Desho grass in terms of different criteria, but the palatability of elephant grass decreases as its maturity increases, and accordingly, the farmer's Desho grass has a highly palatable nature. However, it was not easily established because the study area was dry and also because the harvesting frequency was low compared with elephant grass. However, elephant grass within a month is harvested 2-3 times and recovers rapidly even in dry situations**.**

Desho grass is used as a year-round livestock fodder. It is a very palatable species to cattle and sheep (Ecocrop, 2010), mainly grown on small home plots used for livestock fodder fodder, soil conservation practices, and sold for income generation as small business opportunity, mostly for high land Ethiopian farmers (IPMS, 2005; Shiferaw *et al.*, 2011; Leta *et al.*, 2013). It is a very palatable species to cattle and sheep (Ecocrop, 2010) and is mainly grown on small home plots used for livestock fodder and soil conservation practices.

Biological practices are quick and cheaper than physical structures, compassionate to rehabilitation lands, protect land from further degradation, and stabilize physical structures for a long period of time (Abinet, 2011; Terefe, 2011).

Table 1. Farmer's perception and preference of desho and elephant grass strips based on evaluation criteria

		Preference ranking	
No.	**Criteria for comparison**	**Desho grass**	**Elephant grass**
1	Reduce soil loss	1	3
2	Drought resistance	1	3
3	Animal preference	3	1
4	Harvesting frequency	1	2
5	Easy establish	1	3
6	Fast growing	1	2
	Mean	0.8	1.4
	Rank	2nd	1st

Scores: 3= excellent, 2 very good 1, for good and 0 for not good

3.2 Grass Biomass Means under the Treatments

As shown in the above Table 2, only elephant grass fresh biomass data was taken because elephant grass survived and established earlier than desho grass. This could be due to the fast-growing nature of the grass. However, due to their inability to withstand the drought conditions in the research regions, nearly 50% of the planted seedlings did not survive in the first year. My personal experience has shown that highland areas are typically ideal for desho grass. According to Smith (2010) who reported that desho grass is naturally spreading across the escarpment of the highlands and used for multiple purposes.

Table 2. Mean performance of grass strip biomass

	Biomass yield, ton/ha	
Plants	**2011 year**	**2012 year**
Elephant grass	56	61.1[a]
Desho grass	-	13[b]
LSd (%)	-	4.4
Cv (%)		41

In year two, there were significant ($P < 0.05$) differences between desho (61.1 tons/ha) and elephant grasses (134 tons/ha). The highest fresh weight biomass data were produced from elephant grasses due to their rapid growth rate. Elephant grass has higher annual biomass productivity than desho. According to Karlsson and Vasil (1985), elephant grass is the fastest-growing plant in the world. A study in Florida reported a dry biomass yield of 45 dry $ha^{-1}year^{-1}$ (Woodard and Sollenberger, 2008). Elephant grass has for long been an important forage crop in the tropics because of its high yields and nutrient value. The biomass yields of approximately 80 dry t $ha^{-1}year^{-1}$ (Vicente-Chandler *et al.*, 1959) in the tropics and exceeding 45 dry t $ha^{-1}year^{-1}$ (Prine *et al*., 1988) at ~30°N latitude (Gainesville, Florida, USA) have been reported.

3.3 Mean of Soil Loss

As we can see in Table 3, there was no significant (P > 0.5) difference between the treatments in 2011. This is due to the vegetal zed structures helping reduce the effects of soil erosion because the grass strips were not successfully established and covered the soil in the first year. Vegetative barriers such as grass can retard runoff and capture sediment from concentrated flow (Meyer *et al*., 1994). Thus, as a vegetative barrier develops, it decreases water speeds and forms a broad, identical vegetative surface for the uptake of nutrients. Vegetative barriers have the potential to not only reduce erosion but also increase vegetated filter strips' uptake of nutrients. In year two, there was a significant ($P<0.05$) difference between the elephant grass (8.633 ton/ha) compared with the control (24.3 ton/ha), but no significant difference ($P > 0.05$) between the elephant grass (8.66 ton/ha) compared with the desho grass (18.14 ton/ha) and the control (24.3 ton/ha) compared with the desho grass (18.14 ton/ha) treatments. The results show that elephant grass has great potential to control soil loss through a strong root system and recover quickly even under severe drought conditions, compared with desho grass.

Table 3. Soil loss means under the different treatments

Treatments	**Soil loss ton/ha/yr-1**	
	2011 year	**2012 year**
Desho grass	15.24a	18.14ab
Elephant grass	12.75a	8.633b
Control	19.165a	24.3a
Lsd (%)	17	12.7
Cv (%)	50	32.9

Similarly, elephant grass has been used as mulch (a 25-cm layer) for weed control, water storage, and to reduce soil losses on slopes (Adekalu *et al*., 2007; Francis, 2004). Elephant grass grows a vigorous root system that may help inhibit river bank erosion. Planted as borders, elephant grass makes barriers and provides effective windbreaks for crops and houses. It is used for erosion control and forage production in alley-cropping systems of agroforestry (Magcale-Macandog *et al*., 1998). The soil loss was high in control (without a grass strip) compared with desho grass and elephant grass. Soil erosion and loss of organic matter associated with conventional tillage practices were high, which left the soil bare and unprotected in times of heavy rain and wind (Chivenge *et al*., 2007).

3.4 Nutrient Loss

The different nutrient losses and soil erosion affect the ecosystem via nutrient deposition and sedimentation. As we can see from the above table 4, the control (without a grass strip) is the most sensitive to fertility erosion, with the highest amounts of N, P, and OC losses (25.6; 8.3; 293.12 in the first year and 28; 9.08; 320.6 kg ha-1, respectively). The detached top layers are highly concentrated in soil nutrients (Thomas et al., 1993), and this strongly compromises agricultural activities due to acute nutrient depletion in eroded soils. Under high rates of runoff and sediment, nutrient dilution is high (Sidibé, 2005), while elephant grass had the lowest values (16.8; 4.56; and in the 2nd year, 4.56; 194 kg ha-1), all three nutrient elements. The results of the study show that efforts should be geared toward implementing physical soil conservation measures alongside fertility-improving methods. Soil conservation is fundamentally a matter of determining the correct form of land use and management (Sanders, 2002).

Table 4. The nutrient loss under the treatments (kg/ha/yr)

Treatments	2011year				2012 year			
	Total soil loss	TN loss	AP loss	OC loss	Total soil loss	TN loss	AP loss	OC loss
Elephant grass	8400	16.8	4.56	194	4800	9.6	2.6	110.88
Control	12800	25.6	8.3	293.12	14000	28	9.08	320.6
Desho grass	12000	24	7.5	292.8	9800	19.6	6.12	239.12

Soil loss can be reduced by appropriate crop management, which includes cover cropping, multiple cropping, and high-density planting (Junge *et al*., 2008). The highest nutrient loss was observed on the control plots and the least on the elephant grass plots, which received external inputs, especially inorganic fertilizer treatments. The relatively lower amounts of nutrient loss observed under elephant grass strip-treated plots could be explained by the least soil loss under this treatment. With respect to the higher amount of N, P, and OC lost under control (without a grass strip), there were no vegetative barriers with increased soil sediment transport. This study agreed that under high rates of runoff and sediment, nutrient dilution is high, and the total amounts of nutrient loss were higher on the untreated plots than the treated plots (Sidibé, 2005).

3.5 Mean of Maize Yield and Yield Components

In both years, there was no significant (P > 0.05) difference between the treatments in all parameters (Table 5). This result shows that the effect of soil and water conservation structures is observed after some years of the structure being built. This finding agrees with the studies conducted by Herweg and Ludi (1999) who reported that comparisons made between local cultivation and SWC structures at experimental sites in Ethiopia showed that soil loss is reduced significantly for the majority of SWC treatments, such as level bunds, but production rarely increases as a result of SWC in three to five years of age.

Table 5. Mean performance of maize growth parameters under treatments

	2011 year			2012 year		
Treatments	**plant height, m**	**DMB, t/ha^{-1} year^{-1}**	**Grass yield, t/ha^{-1} year^{-1}**	**Plant height**	**DMB**	**Gy**
Elephant grass	2.43	7.1	6	1.94	6.9	5.4
Desho grass	2.45	8.3	5.575	2	8	5
Control	2.372	8	5.75	2.1	7.6	5.6
Lsd (%)	NS	NS	NS	NS	NS	NS
Cv (%)	5	10	8	6	20	17

M, metere; Gy, grass yield

Wolka *et al*. (2013) reported that 79.3% of the interviewed farmers perceived the increment in yield after 2 years of SWC structures (the soil bund and stone bund) were put in place. Herweg and Ludi (1999) indicated a 4-50% decline in yield during the first 3–5 years after the construction of SWC measures.

CONCLUSION AND RECOMMENDATION

A participatory demonstration and pre-scaling up of Desho grass and Elephant works was accompanied in Denba Gofa woreda with the objectives of the Desho and Elephant grasses contribution to controlling soil erosion and farmers perceptions of these measures. The maize data collected were plant height, biomass matter, and grain yield, but there was no great difference between all the treatments. However, soil loss ton per hectare was higher in control plots and low in elephant and desho grass plots. Soil erosion is a threat to the decline of agricultural productivity. Areas with a slope greater than 5% are more prone to soil erosion that decreases soil fertility. Therefore, it is critical to use and apply soil conservation measures in the areas to prevent soil loss from erosion. Based on the study results, elephant grass has a great potential to control soil loss through a vigorous root system and recover rapidly even under severe drought conditions compared with Desho grass. Besides, farmers' evaluations of grass strips showed a higher interest in elephant grass than Desho grass due to the fast-growing nature of the grass and its highest fresh-weight biomass. Additionally, the cut grass can be used as livestock fodder. In this regard, elephant grass was recommended in our study area and in similar agroecologies for future demonstration and scaling up for soil loss control under a slope of 5%. Hence, there is a need to disseminate the results of the present study to end users, even though further research should be carried out to support the recommendation.

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