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Participatory Demonstration and Evaluation of Integrated Maize-Forage Production and Soil Conservation through Forage Legumes under Sowing and Grass Strips on Soil Bunds

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Abstract
Soil conservation through integrating legumes with grain crops, and grass strips on soil bunds is an important option for food and feed security of human and livestock respectively. Based on this notion, this research activity was conducted with objectives of improve productivity of land and livestock through the integrated conservation and farm management, demonstrate integrated maize-forage production, and practices of soil and water conservation practices and improve soil fertility through the biological and physical conservation practices from 2016 to 2018 main cropping season in selected sites Kile, Adada1 and Wahil kebeles. The trial was conducted following the procedure of Randomized Control Block Design on three farmers' fields at each site where farmers are used as replication. Soil bunds extending 20m across contour were constructed on each farm of three farmers. The design of structure was based on the slope of the land which encompasses bund height 70cm and bund width 50cm to protect over toping of flood and increases water retention in the soil. This research found that maize yield 2447.2 kg/ha, 3311.13kg/ha and 3808.66kg/ha; fresh weight of elephant grass 15, 400kg/ha, 6150kg/ha and 20,200kg/ha; and pigeon pea 8200kg/ha, 9620kg/ha, 13800kg/ha an increasing trend across sites throughout three years from the constructed soil bund with integrated system. Soil laboratory analysis also shows an increasing organic matter, available phosphorus and nitrogen because of these integrated systems. Therefore, promoting this integrated system is recommended to small holder farmers by government, Nongovernment and other stakeholders.
Key words: Soil bund, Elephant grass, Pigeon pea, Conservation
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Introduction

Low productivity of crops due to soil fertility depletion and livestock feed shortage are among the major factors limiting agricultural production in eastern Ethiopia. In the region, because of the undulating topography and low vegetation cover, vast areas of farmland are suffering soil degradation (Bojö and Cassels, 1994). The problem of soil degradation is exacerbated by deforestation, continuous cropping, crop residue removal, and soil pulverization to create fine seedbed (Mulugeta *et al*, 2005). Particularly important in this respect is the decrease in soil organic matter which is the basis for soil fertility in agricultural systems due to its multiple physical, chemical, and biological functions. In addition, shortage of feed is the key limiting factor for livestock production in the region, and the possibility of producing forage as sole cropping is impractical due to severe shortage of land.

As a result, livestock are mostly fed with crop residues (Abiy, 2008). This practice, on top of depleting soil fertility, it supplies livestock with low nutrients and results in low productivity. Hence, to improve the nutritive value residues it is important to supplement with forage legumes as fresh or conserved hay. Apart from their feed values, forage legumes fix atmospheric nitrogen and improve soil fertility (Defoer and Hilhorst 1995). Hence, the shortage of feed could be alleviated through integrating forage production with the existing cropping system. On the other hand, to conserve soil and moisture, farmers usually construct soil bunds along the contour on the farm land. The ever-increasing land use change is aggravating the rates of soil erosion, soil fertility reduction, crop yield decline, and food insecurity (Haregeweyn *et al.,* 2005).To combat land degradation at a national level, environmental conservation and land rehabilitation effort was started in 1970 s, with a particular focus on the construction of physical structures (bunds, terraces etc.) in the fast deteriorating highland areas of Ethiopia (Abinet, 2011).

The intention of these efforts is to reduce soil erosion, restore soil fertility, rehabilitate lands, improve microclimate, and boost agricultural production and productivity. Integration of biological practices with physical structures is highly contributed for the improvement soil fertility and crop production (Abay, 2011; El-swify and Hurni, 1996). Biological practices are enhancing the overall and cheaper than physical structures, compassionate to rehabilitation lands, protect land from further degradation, and stabilize physical structural for long period (Abinet, 2011; Bot and Bentites, 2005).Therefore, there is high possibility of integrating food and forage crops production, and soil and water conservation practices to alleviate feed shortage and improve productivity of soil. In this innovation, forage legumes (pigeon pea) is sown under maize in between the soil bunds and grass (elephant grass) is planted on the soil bunds along the contour.

Objectives

- To improve productivity of land and livestock through the integrated conservation and farm management
- To demonstrate integrated maize-forage production, and practices of soil and water conservation practices
- To improve soil fertility through the biological and physical conservation practices

2. Materials and Methods

2.1 Description of the study area

The experiment was conducted at Dire Dawa administration and Harari Region.

Site and farmer's selection

Farmlands that are prone to soil erosion were selected in the study area in close collaboration with DAs and farmers. Kebeles were selected purposively based on the potentiality, appropriateness of the area by considering lodging, slope land escape, access to road, suit for repeatable monitoring and evaluation in progress of sowing to harvesting. Kile from Sofi, Adada1 from Biyo Awale, Wahil from Wahile districts were selected purposively.

Farmers were selected purposively based on their interest, innovation he/she has, land provision for this participatory evaluation and demonstration, interest in cost-sharing, willingness to share experiences for other farmers, and studying their profile with the participation of DAs and community leaders. The selected farmers were grouped in form of Farmers Research Group (FRG) with the member of 15 farmers per PAs in consideration of gender issues (women, men and youth). In the form of establishing FRG in each two study areas total of 4 FRGs (FRG/ Kebeles - from one PA 15 farmers and a total of 60 farmers were grouped in 4 FRG). In the FRG, 4 farmers was trial farmers per kebeles (3 male trial farmers and 2 female trial farmers) and 10 farmers had worked with trial farmers.

Table 1: Summary of selected site and farmers with area coverage of the experiment

Districts	Kebeles	No. of trial farmers	FTCs	Area covered
Wahile	Wahil	3	1	20mx 10m for each plots
Biyo awale	Adada1	**4**	**1**	
Sofi	Kile	4	1	
	Total	11	3	

Technology evaluation and demonstration methods/technique

Participatory evaluation and demonstration of the trial was implemented on farmers' fields to create awareness about the integrated soil and water conservation. The evaluation and demonstration of the trials were followed process of demonstration approach by involving FRGs, development agents and experts at Different growth stage of the crop and during construction of soil bund. The activity was jointly monitored by FRGs, researchers, experts and development agents.

Data Collection.

Both quantitative and qualitative data were collected through personal field observation, individual interview, Focus Group Discussion, and using checklist and data sheet tools respectively.

Data analysis

Quantitative data was summarized using simple descriptive statistics (Mean, average, Frequency and Percentage) while the qualitative data collected were analyzed using narrative.

Implementation of Design

The trials for evaluation and demonstration of improved integrated maize-forage production and soil conservation were implemented on the farmers' fields in the target areas. The trial was conducted following the procedure of RCBD on three farmers' fields at each site where farmers are used as replication. Soil bunds extending 20m across contour were constructed on each farm of three farmers at Harari and dire dawa respectively. The design of structure was based on the slope of the land which encompasses bund height 70cm and bund width 50cm to protect over toping of flood and increases water retention in the soil. Elephant grass (cita in local language) on is planted on the structures for the stabilization purpose.

Besides stabilize the structure, grass is provided as fodder for livestock and improving soil fertility. Maize sown between the grass strips (soil bunds) and the legumes (pigeon pea) under sown at 3-4 leaf stage of maize. Distance between the strips was kept at 6 m wide. The grass planted densely at 15 cm between slips at start of the rainy season for better establishment. The alleys between the strips is equally divided into 3 parts (plots) planted to the legumes along with control.

3. Result and Discussion

This trial was conducted following the procedure of RCBD on three farmers' fields at each site where farmers are used as replication. Soil bunds extending 20m across contour were constructed on each farm of three farmers at Harari and Dire Dawa respectively.

Ass shown on Table 1 the variation in both grain yield and biomass data are mainly due to soil textural distribution and pervious soil fertility level. The highest record for both grain and biomass yield of maize was taken from Adad1that is 3375kg/ha and 1950kg/ha. This is due to the existence of previous good soil depth and fertility status of the field during first year. The lowest yield was recorded from Wahil that is 2250 kg/ha and 1850kg/ha in case of shallow soil depth and also to some extent the availability of termite.

Table 1 Yield and biomass data of maize and forage at three sites 2016

No	**Site Name**	**Average Maize yield (kg/ha)**	**Maize Stock kg/ha**	**Average Elephant grass (Kg/ha)**	**Average Fresh pigeon pea biomass (kg/ha)**
1	Adada1	3375	1950	15000	7200
2	Wahil	2250	1850	12000	8400
3	Kile	1716.6	1150	19200	1716.6
	Average	2447.2	1650	15,400	8200

According to the table 2 highest Maize grain yield per hectare, average fresh weight of elephant grass and fresh weight of pigeon pea biomass was collected from Kile that is 28000 kg/ha, 19800 kg/ha 10,200kg/ha respectively and the lowest data was collected from the Wahil that is 3133.4 kg/ha, 11220kg/ha and 9780 kg/ha respectively. This variation of data from site to site is in case of the soil textural distribution and water holding capacity of soil, stabilized soil bund, and good bund spacing. It also depends on the initial soil depth. On the other hand, the lowest yield was recorded in case soil textural distribution affect water holding capacity and also the degree that soil aggregation is improved.

Table 2 Grain and fresh weight biomass yield data at three sites 2017

No	Site name	grain yield of maize(kg/ha)	Maize stock(kg/ha)	Average biomass of elephant grass(kg)/ha	Average biomass of pigeon pea(kg)/ha
1	Kile	28000	2543	19800	10,200
2	Ada1	3,466.7	1550	18,900	8880
3	Wahil	3,133.4	2900	11220	9780
	Average	**3311.13**	**2331**	**6150**	**9620**

Here under table 3 the highest maize yield 3975kg/ha and fresh biomass data of animal feed was obtained at Dire Dawa, but at Kile, the highest elephant grass fresh weight biomass 21000kg/ha and pigeon pea fresh weight biomass 15000kg/ha was recorded. This is because of well stabilized soil bund and good bund width and height. Thus why, both maize grain and fresh weight biomass of elephant grass and pigeon pea shows an increasing pattern.

Table 3 Maize yield and forage biomass data at three sites 2018

No	**Site Name**	**Average Maize yield (kg/ha)**	**Maize Stock (kg/ha)**	**Average Elephant grass(Kg/ha)**	**Average Fresh pigean pea biomass(kg/ha)**
1	Adada1	3975	2588	20,400	12000
2	Wahil	3817	2383	19200	14400
3	Kile	3633	5556	21,000	15000
	Average	**3808.66**	**3509**	**20200**	**13800**

Soil analysis

Soil samples before and after were collected using zigzag method and taken to soil laboratory and physical and chemical parameter was analyzed.

Table 3. Laboratory result for different parameters.

	Parameters	Parameters trend across Years				
S N		Year 2016	Year 2017	Year 2018	Year 2019	Year 2020
1	PH H2o(1:2.5)	8.74	8.1	7.92	7.6	7.5
2	ECmhos/cm	0.5	0.449	0.412	0.391	0.202
3	CEC meq/100g	34.14	31.648	28.452	25.682	22.15
4	Av.p(ppm)	6.10	11.17	24.13	29.8	31.6
5	AvTotal nitrogen	0.04	0.057	0.071	0.088	0.097
6	Total carbon result %	1.09	1.18	1.88	2.03	2.07
7	%OM	1.88	2.04	3.21	3.51	3.61

According to the table above, soil parameter analysis shows an increasing trend especially in terms of, total nitrogen, organic matter and to some extent available p which are the indicator of soil fertility improvement. This finding is also agree with Mulugeta and Karl (2010) who are reported that the land with physical SWC measures have high total nitrogen as compared to the non-conserved land. This result also coincides with Million (2003) found that the mean total N content of the terraced site were higher than the average total N contents in the corresponding non-terraced/conserved sites.

Training

Training was given to farmers, districts' experts, DA's, were participated that training mainly based on the importance of technology (moisture and soil conservation, land saving, increases production and productivity of both land and livestock), construction of the soil bund, spacing, height and others.

Table 4 number of participants during the training at two districts

		Kile		Wahil	Adada1		
No.	Participants	Male	Female	Male	male	female	Total
1	Farmers	45	20	**40**	72	**20**	**217**
2	Das	9	**1**	5	6	5	26
3	District experts	4	1	3	4	1	13
4	Journalist	1	0	0	1		2
	Total	**59**	**22**	**48**	**83**	**26**	**258**

Farmers ranked the structures according to their own criteria, accordingly Integrated physical and biological soil water conservation ranked first good bunds width that is suitable for forage production over the bund, water holding capacity, land saving, good bund height for protection of run of destruction and improve soil depth as shown table 5.

Table 5: Ranks of the varieties based on farmers' selection criteria.

Types of technology	Farmers rank	Reasons
Integrated physical and biological swc	1st	Good bund width that is suitable for forage production over the bund, water holding capacity, land saving Good bund height for protection of run of destruction. Improve soil depth
Soil bund farmers practice	2nd	Poor water holding capacity, shallow soil depth, un appropriate design

Table 6: Pair-wise ranking matrix result to rank improved soil water conservation measures.

Code no.	Parameter of selection	width	height	Soil depth	Water holding capacity			Bulb skin color	Seed set
1	Bund width		2	3	1	1	6	1	1
2	Bund height			3	2	2	2	2	2
3	Land saving				3	3	3	3	3
4	Water holding capacity					5	5	4	4
5	Erosion control capacity						5	5	5
6	Maize yield							6	6
7	Total fresh biomass harvested								7
8									

4. Conclusion and Recommendation

Integrated physical and biological soil and water conservation measure is one of climate smart agriculture that alleviates land degradation and enhances soil fertility. On cite the farmers participated in conduction soil and water conservation integrated with grain, and animal forages research activity. Thus, this research activity found that the highest yield of maize 2447.2 kg/ha, 3311.13kg/ha and 3808.66kg/ha were recorded from the constructed soil bund integrated with animal feed forages like elephant grass 15,400kg/ha, 6150kg/ha 20200kg/ha and pegean pea 8200kg/ha, 9620kg/ha, 13800kg/ha across all sites within the three consecutive rainy season 2016 to 2018.

In addition farmers ranked the structures according to their criteria, as a result, ranked integrated physical and biological soil water conservation due to good bunds, width that is suitable for forage production over the bund, water holding capacity, land saving good bund height for protection of run of destruction and improve soil depth as compare to Soil bund of farmers practice ranked second.

Therefore, it is indispensable and recommended to promote the integrated physical and biological soil water conservation to large number of small holder farmers through different government, Non-government and stakeholders programs.

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