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Participatory evaluation and demonstration of Fanya Juu with grass strips as soil and water conservation measures for rehabilitation of degraded Farmlands in Kamba District, Southern Ethiopia

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Abstract

Land degradation due to soil erosion and soil fertility depletion is a significant threat to the agricultural system, that limiting food security and sustainable agricultural production. This study demonstrated and evaluated Fanya juu with elephant grass strips as soil and water conservation measures for rehabilitation of degraded lands in Kamba district Gamo Zone South Ethiopia. The study used Three treatments namely; Fanya juu with Elephant grass, Fanya juu only and control plots without interventions. The treatments were laid on Randomized Complete Block Design on Six trial farmers field which used as a replication. The size of each experimental plot was 20 m x 20 m and used 1 m space between the plots. The selected physicochemical properties of soil parameters, yield and yield components of maize were analyzed using SAS computer software. The study reveals the selected physicochemical properties of soil, yield and yield components of maize had significantly affected by the treatments. The highest clay fraction, soil moisture content, soil pH, OC, TN, AvP, and AvK were found in the plots having Fanya juu with Elephant grass treatment than only Fanya juu and control plots. The study also confirms, cob number, biomass and grain yields of maize were significantly highest under Fanya juu with elephant grass treatments. Based on the result, the study concluded that demonstrated Fanya juu with Elephant grass strips had affected the physicochemical soil properties while, consequently used as rehabilitating degraded lands. Additionally, the study also concluded implementing Fanya juu and Elephant grasses were significantly increasing yield and yield components of maize. Based on the findings, it is better to demonstrate Fanya juu with Elephant grass to conserved soil and water and thereby maximize grain yield of maize for the study area and similar agro ecology.

Keywords: Elephant grass strips; Fanya juu; Selected Physicochemical Soil Properties; Soil erosion

1. Introduction

Soil erosion is the removal of top productive soil causing a 17% reduction in crop productivity (Angima et al., 2003). Its extent and distribution are widespread in Africa and Asia, due to high population pressure, land shortage and critical lack of resources for conservation by subsistence small holder farmers (Blanco and Lal, 2008). Its effects are also recognized to be severe threats to the national economy of Ethiopia due to cultivation on steep slopes, clearing of vegetation and over grazing (Tamene, 2005). It causes strong environmental impacts and major economic losses from decreased agricultural production and effects on infrastructure and water quality by sedimentation processes (Amsalu et al., 2007). The major factors contributing for soil fertility decline are clearing of forests, the removal of crop residues from the fields, land fragmentation, reduction of fallows, overgrazing, low fertilizer inputs, inadequate soil and water conservation measures, cropping of marginal lands and poor soil management. These factors have resulted in lower

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crop yields and lower livestock numbers leading to reduced food security and increased poverty (Pound and Ejigu, 2005).

To resolve the trouble of soil erosion, soil and water conservation (SWC) practice was initiated in Ethiopia during the 1970s and 1980s. The main intent of the initiatives was to minimize erosion, restore soil fertility, rehabilitate degraded land, and increase agricultural productivity (Adimassu et al., 2014 and Haregeweyn et al., 2015). Since, 2012 the country has developed community-based watershed development guideline, in which the participation of community gets due consideration for sustainable watershed development and management approach. Significant effort is occurring to replicate community based participatory integrated watershed management activities in the most of the regions. As a component of this effort, in the last ten years a nationwide 30 days public work campaign for watershed management has been started (Haregeweyn et al., 2012). In the study area, the potential use of these grasses as agronomic and biological soil and water conservation methods are minimally exploited with physical structures. The effect of different grass strips namely Desho, Elephant, and Guatemala grasses as biological soil and water conservation measure alone and with physical structures on soil erosion control, soil properties and crop grain yield have been evaluated and demonstrated in plot basis in different parts of Southern Ethiopia. However, the integration of biological soil and water conservation measures with physical structures are not widely promoted at watershed scale in different parts of the region to ensure the watershed sustainability and livelihood of communities. Therefore, this study was demonstrated and evaluate the integrated effect of Fanya Juu with Elephant grasses as soil and water conservation measures for rehabilitation of degraded farmlands in Kamba District of South Ethiopia regional state.

2. Material and methods

2.1. Study area description

The study was conducted at Dollo irrigation scheme in Kamba woreda, Gamo Zone, South Ethiopia Regional State. Geographically, the study area located between 5º 58' 30"N - 6º 15' 0" N and 37º 4' 0" E - 37º 20' 30" E. Based on the 2007 census conducted by the CSA, Kamba woreda has a total population of 155,979, of whom 79,273 are men and 76,706 women; 4,702 or 3.02% of its population are urban dwellers (CSA, 2007).

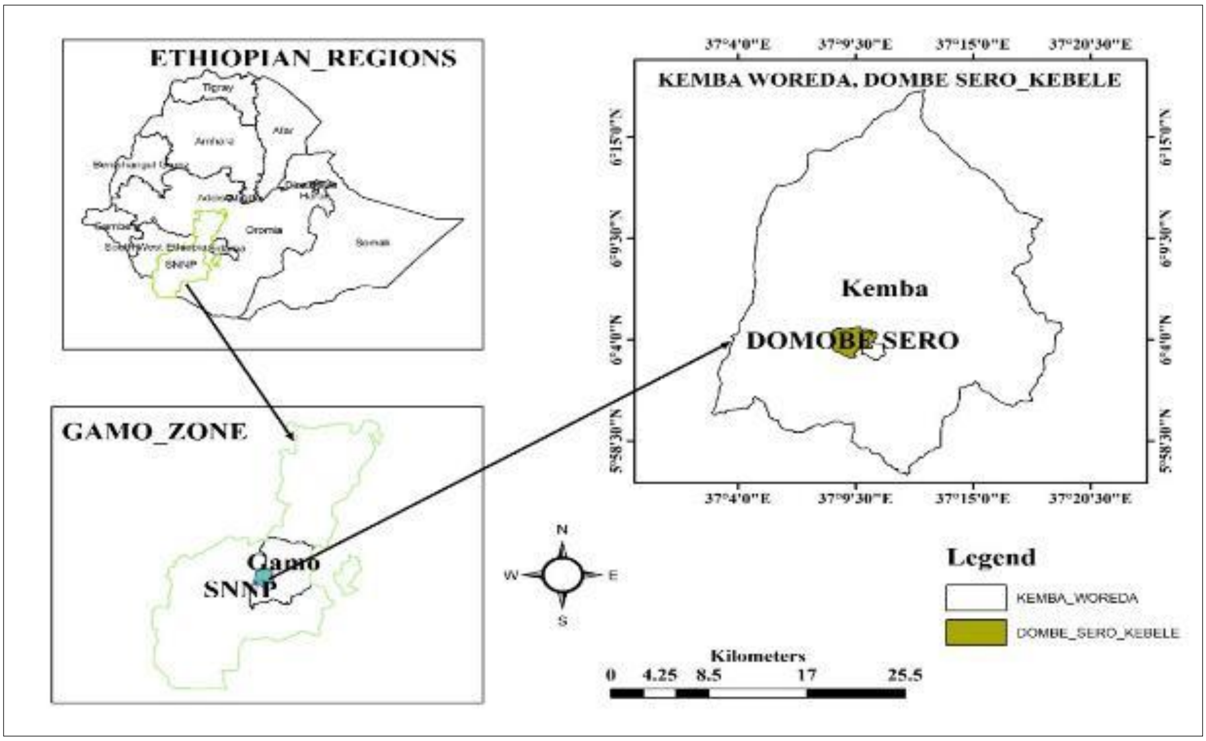

Figure 1 Location map of the study area

As shown in Figure 2 below the area received maximum and minimum monthly rainfall of (5.68 mm and 0.84 mm) in 2022 and (10.11 mm and 0.65 mm) in 2023 respectively. The maximum and minimum monthly rainfall was recorded on october and december respectively.

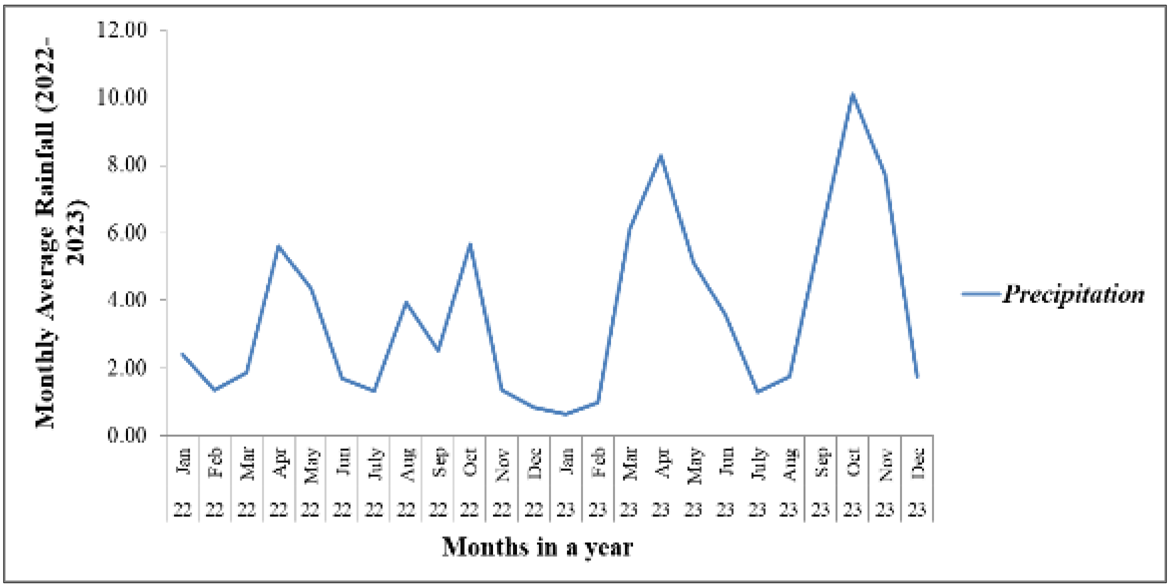

Figure 2 Rainfall distribution from the year 2022 to 2023/Source google earth engine accessed 05/20/2024

2.2. Site and farmers' selection

Primary field observation through transect walk was conducted prior to demonstration particularly on the problem of soil erosion, availability and potential of selected grass, potential crop types grown in the area with participating the farmer research and extension group (FREG). Dolo irrigation scheme was purposely selected based on severity of soil erosion which highly affects the irrigation scheme within the watershed. Six (6) adjacent trials farmers were selected from members of each FREG in the watershed to participate on the demonstration. The trial farmers have been selected due to access of farmlands having a slope measuring 8-15% and existence of adjacent farmland ownership.

2.3. Treatments and research Design

The study used Three treatments namely; Fanya juu with Elephant grass (FJ+EG), Fanya juu only (FJ) and control (plots without interventions). The treatments were laid on Randomized Complete Block Design (RCBD) on Six farmers field which used as a replication. The size of each experimental plot was 20 m x 20 m and used 1 m space between the plots.

2.4. Implementation procedures

Fanya juu terraces were constructed in the area where slope range of 8-15% via mass mobilization of FREG members. The structures were constructed at the middle part of the plot and tied at 10m distance according to recommended specification having embankment height of 50- 75 cm, a bottom width of 100-150 cm and 50 cm ditch depth.

2.5. Land and input preparation

The selected trail farmers have been prepared their farmlands as part of their usual land preparation and all the necessary inputs such as Maize seed, fertilizers and Elephant grasses have been provided from the Arba Minch Agricultural Research Center. After land preparation, BH546 Maize verity was planted as a test crop with a seed rate of 25 kg/ha based on the crop calendar of the study area. The recommended amount of Nitrogen and Phosphorus fertilizers were used. Urea fertilizer was applied two times in which 1/3 at planting and 2/3 was top dressed at knee height. The Elephant grass strips were planted at a spacing of 15 and 10 cm between rows and split respectively. Three rows were used per bund and the grass was planted on the top of the bund during the rains.

2.6. Data collection

2.6.1. Soil sample preparation and laboratory analysis

Soil samples were collected from each farmland before and after the demonstration to analyze the selected physico-chemical soil properties such as, soil moisture, bulk density (BD), soil texture, pH, soil organic carbon (SOC), available phosphorus (Av. P), available potassium (Av. K) and total nitrogen (TN). The soil samples were taken from 0-20 cm soil depth, assuming that the deposited sediment depth due to the implemented soil and water conservation practices would not exceed this depth (Admasu et al., 2014). The collected soil samples were analyzed at Jinka Agricultural Research

Center based on their specific soil laboratory analysis procedures. Accordingly, the soil pH was determined by a 1:2.5 soil: water ratio using a pH meter as described by (Van Reeuwijk, 2002). The soil organic carbon concentration was determined by Walkley and Black rapid titration method as described in Sakar, & Haldar (2005). Total nitrogen was determined by the modified Kjeldahl methods as modified by (Sakar, & Haldar, 2005). The available phosphorus content was determined using Bray-II extraction method.

2.6.2. Maize yield and yield component

Plant height was measured in (cm) as the height from ground level to the base of the tassel by taking ten randomly selected plants per plot using measuring stick. Cob length was measured in cm from base level to the tip along the length of the cob from Ten randomly selected cobs per plot with ruler and the average was recorded. Above ground biomass was determined after harvesting the crop. Grain yield per hectare was obtained from the central four rows of maize, and then the yield was measured after the seeds are picked and shelled by hand. The grain yield was adjusted to 12.5% moisture level and then converted to hectare bases and calculated as follows;

$$\text{Adjusted Grain Yield}(\frac{\text{kg}}{\text{ha}}) = \frac{Actual\ Grain\ Yield * 100 - M}{100 - \text{D}}$$

Where; M, is the measured moisture content in grain and D is the designated moisture content (12.5%).

- **Data analysis:** The selected physico-chemical soil properties, yield and yield components data of Maize were analyzed using analysis of variance (ANOVA) with SAS software and least significant difference (LSD) test were used to compare the treatment means when the main effect had been significant at a 5% significance level

3. Results and discussion

3.1. Effects on Selected Physicochemical Soil properties

According to the statistical analysis result of the study, the selected physicochemical soil properties (clay, BD, SMC, pH, TN, SOC, Av. K and Av. P) had been statistically significantly ($p \leq 0.05$) affected by the treatments. While, silt and sand fraction of the soil were not statistically affected by the effect of integrated Elephant grass with Fanya juu as soil and water conservation measures (Table 1&2).

3.2. Soil textural class (%)

The study result shows, the soil textural class of clay fraction is significantly ($p \leq 0.05$) affected by the treatments. While, silt and sand fractions of the soil are not affected by the treatments (Table 1). The highest (42.2%) clay fraction of the soil is recorded within the plot having FG+EG treatment. Contrary, the lowest clay fraction of the soil is found within the control (38.6%) and plots having only FJ (40.6%). The highest clay fraction of a soil under FG+EG might be due to the integrated effects of Fanya juu physical soil and water conservation structure and Elephant grass in reducing soil erosion and trapping fine particles. The result of this study is in lined with (Mengistu et al., 2016 and Mengie et al., 2019), who determined better clay fraction in croplands beneath terraced than adjacent non-terraced croplands. According to USDA soil textural class classification delineated by Osman (2013), the textural class of the study area is dominated by Sandy clay (Table 1).

3.3. Soil bulk density (SBD, g/cm^3)

The bulk density of the soil turned into statistically significantly ($p \leq 0.05$) affected by the treatments. The lowest BD of the soil turned into determined in the FG+EG (1.22 g/cm^3) plot than only FJ and control plots (1.27 g/cm^3) and (1.4 g/cm^3) respectively (Table 1). The lowest bulk density of a soil found in the FG+EG plots might be the integrated effects of Fanya Juu and Elephant grass strips in reducing soil erosion, retaining more water, providing highest clay fraction and total porousness of the land. The result of the present study is in lined with (Worku, 2017) who reported a significantly higher value of BD was found in the non-conserved watersheds with soil and water conservation measures. According to Landon (2013) soil classification, the grand mean BD (1.3 g/cm^3) of the soil in the study area is dense.

3.4. Soil moisture (%)

The moisture content of the soil is statistically ($p \leq 0.05$) affected by the treatment. Significantly the highest (11.94%) soil moisture is recorded within the plot having FG+EG treatment than control (9.08%) and plots having only FG (9.92%) treatment. The highest soil moisture content found in the FG+EG plots is due to the integrated effects of grass strips and physical soil and water conservation measures to reduce soil erosion and retain more water. A study conducted by Umer et al. (2019), was revealed that, the root systems of the Desho grass strips conserve moisture through minimizing erosion, evaporation, surface runoff and modifying soil microenvironment.

Table 1 Status of selected physical soil properties

Treatments	Soil parameters				
	BD (g/cm^3)	SMC (%)	Clay (%)	Silt (%)	Sand (%)
Control	1.42^a	9.08^a	38.6^a	7.8^a	53^a
FG only	1.27^b	9.92^{ab}	40.6^b	8.2^a	51.2^a
FG+EG	1.23^b	11.94^c	42.2^c	8.8^a	49.2^a
Grand mean	1.30	10.31	40.5	8.3	51.1
CV	2.06	15.32	0.78	7.96	2.57

Note: Means within columns followed by the same letters are not significantly different at *p≤0.05*; FG+EG, fanya juu with elephant grass; FJ, only fanya juu; BD, bulk density; SMC, soil moisture contents.

3.5. Soil reaction (pH^+)

The soil reaction (pH^+) value of the studied scheme was statistically significantly ($p \leq 0.05$) affected by the treatments. Significantly the highest mean value of soil pH^+ was found within FG+EG (5.94) than only FJ and control plots (5.6) and (5.5) respectively (Table 2). The highest soil pH found within FG+EG plot could be the soils protected with integrated soil and water conservation practice would retain the basic cations along with fine fraction, raising the soil pH^+. The study is in lined with (Ademe et al., 2017), who reported the higher pH^+ value of a soil was found in the land treated with soil and water conservation measures than plots without interventions. According to London (2013) soil classification, the grand mean (5.7) soil pH^+ value of the study area is slightly acidic.

3.6. Soil organic carbon (SOC, %)

The SOC was statistically significantly ($p \leq 0.05$) affected by the treatments. Significantly the highest SOC was found within FG+EG (1.56%) than only FJ and control plots (1.31%) and (0.93%) respectively (Table 2). The highest SOC within FJ+EG plots could be due to the effect of integrated Fanya juu and Elephant grass strips to provide mechanical barriers to the runoff water would have reduced the loss of fine soil fractions and accumulated and maintained organic matter and organic carbon. This study is in lined with (Sirna and Leta, 2020) who reported, significantly highest mean value of SOC was recorded from conserved than non-conserved plots with soil and water conservation measures. According to London (2013) soil classification, the grand mean value of SOC (1.27%) of the study area is low.

3.7. Total nitrogen (TN, %)

Table 2 Status of selected Chemical soil properties

Treatments	Soil parameters				
	pH^+	Av. P (ppm)	Av. K%	SOC%	TN%
Control	5.5^a	5.47^a	113.8^a	0.93^a	0.098^a
FG only	5.6^a	6.69^b	116.9^b	1.3^b	0.12^a
FG+EG	5.9^b	7.37^c	119.7^c	1.56^c	0.14^a
Grand mean	5.7	6.51	116.8	1.27	0.12
CV	0.95	4.45	0.48	13.2	23.8

Note: Means within columns followed by the same letters are not significantly different at *p≤0.05*; pH^+, Hydrogen ion concentration; AvP, available phosphorus; AvK, available potassium SOC, soil organic carbon TN, total nitrogen

The total nitrogen of the soil was statistically significantly ($p \leq 0.05$) affected by the treatments. Significantly the highest imply cost of TN of the soil found in FG+EG (0.14%) than FJ and control plots (0.12%) and (0.098%) respectively (Table 2). The better TN within FJ+EG plots probably due to the result of integrated effect of Elephant grass and Fanya Juu SWC practices in reducing runoff and soil loss and enhancing profile water storage would enhance crop growth and contribute to organic matter and nitrogen input in the soil. Similarly, the study conducted by Telila et al. (2024), was also confirmed significantly the highest mean value of TN was found in the conserved than control plots (without in situ soil moisture conservation practices). According to Landon (2013) USDA soil classification, the grand mean value of TN (1.2%) in the study area is lower.

3.8. Yield and yield components of Maize

The results of the study show, the yield and yield components (cob number, biomass and grain yield) of the Maize is significantly (*p≤0.05*) affected by integrated soil and water conservation measures at Kamba District (Table 3). While, plant height, cob length and thousands of seed weight of Maize are not statistically affected by the treatment.

3.9. Cob number and Biomass

The study revealed that, there was a significant variation in cob number among the treatments. The highest mean (1.44) value of the cob number was found in the plot having FJ+EG treatment than only FG and control plots (1.28) and (1.3) respectively.

The study also reveals, biomass of the maize was statistically significantly (*p≤0.05*) affected by the treatments. The highest mean value of maize biomass is recorded in the plots having FJ+EG treatment followed by only FG plots. While, the lowest biomass was found in the control plots. The highest cob numbers and biomass of maize recorded in the plot having FJ+EG treatment could be due to the integrated effect of Fanya juu structure and Elephant grass strips in reducing soil erosion and increases soil moisture, total porosity, SOC, TN, consequently that increases plant nutrients, cob numbers and biomass of maize. The study is in lined with Telila et al. (2024), who reported the highest biomass of maize was recorded in the plots having in situ SWC measures than control plots.

3.10. Grain yield

The study also reveals, there was a significant (*p≤0.05*) variation in grain yield among the treatments. The highest (5.8 tons/ha) grain yields of maize were found in the plots covered with Fanya Juu and Elephant grass strips than Fanya Juu only and control plots (4.8) and (4.2 tons/ha) respectively. The highest grain yields of Maize found within FJ+EG plots might be due to the integrated effects of Elephant grass strips and Fanya juu structures as a barrier in reducing runoff and soil loss, enhancing total porosity of the soil, accumulating organic matter, total nitrogen and soil carbon, consequently it increases the yield of Maize. The current study is in lined with Wudinesh et al. (2023) and Gojjam et al. (2024) who reported the highest yield of maize was found in the plots having integrated soil and water conservation measures.

Table 3 Mean yield and yield components of maize (2021-2023 GC)

Treatments	**Yield and yield component parameters**					
	PH (m)	**CL (m)**	**CN (No)**	**TSW (kg)**	**BM (ton/ha)**	**GY (ton/ha)**
Control	2.1^{a}	0.22_{a}	1.28^{a}	0.034^{a}	16.3^{a}	4.2^{a}
FJ	2.13^{a}	0.21^{a}	1.3^{ab}	0.034^{a}	17.3^{b}	4.8^{b}
FJ+EG	2.16^{a}	0.22^{a}	1.44^{b}	0.034^{a}	18.6^{c}	5.8^{c}
Grand mean	2.13	0.21	1.34	0.034	17.1	4.95
CV	6.5	3.37	4.01	2.02	2.58	11.35

Note: Means within columns followed by the same letters are not significantly different at p≤0.05; FG+EG, fanya juu with elephant grass; FJ, only fanya juu; Ph, plant height; CL, cob length; CN, con number; TSW, thousands of seed weight; BM, biomass; GY, grain yield.

4. Conclusion

Based on the results, the study concluded that demonstrated Fanya juu with Elephant grass strips had affected the selected physicochemical soil properties. Clay fraction, soil moisture content, soil pH, OC, TN, AvP, and AvK. were significantly affected by the integrated effects of Fanya juu and Elephant grass strips. The study also concluded implementing Fanya juu with Elephant grass strips had affected yield and yield components of maize. Cob number, biomass and yield of maize was affected by the integrated effects of Fanya juu with Elephant grass. Based on the findings, the study recommends, it is better to demonstrate Fanya juu with Elephant grass to conserve soil and water and thereby maximize grain yield of maize for the study area and similar agro ecology.

Compliance with ethical standards

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Disclosure of conflict of interest

We declare that the authors have no competing interests as defined by this Journal, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

All the authors have made significant contribution in the demonstration of the study, data collection, data analysis, interpretation and the final manuscript preparation.

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