



OPEN ACCESS

EDITED BY

Anwarul Abedin,
Bangladesh Agricultural University,
Bangladesh

REVIEWED BY

Thomas M. R. Maxwell,
Lincoln University, New Zealand
Christopher Chagumaira,
Agri-Food and Biosciences Institute,
United Kingdom

*CORRESPONDENCE

Leta Hailu
✉ latahailu@gmail.com

RECEIVED 29 December 2024

REVISED 14 August 2025

ACCEPTED 20 November 2025

PUBLISHED 07 January 2026

CITATION

Hailu L, Tesfaye G, Teka W, Debebe Y and Bayata A (2026) Evaluation of selected grass species for soil and water conservation, and carbon sequestration under farmland at Jimma zone, southwestern Ethiopia. *Front. Sustain. Food Syst.* 9:1552901. doi: 10.3389/fsufs.2025.1552901

COPYRIGHT

© 2026 Hailu, Tesfaye, Teka, Debebe and Bayata. This is an open-access article distributed under the terms of the [Creative Commons Attribution License \(CC BY\)](#). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

Evaluation of selected grass species for soil and water conservation, and carbon sequestration under farmland at Jimma zone, southwestern Ethiopia

Leta Hailu^{1*}, Gizaw Tesfaye², Wondimagegn Teka¹, Yalemstehay Debebe¹ and Aduugna Bayata¹

¹Jimma Agricultural Research Center, Jimma, Ethiopia, ²Melkasa Agricultural Research Center, Adama, Ethiopia

The objective of this study was to evaluate the effects of different grass species on soil and water conservation and carbon sequestration at a farmland in Jimma, Ethiopia. The experiment was set out as a randomized complete block design with three replications. The treatments were vetiver grass (*Chrysopogon zizanioides* L.), Desho grass (*Pennisetum pedicellatum*), Phalaris grass (*Phalaris arundinacea* L.) hedgerows, and the control (plots without grass). Soil erosion monitoring pins were installed, and the data were collected every 15 days. Soil samples were collected at 20 cm intervals in the top 100 cm before the grass hedgerows' establishment and after harvesting seasons in December (2016–2019 G. C.). Fresh and oven-dry matter biomass (shoot and root) data were measured. The collected soil samples and grass biomass analysis for carbon fraction were determined following [Wakley and Black \(1934\)](#) and the loss on ignition standard procedure methods, respectively. Pin heights and soil moisture data were analyzed using R software. Results show that, significantly ($p < 0.05$), the highest mean value of pin height was observed in a control plot as compared to plots with grass species. Conversely, soil moisture and crop yield showed no significant variation between treatments. However, the highest mean value of soil moisture content was exhibited under the plot with the vetiver grass hedgerow. Vetiver grass possesses the highest potential for carbon content in the shoot (22.06 Mg C ha⁻¹ yr⁻¹), root (8.98 Mg C ha⁻¹ yr⁻¹), and soil (15.9 Mg C ha⁻¹ yr⁻¹). Furthermore, the Vetiver grass sequesters (172.27 Mg C ha⁻¹ yr⁻¹) more carbon as compared to Desho grass (112.85 Mg C ha⁻¹ yr⁻¹), Phalaris grass (78.35 Mg C ha⁻¹ yr⁻¹), and plots without grass species (44.41 Mg C ha⁻¹ yr⁻¹). This study suggests vetiver grass for soil and water conservation and carbon sequestration purposes to contribute to the mitigation of climate change. Further study of the potential of grass species on carbon sequestration under controlled experimental plots is encouraged since collecting fibrous root biomass is difficult on farmlands.

KEYWORDS

carbon sequestration, grass hedgerows, grass species, soil erosion, southwest Ethiopia

1 Introduction

Land degradation greatly affects food production in sub-Saharan Africa (Amede, 2003). Since much of the arable land is degraded (Nkonya et al., 2008), the main causes include inadequate land management, population growth, soil erosion, nutrient mining, and a lack of resources (Amede, 2003). Soil erosion, which alters topsoil and soil carbon store, is regarded as the most important soil degradation process (Mitiku et al., 2006). According to Gebreselassie et al. (2016), more than 85% of Ethiopia's land is considered to be moderately to severely eroded and current satellite imaging estimates show that over the last three decades, around 23% of the land area has been covered by land degradation hotspots. The annual cost is approximately \$4.3 billion. This problem has been particularly serious in the Ethiopian highlands, where the majority of arable land is found and occupied by 90% of the human population and 60% of all livestock, resulting in natural resource degradation (Hurni et al., 2010; Daley, 2015). The plan to combat land degradation has to concentrate on and address local causes, such as understanding household behavior toward land management, policy, and institutional variables/factors that hamper or facilitate the implementation of technical remedies, institutional issues like communal or public ownership of farm lands as well as high poverty/food insecurity level make efforts to address land degradation difficult and complex that influence decisions (Gebreselassie et al., 2016). The degradation processes may take various forms. For instance, physical (compaction, hard setting, crusting, etc.), chemical (acidification, salination, etc.), and biological (depletion of vegetation cover and organic matter, reduction of biological activity). Most of the time, depending on the land management practices in place, the degradation processes occur simultaneously (Mitiku et al., 2006; Nkonya et al., 2008). Soil and water conservation practice is adopted by farmers to reduce soil loss and the risk of production (Kato et al., 2011; Adimassu et al., 2012). Physical conservation measures are a necessity in Ethiopia (Morgan, 2005). However, these alone do not directly influence biomass production. Inadequate biomass on the land means ineffective plant cover, low soil fertility, and reduced productivity of the land. One of the main gaps of previous conservation efforts in this country was inadequate attention given to the implementation of biological conservation measures. Perennial grass, on the other hand, serves to replenish various soil carbon pools. Crow et al. (2018) and Bresciano et al. (2019) found that active plant biomass contributes to the buildup of carbon in mineral-dominated pools through aggregate decay products. Grass species differ in their capacity to create dry matter, store carbon, and sequester carbon (Odiwe et al., 2016). Different studies revealed that vetiver grass hedgerows had the potential to improve the natural resource base in degraded areas, stabilize physical structures, and sequester carbon (Kebede and Yaekob, 2009; Munnu Singh et al., 2014). This is due to the fact that the grasses form hedges or living porous barriers, which slow and spread runoff water and trap sediment (Gesesse et al., 2013). Soil carbon sequestration improves soil quality, which increases crop yields and slows the rate of CO₂ enrichment in the atmosphere (Nazir et al., 2024). Thus, restoration, enhancement, and improvement of soil carbon stock are essential since carbon sequestration improves and sustains biomass productivity (Lal, 2004). There have been enormous efforts made to utilize indigenous and exotic grasses as hedgerows to reduce soil and nutrient losses in Ethiopia (Mekonnen et al., 2016; Adugna et al., 2019; Hailu et al., 2020; Bekele et al., 2023; Zena and

Abie, 2023). On the other hand, with the ongoing climate variability in Ethiopia (Kassie, 2014; Demem, 2023; Gashaw et al., 2023; Cheru, 2024; Aniye et al., 2025). The presence of erratic rainfall has created moisture stress (Tefera et al., 2019). Studies indicate that between 1960 and 2006, the average annual temperature rose by 1.3 °C, or 0.28 °C every decade (McSweeney et al., 2010). Grass species play a great role in sequestering carbon that has implications for climate change mitigation (Munnu Singh et al., 2014; Pinner, 2014; Tessema et al., 2021). Thus, it is important to prioritize different grass species for a specific agro-ecology based for soil and water conservation, and carbon sequestration potentials. However, there is limited information on the Desho, Phalaris and Vetiver grass species with respect to its potential for carbon sequestration and soil and water conservation in Ethiopia generally and specifically in the study area. Moreover, the capacity of different grass species to sequester carbon and serve as biological soil and water conservation is site-specific due to variations in climate and soil conditions. Therefore, the experiment was conducted with the objective to evaluate the effects of different grass species on soil and water conservation and carbon sequestration on station at Melko, Jimma zone of Ethiopia.

2 Materials and methods

2.1 Study area description

The study was conducted at Melko, the Jimma Agricultural Research Center (JARC), Jimma Zone, and Southwestern Ethiopia. It is located 364 km from Addis Ababa, the capital city of Ethiopia, and 12 km from Jimma town. The study site is located on 36° 41' 0" E and 7° 45' 0" N (Figure 1). The surface soil's chemical and physical properties were described as follows: soil reaction (pH) 5.29, available phosphorus (ppm) 3.95, total nitrogen (%) 0.15, organic carbon fraction (%) 2.05, exchangeable acidity (meq/100 g) 0.18, and sandy clay loam as the dominant textural class. The area is known by a sub-humid type of climate (Jimma Agricultural Research Center / JARC/, 2020). The area has a mean minimum and maximum temperature of 11.1 °C and 26.8 °C, respectively, and receives a mean annual rainfall of 1701.8 mm (Figure 2). The altitude of the experimental site is 1753 m above sea level. The slope of the field was 13.2%.

2.2 Experimental design

The experiment was conducted on farmland under a randomized complete block design (RCBD) with three replications [Control (bare land); Vetiver grass (*Vetiveria zizanioides*), Desho grass (*Pennisetum pedicellatum*), Phalaris grass (*Phalaris arundinacea* L.) hedgerows]. The planting materials Vetiver; Desho; and Phalaris grasses were used from Jimma Agricultural Research Center, Integrated Watershed Management Research program Nursery site. The experiment was conducted for four consecutive years (2016–2019 G. C.) on the station. The experimental plots were laid out across a slope. The plots were replicated three times along the slope and blocked with a soil bund. The 10-meter-long grass hedgerow was established at the edge or at lower part of each plot following the contour line, and the control plot was left without grass hedgerows. Grass hedgerows were established

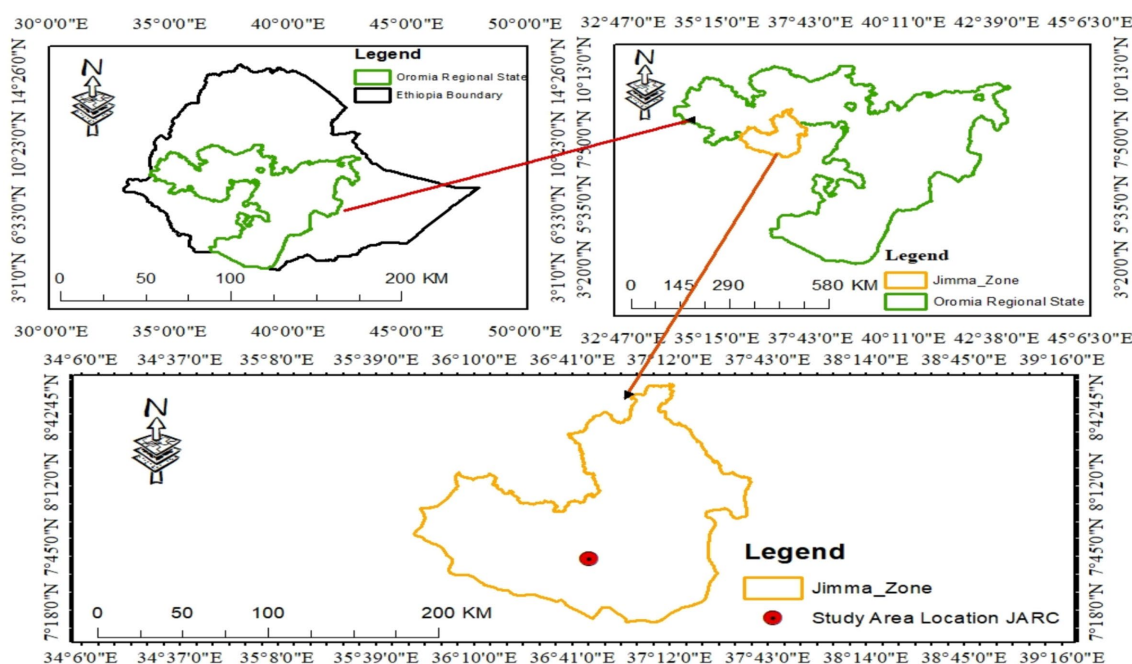


FIGURE 1
Jimma agricultural research center experimental site location, Jimma zone.

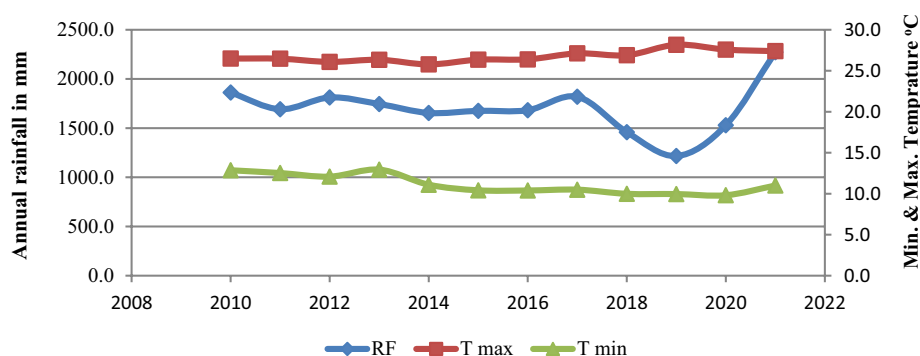


FIGURE 2
Mean annual rain fall and minimum and maximum temperature of Melko, JARC. RF, Rainfall (mm); T max, maximum temperature (°C); T min, minimum temperature (°C).

with double rows, and two tillers of grass were planted in staggered form (20 cm x 20 cm, intra- and inter-spacing), and the control plot was left bare. The spacing of consecutive grass hedgerows was determined at 1 m vertical interval (VI) of the slope. The area between grass hedgerows soybean was used as test crops. Field management and agronomic practices were conducted as per recommendation.

2.3 Sample collection

The soil samples were collected before grass hedgerow establishment and each year after the harvesting time in December, up to 1 m in depth at a 20 cm interval from each plot. At the end of the harvesting season, five (5) representative clumps were randomly

sampled from each grass hedgerow. Above-ground shoot and root biomass was collected at each harvesting time in December. Furthermore, to monitor soil erosion caused by runoff between hedgerows, erosion pins 30 cm tall were placed 50 cm apart at the upper and lower parts of each hedgerow, as well as in the center of the hedgerow. Throughout the wet season, we measured the erosion pin height every 15 days. A decrease in pin height indicates deposition, whereas an increase in pin height implies erosion.

2.4 Laboratory and data analysis

The soil organic carbon fraction (%OC) was determined by the Walkley and Black method (Wakley and Black 1934). Sampled shoots

and root biomass were weighed fresh and dried in the oven at a temperature of 80 °C for 24 h and weighted to obtain the dry weight biomass of the sample. The organic carbon fraction (%OC) of shoot and root biomass was analyzed by Loss on Ignition following the standard procedures. Regarding the carbon content of grasses, the biomass was estimated from above and underground using the following Equation 1:

$$C_{\text{grass}} = C_{\text{leaf}} + C_{\text{root}} \text{ (first, second, third, and fourth years)} \quad (1)$$

Where:

$C_{\text{leaf}} = \% \text{ OC}_{\text{leaf}} * M_{\text{leaf}}$

$C_{\text{root}} = \% \text{ OC}_{\text{root}} * M_{\text{root}}$

C_{grass} denotes total carbon content (Mg/ha/year).

C_{leaf} and C_{root} are the total carbon content in leaf and root (Mg/ha/yr).

$\% \text{ OC}_{\text{leaf}}$ and $\% \text{ OC}_{\text{root}}$ are percentages of organic carbon in leaf and root. M_{leaf} and M_{root} are the dry biomass of leaf and root (Mg/ha/yr; Wattanaprapat et al., 2006; Singh et al., 2011; Nopmalai et al., 2015).

The carbon content of the soil was determined in 5 soil layers; 0–20, 20–40, 40–60, 60–80, and 80–100 cm depth by the Walkley and Black method.

Total carbon content was calculated by the summation of soil carbon in each layer by the following equation:

Soil carbon stock of the soil was computed with the following Donovan (2013) Equation 2:

$$\text{Soil carbon stock} \left(\text{t ha}^{-1} \right) = \text{Soil OC} (\%) * \text{BD} \left(\text{Kg m}^{-3} \right) * V * 10^{-3} \quad (2)$$

Where BD: bulk density (kg m^{-3}) and V: volume of the soil in cubic meter = depth of soil (m) $\times$ area of soil (m^2).

Carbon sequestration (t ha^{-1}) refers to the amount of carbon stored in the form of CO_2 . It is obtained by multiplying SOC by 3.67 (i.e., molecular mass of CO_2 per atomic mass of C) Equation 3:

$$\text{Carbon sequestration} \left(\text{t ha}^{-1} \right) = \text{SOC} \left(\text{t C ha}^{-1} \right) * \text{CO}_2 / \text{C} \quad (3)$$

2.5 Data analysis

The collected data for all measured parameters were checked and cleaned. Following that the data was analyzed to check for normality (Shapiro–Wilk normality test) and homogeneity, was checked for the data. Subsequently, the data collected across all experimental years were analyzed following using a RCBD model framework. Analysis of variance (ANOVA) was performed in R software (R Core Team, 2023) via R Studio environment, employing the agricolae package version 1.3–7 (De Mendiburu, 2023). Linear model was fitted to evaluate treatment effect considering year and blocks factors. The Equation 4 of LM was given by: for single year analysis

$$Y_{ij} = \mu + \tau_i + \beta_j + \varepsilon_{ij} \quad (4)$$

Y_{ij} = Observed response for treatment i in block j , μ = overall mean, τ_i = effect of the i^{th} treatment ($i = 1, 2, \dots, t$), β_j = effect of the j^{th} block ($j = 1, 2, \dots, b$) and ε_{ij} = random error associated with the ij^{th} observation. The LM was chosen for simplify treatment comparison and capacity to validate interaction effects and easy in RCBD across seasons.

LM for pooled mean across years, the Equation 5 is given by:

$$Y_{ijk} = \mu + \gamma_k + (\tau\gamma)_{ik} + \beta_{j(k)} + \varepsilon_{ijk} \quad (5)$$

Where: Y_{ijk} are observed responses; γ_k is the effect of year k ; $(\tau\gamma)_{ik}$ is the treatment-by-year interaction; $\beta_{j(k)}$ denotes the effect of block j nested within year k ; and ε terms are random errors with mean zero and constant variance.

Pooled analyses over years were performed for all measured parameters to evaluate the combined effects of treatments across the years. Treatment mean differences for each response variable were separated using the LSD test ($p = 0.05$) level (Gomez and Gomez, 1984).

3 Results and discussion

3.1 Effect of different grass species on soil and water conservation, and crop yield

The control plots showed an increase in pin height due to topsoil loss from erosion. The significant ($p \leq 0.05$) difference in pin height was observed under plots without grass hedgerows as compared to plots with different grass species. The installed pins were set to a height of 10 cm above ground, with increasing and decreasing pin height designating erosion and deposition, respectively. However, there was no significant ($p < 0.05$) difference exhibited among Phalaris, Desho, and Vetiver grass (Table 1). Apparently, due to transportation of the soil through the erosion process on plots without grass species, the highest pin height (10.7 cm) was recorded. While the lowest mean value of pin height was observed under Desho grass species, this might be due to the development of the grass into hedgerows and the formation of barriers rapidly as compared to other grass species and plots without grass species. Thus, runoff velocity was reduced, resulting in the deposition of eroded soil under established grass hedgerows. This finding is consistent with Mekonnen et al. (2016), who found that desho grass with the highest tiller number and density and the second highest root length (depth) had a higher sediment trapping efficiency (76%) than the other grass species, Vetiver (59%), Senbelet (49%), Akirma (36%), and Sebez (20%). Additionally, Kelbore and Wote (2023) noted that the desho plants maintained 20 cm apart on the Fanyaju embankment demonstrated robust root and stem growth and strengthened the physical structure.

Furthermore, the Desho grass hedgerow expands up to 2 meters wide. Effective management practices, such as regular trimming and monitoring, are essential to ensure that the hedgerow remains

beneficial without encroaching on productive land. This careful balance allows farmers to harness the advantages of the Desho grass.

Organic carbon fraction (%), the analysis exhibited significant difference between the treatments for surface soil (0–20 cm). Plots treated with desho grass showed a significant difference as compared to other treatments (Table 1). This might be due to the higher biomass production potential of the grass and the input of organic matter as litter in plots treated with desho grass. According to Sinore and Doboch (2021), the highest mean value of soil organic carbon (4.01 ± 0.44) was recorded in the soil bund with desho grass and the lowest mean value (1.88 ± 0.88) was observed in the adjacent soil bund only. Similarly, the maximum mean average value of soil organic matter (SOM; 3.05 ± 0.21) observed in conserved farmland with Desho grass and the lowest mean average of soil organic matter (SOM; 1.88 ± 0.12) at un-conserved farmland with control farmland (Tuji and Moges, 2022).

Regarding soil moisture content (%), There was significant ($p > 0.05$) difference shown between the treatments, the highest mean value was exhibited under plots with Vetiver grass hedgerows as compared to plots with Phalaris and Desho grass hedgerows and plots without grass species (Table 1). This was probably due to the greater root system biomass of vetiver grass that helps to store more water in the soil profile. According to Gesesse et al. (2013), the use of vetiver grass improved the soil moisture content, and the lowest runoff and soil loss were recorded from the vetiver grass (Welle et al., 2006).

The analysis indicated that there was no significant ($p > 0.05$) variation in yield of soybean between the treatments (Table 1). This could be owing to the younger age of grass hedgerows; soil fertility improvement may take longer to exhibit results, and vice versa. This may imply that continual maintenance and monitoring of the farmland under treatment is required to increase long-term farm productivity. In contrast to this finding, Hailu et al. (2020) reported that farm land treated with vetiver grass hedgerows significantly improved crop yield.

3.2 Interaction effect of different grass species and years on organic carbon, pin height, soil moisture and soybean yield

Organic carbon fraction (%): The analysis revealed that the interaction effect of the treatments and years did not show significant differences for soil organic carbon fraction in surface soil (0–20 cm) under the treatments and years (Table 2).

Erosion and deposition monitoring pin height (cm): The interaction effect of treatments and years showed significant differences ($p < 0.05$) in pin height (cm) under the control plot in 2009, 2010, and 2011 as compared to other treatments and years (Table 2). This might be due to exposure of the control plot (untreated with grass species) to soil erosion.

Soil moisture content (%): The analysis depicts that the interaction effect of the treatments and years showed significant differences ($p < 0.05$) under plots treated with vetiver grass and desho grass for soil moisture content as compared to other treatments in 2012 (Table 2). This is probably due to vetiver grass and desho grass producing more aboveground and belowground biomass, which improves organic matter input and enhances soil structure and soil moisture retention under the plots treated with the grasses. Adugna (2024) reported that vetiver and Desho hedges showed the highest potential of conserving soil moisture, whereas the plot not treated with grass hedges showed the lowest soil water, which is in line with our finding.

Soybean yield (kg ha^{-1}): The analysis of the result indicates that the interaction effect of the treatments and years did not show significant differences for the yield of soybean under the treatments and years (Table 2).

3.3 Comparisons of the organic carbon content of different grasses in the shoot, root, and soil ($\text{Mg C ha}^{-1} \text{ yr}^{-1}$) at Melko

A comparison of shoot biomass and carbon content of different grass species has shown that Vetiver grass possesses higher potential in dry weight biomass and organic carbon content than other grass species. However, the higher mean value was exhibited in fresh weight and organic carbon fraction under Desho grass (Table 3).

A significant amount of root fresh weight, dry weight biomass, and carbon fraction were observed in Vetiver grass as compared to Desho and Phalaris grasses. Phalaris grass possesses a higher potential for both fresh and dry root biomass and carbon fraction than Desho grass (Table 4). According to Munnu Singh et al. (2014), aromatic grass, vetiver sequesters (*Vetiveria zizanioides* L.) $15.24 \text{ Mg C ha}^{-1} \text{ year}^{-1}$ in shoots and roots, much higher than that for lemongrass (*Cymbopogon flexuosus*) with $5.38 \text{ (Mg ha}^{-1} \text{ year}^{-1})$, and palmarosa (*Cymbopogon martinii* var. *motia*) with $6.14 \text{ (Mg ha}^{-1} \text{ year}^{-1})$. This significant difference highlights the potential of vetiver grass as an effective tool for carbon sequestration in sustainable land management

TABLE 1 Over year mean value of selected parameter as influence by different grass species at Melko.

Treatments	OC % (0–20 cm)	SM % (0–20 cm)	PH (cm)	Yield Kg ha^{-1}
Control	2.1	29.6	10.7	2211
Phalaris	2.3	30.6	9.4	2333.2
Desho	2.3	29.7	9.3	2135.9
Vetiver	2.1	32.9	9.4	2196.1
mean	2.2	30.7	9.7	2219
CV (%)	13.4	8.1	3.1	26.6
LSD (<0.05)	0.24	2.06	0.25	NS

OC: percent of Organic carbon fraction; PH: Erosion or deposition monitoring pin height (cm); SM: Percentage of soil moisture content; Yield in kilogram per ha; CV: Coefficient of variation; LSD: Least significance differences; NS: non-significant differences.

TABLE 2 Mean value of different grass species interaction with years for selected parameters at Melko.

Year	Treatments	OC % (0–20 cm)	SM % (0–20 cm)	PH (cm)	Yield Kg ha ⁻¹
2009	Control	1.93	24.77f	10.43b	
2009	Phalarais	2.176	24.23f	9.67c	
2009	Desho	2.39	24.83f	9.63c	
2009	Vetiver	1.56	25.33f	9.57c	
2010	Control	2.24	22.133fg	11.40a	1429.91
2010	Phalarais	2.6	18.50g	9.40cde	1592.7
2010	Desho	2.59	20.07g	9.47cd	1403.18
2010	Vetiver	2.49	18.47g	9.57c	1609.32
2011	Control	2.09	31.24e	11.57a	2506.12
2011	Phalarais	2.39	32.69de	8.97def	2459.86
2011	Desho	2.49	31.37de	8.67f	2399.95
2011	Vetiver	2.03	35.39d	8.93ef	2537.73
2012	Control	2.04	40.33c	9.23cde	2696.83
2012	Phalarais	1.84	46.87b	9.50c	2947.01
2012	Desho	1.89	42.67c	9.60c	2604.61
2012	Vetiver	2.24	52.37a	9.57c	2441.19
CV (%)		13.43	8.06	3.11	26.63
LSD(<0.05)		NS	4.13	0.5	NS

OC: percent of Organic carbon fraction; PH: Erosion or deposition monitoring pin height (cm); SM: Percentage of soil moisture content; Yield in kilogram per ha; CV: Coefficient of variation; LSD: Least significance differences; NS: non-significant differences.

TABLE 3 Mean Shoot Carbon content (Mg C ha⁻¹yr⁻¹) and carbon sequestered in relation to different grass species at Melko.

Treatments	Shoot				
Grass species	Fresh wt Mg ha ⁻¹ yr ⁻¹	Dry wt Mg ha ⁻¹ yr ⁻¹	OC%	Mg C ha ⁻¹ yr ⁻¹	Carbon sequestered (ton ha ⁻¹)
Phalaris grass	50.16	17.6	49.96	8.8	32.296
Desho grass	92.69	33.3	51.71	17.22	63.1974
Vetiver grass	92.07	43.6	50.65	22.08	81.0336

Wt: weight; Mg ha⁻¹yr⁻¹: Mega gram per hectare per year; OC: Organic carbon fraction; C: Carbon.

TABLE 4 Mean value of Carbon root (Mg C ha⁻¹yr⁻¹) in relation to different grass species at Melko.

Grass species	Root				
	Fresh wt Mg ha ⁻¹ yr ⁻¹	Dry wt Mg ha ⁻¹ yr ⁻¹	OC%	Mg C ha ⁻¹ yr ⁻¹	Carbon sequestered (ton ha ⁻¹)
Phalaris grass	2.02	0.11	45.01	0.048	0.18
Desho grass	0.55	0.03	47.66	0.016	0.06
Vetiver grass	10.93	1.85	48.6	8.98	32.96

Wt: weight; Mg ha⁻¹yr⁻¹: Mega gram per hectare per year; OC: Organic carbon fraction; C: Carbon.

practices. Furthermore, understanding the carbon storage capabilities of various aromatic grasses can inform agricultural strategies aimed at mitigating climate change impacts.

The higher mean value of soil organic carbon stock (15.9 Mg C ha⁻¹ yr⁻¹) and carbon sequestration (58.35 Mg ha⁻¹ yr⁻¹) were recorded under Vetiver grass, than under Desho, Phalaris grass, and plot without grass (control) within 0–100 cm of soil depth (Table 5). Tuji and Moges (2022), reported that vetiver and desho grass showed the significant ($p \leq 0.05$) difference in soil organic matter as compared

to untreated adjacent land. Furthermore, Tessema et al. (2024) reported that vetiver grass and undisturbed native pastures has on average a high accumulation rate of a more stable carbon.

3.4 Carbon sequestration (mg ha⁻¹ yr⁻¹)

Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide (Donovan, 2013; Herzog and Golomb,

TABLE 5 Mean value of SOC stock ($\text{Mg ha}^{-1} \text{yr}^{-1}$) and carbon sequestered (ton ha^{-1}) in 0–100 cm depth in relation to different grass species at Melko.

Treatments	SOC stock ($\text{ton ha}^{-1} \text{yr}^{-1}$)	Carbon sequestered (ton ha^{-1})
Control	12.1	44.407
Phalaris grass	12.5	45.875
Desho grass	13.5	49.545
Vetiver grass	15.9	58.353

SOC: Soil organic carbon; $\text{Mg ha}^{-1} \text{yr}^{-1}$: Mega gram per hectare per year.

TABLE 6 Mean total carbon stock ($\text{Mg ha}^{-1} \text{yr}^{-1}$) and carbon sequestered by different grass species at Melko (in shoots, roots, and (soil 0–100 cm)).

Treatments	Total carbon content ($\text{Mg ha}^{-1} \text{yr}^{-1}$)	Carbon sequestered ($\text{Mg ha}^{-1} \text{yr}^{-1}$)
Control	12.1	44.41
Phalaris grass	21.35	78.35
Desho grass	30.75	112.85
Vetiver grass	46.94	172.27

$\text{Mg ha}^{-1} \text{yr}^{-1}$: Mega gram per hectare per year.

2004). Here, carbon storage denotes the summation of total carbon sequestered in grass biomass both in grass shoots and roots and in the soil profile. Vetiver grass possesses the highest potential in carbon stock ($46.94 \text{ Mg ha}^{-1} \text{yr}^{-1}$) and sequesters more carbon ($172.27 \text{ Mg ha}^{-1} \text{yr}^{-1}$) as compared to Desho grass ($112.85 \text{ Mg ha}^{-1} \text{yr}^{-1}$), Phalaris grass ($78.35 \text{ Mg ha}^{-1} \text{yr}^{-1}$), and plots without grass species ($44.41 \text{ Mg ha}^{-1} \text{yr}^{-1}$). This might be due to unique characteristics of the physiology of the grasses such as a deep, finely structured root system, drought tolerance, and the ability to absorb heavy metals and nutrients, making it a valuable tool for soil conservation, remediation and carbon sequestration (Abate and Simane, 2001; Pang et al., 2003; Dorafshan et al., 2023). Conversely, the lowest mean value of total carbon content ($12.1 \text{ Mg ha}^{-1} \text{yr}^{-1}$) and carbon sequestered ($44.41 \text{ Mg ha}^{-1} \text{yr}^{-1}$) showed under control plot (Table 6). This result is in line with the findings of (Munnu Singh et al., 2014), who reported that vetiver grass has exhibited a highest potential for carbon sequestration as compared to other perennial aromatic grass species. This implies that grass species, particularly Vetiver grass, have the potential to reduce soil erosion and sequester carbon, both of which contribute significantly to climate change mitigation. However, there are limitations to encouraging this breakthrough technology's widespread use on all farmlands for a variety of reasons. For example, the bottleneck problem is free grazing; a lack of awareness of grass's multiple benefits, the availability of planting materials, and so on. Thus, developing and raising awareness about enhanced grazing systems such as cut and carry systems is critical, and all stakeholders should collaborate to expand planting materials and raise awareness about the multipurpose benefits of grass species.

The implication of this study was that different grass species have varied potential for soil and water conservation and carbon sequestration, which may be due to phenology of the grass. Vetiver grass conserved a significant amount of soil moisture and had the

highest value of carbon sequestration in shoot, root, and soil as compared to desho, phalaris, and control. Thus, vetiver systems are an innovative technology that contributes to climate change mitigation.

4 Conclusion and recommendation

The study revealed that the highest pin height was found in plots without grass species. In contrast, the lowest mean value was observed in the Desho grass species. The highest mean value of soil moisture content (%) was recorded under vetiver grass. Vetiver grass has the largest potential for carbon content in the shoot, root, and soil when compared to other grass species and control plots. In general, vetiver grass sequestered more carbon as compared to Desho and Phalaris grass. The vetiver grass system is easy, environmentally friendly, and low-cost to establish the grass hedgerows for soil and water conservation, farm boundary protection, and degraded land rehabilitation. Thus, the study suggests the use of vetiver grass hedgerows for soil and water conservation and carbon sequestration by integrating them into land management practices for similar agro-ecology, and further investigation is suggested for detailed experimentation and under different agro-ecological settings.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

LH: Data curation, Formal analysis, Investigation, Project administration, Writing – original draft, Writing – review & editing. GT: Conceptualization, Investigation, Methodology, Project administration, Writing – review & editing. WT: Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. YD: Conceptualization, Data curation, Investigation, Methodology, Writing – review & editing. AB: Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This work was supported by the Ethiopian Institute of Agricultural Research (EIAR).

Acknowledgments

We acknowledge the Ethiopian Institute of Agricultural Research for financially supporting the activity. We are also thankful to the Jimma agricultural research center soil and plant tissue analysis laboratory for soil sample and grass shoots and roots analysis. Our

gratitude goes to Mifta Abatemam and Tamirat Kebede for their ample support on fieldwork that makes our work very fruitful.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

References

- Abate, H., and Simane, B. (2001). Multiple benefits of the vetiver system and its environmental application in Ethiopia.
- Adimassu, Z., Mekonnen, K., Yirga, C., and Kessler, A. (2012). Effect of soil bunds on runoff, soil and nutrient losses, and crop yield in the central highlands of Ethiopia. *Land Degrad. Dev.* 25, 554–564. doi: 10.1002/ldr.2182
- Adugna, O. (2024). Effect of different grass species on soil and water conservation at Assosa, Benishangul Gumuz. *Ethiopia. Int. J. Curr. Res. Acad. Rev.* 12, 22–26. doi: 10.20546/ijcrar.2024.1204.003
- Adugna, O., Alemu, D., and Melkamu, T. (2019). Evaluation of vetiver grass (vetiver zizanodes) potential to soil erosion control at Assosa, benishangul Gumuz, Ethiopia. *Int. J. Environ. Sci. Natural Resources* 16, 33–38. doi: 10.19080/IJESNR.2019.16.555930
- Amede, Tilahun. (2003). Restoring soil fertility in the east African highlands through participatory research. Centro Internacional de Agricultura Tropical (CIAT), Kampala, UG. 2 p. (highlights: CIAT in Africa no. 7). Available online at: <https://hdl.handle.net/10568/70509>
- Aniye, H. W. Y., Bekele, T., and Worku, W. (2025). Trends of climate variability and its association with farmers' perceptions of climate change in Gassera district, southeastern Ethiopia. *Sci. Rep.* 15:4399. doi: 10.1038/s41598-025-89017-w
- Bekele, B., Gemi, Y., and Habtemariam, T. (2023). Desho and elephant grass strips for soil erosion control in sankura district, south Central Ethiopia. *Science* 13, 1–11p. doi: 10.1136/bmjopen-2023-076303
- Bresciano, D., Del Pino, A., Borges, A., Tejera, M., Speranza, P., Astigarraga, L., et al. (2019). Perennial C4 grasses increase root biomass and carbon in sown temperate pastures. *N. Z. J. Agric. Res.* 62, 332–342. doi: 10.1080/00288233.2018.1504089
- Cheru, U. G. (2024). Climate change, variability, and adaptation in Ethiopia. An analysis from the farmers' perception. *J. Selva Andina Biosphere* 12, 111–121. doi: 10.36610/j.jsab.2024.120200111
- Crow, S. E., Deem, L. M., Sierra, C. A., and Wells, J. M. (2018). Belowground carbon dynamics in tropical perennial C4 grass agro ecosystems. *Front. Environ. Sci.* 6:18. doi: 10.3389/fenvs.2018.00018
- Daley, B. (2015). Environmental issues in Ethiopia and links to the Ethiopian economy. *Report*. doi: 10.12774/eod_hd.september2015.daleyb
- De Mendiburu, F. (2023). *Agricolae: statistical procedures for agricultural research*. R package version 1.3–7. Available online at: <https://CRAN.R-project.org/package=agricolae>
- Demem, M. S. (2023). Impact and adaptation of climate variability and change on small-holders and agriculture in Ethiopia: a review. *Heliyon* 9:e18972. doi: 10.1016/j.heliyon.2023.e18972
- Donovan, P. (2013) Measuring soil carbon change: a flexible, practical, local method. pp. 1–56. doi: 10.1080/19371918.2013.774663
- Dorafshan, M. M., Abedi-Koupai, J., Eslamian, S., and Amiri, M. J. (2023). Vetiver grass (*Chrysopogon zizanoides* L.): a hyper-accumulator crop for bioremediation of unconventional water. *Sustainability* 15:3529. doi: 10.3390/su15043529
- Gashaw, T., Wubaye, G. B., Worqlul, A. W., Dile, Y. T., Mohammed, J. A., Birhan, D. A., et al. (2023). Local and regional climate trends and variabilities in Ethiopia: implications for climate change adaptations. *Environ. Challenges* 13:100794. doi: 10.1016/j.envc.2023.100794
- Gebreselassie, S., Kirui, O.K., and Mirzaeva, A., (2016). Economics of land degradation and improvement in Ethiopia. Economics of land degradation and improvement—a global assessment for sustainable development, 401–430. Switzerland: Springer International Publishing AG. doi: 10.1007/978-3-319-19168-3
- Gesesse, A., Balemi, T., Natarajan, P., and Amha, Y. (2013). Effect of Vetiver grass Headges in maintaining soil fertility and productivity at anno agro industry farm, GobuSayo District, Oromiya region, Ethiopia. *J. Sci. Sustain. Develop. (JSSD)* 1, 37–49. doi: 10.20372/au.jssd.1.1.2013.06
- Gomez, K. A., and Gomez, A. A. (1984). Statistical procedures for agricultural research. 2nd Edn. New York: John Wiley & Sons.
- Hailu, L., Tesfaye, G., and Yaekob, T. (2020). Effect of Vetiver grass (Vetiver Zizanodes) hedgerows on selected oil properties and crop yield on farm land at Haru District, western Ethiopia. *Int. J. Res. Stud. Agricul. Sci. (IJRSAS)* 6, 35–41. doi: 10.20431/2454-6224.0605005
- Herzog, H., and Golomb, D. (2004). Carbon capture and storage from fossil fuel use. *Encyclopedia Energy* 1, 277–287. doi: 10.1016/B0-12-176480-X/00422-8
- Hurni, H., Abate, S., Bantider, A., Debele, B., Ludi, E., Portner, B., et al. (2010). "Land degradation and sustainable land management in the highlands of Ethiopia" in With an international group of coeditors. Global change and sustainable development: A synthesis of regional experiences from research partnerships. Perspectives of the Swiss National Centre of competence in research (NCCR) north south, University of Bern. eds. H. Hurni and U. Wiesmann, vol. 5 (Bern, Switzerland: Geographical Bernensia).
- Jimma Agricultural Research Center /JARC/ (2020) in Research Progress report for the period 2018/19. eds. H. Seyoum, M. Tesfa, E. Asfew and Y. Silesh (Jimma: EIAR/JARC), 276.
- Kassie, B. T. (2014). Climate variability and change in Ethiopia: Exploring impacts and adaptation options for cereal production. Wageningen: Wageningen University and Research.
- Kato, E., Ringler, C., Yesuf, M., and Bryan, E. (2011). Soil and water conservation technologies: a buffer against production risk in the face of climate change? Insights from the Nile basin in Ethiopia. *Agric. Econ.* 42, 593–604. doi: 10.1111/j.1574-0862.2011.00539.x
- Kebede, T., and Yaekob, T. (2009). Research and development of Vetiver grass (Vetiver. Zizanioides, L.) in Ethiopia. Jimma, Ethiopia: Jimma Research Center.
- Kelbore, Z. A., and Wote, T. T. (2023). Fanyaa juu stabilization and productivity of *Pennisetum Pedicellatum* in response to planting position and spacing at Hawassa Lake watershed. *Southern Ethiopia. Cogent Food Agriculture* 9:2275401. doi: 10.1080/23311932.2023.2275401
- Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. *Science* 304:396. doi: 10.1126/science.1097396
- McSweeney, C., New, M., Lizcano, G., and Lu, X. (2010). The UNDP Climate Change Country Profiles: Improving the accessibility of observed and projected climate information for studies of climate change in developing countries. *Bulletin of the American Meteorological society*, 91, 157–166.
- Mekonnen, M., Keesstra, S. D., Ritsema, C. J., Stroosnijder, L., and Baartman, J. E. (2016). Sediment trapping with indigenous grass species showing differences in plant traits in Northwest Ethiopia. *Catena* 147, 755–763. doi: 10.1016/j.catena.2016.08.036
- Mitiku, H., Herweg, K., and Stillhardt, B. (2006). A New approach to soil and water conservation in Ethiopia. Mekelle, Ethiopia: land resources management and environmental protection department. *Sustainable Land Manag.*:269. doi: 10.7892/BORIS.19217
- Morgan, R. P. C. (2005). Soil erosion and conservation. Third Edn. Oxford: National Soil Resources Institute, Cranfield University, Blackwell publishing, 1–24.
- Munnu Singh, M. S., Guleria, N., Rao, E. V. S. P., and Prashant Goswami, P. G. (2014). Efficient C sequestration and benefits of medicinal vetiver cropping in tropical regions.
- Nazir, M. J., Li, G., Nazir, M. M., Zulfiqar, F., Siddique, K. H., Iqbal, B., et al. (2024). Harnessing soil carbon sequestration to address climate change challenges in agriculture. *Soil Tillage Res.* 237:105959. doi: 10.1016/j.still.2023.105959
- Nkonya, E., Pender, J., Kaizzi, K. C., Kato, E., Mugarura, S., Ssali, H., et al. (2008). Linkages between land management, land degradation, and poverty in sub-Saharan Africa: the case of Uganda. *Res. Report Int. Food Policy Res. Institute*. 159. doi: 10.2499/9780896291683RR159

- Nopmalai, P., Sukhkasem, A., Kanjanathanaset, K., Wattanaprat, K., and Meesing, I. (2015). Study on carbon storage and carbon balance in vetiver grass cultivation areas in northern Thailand. Chatuchak, Bangkok, Thailand: Land Development Department.
- Odiwe, A. I., Olanrewaju, G. O., and Raimi, I. O. (2016). Carbon sequestration in selected grass species in a tropical lowland rainforest at Obafemi Awolowo university, Ile-Ife, Nigeria# [January 26, 2017: [expression of concern] plagiarism has been detected in this manuscript. *J. Tropical Biol. Conservation (JTBC)* 13, 1–12. doi: 10.51200/jtbc.v13i.393
- Pang, J., Chan, G. S. Y., Zhang, J., Liang, J., and Wong, M. H. (2003). Physiological aspects of vetiver grass for rehabilitation in abandoned metalliferous mine wastes. *Chemosphere* 52, 1559–1570. doi: 10.1016/S0045-6535(03)00496-X
- Pinnars, E. (2014). Vetiver system: reversing degradation on and off farm to keep soil carbon in place, build up root biomass, and turn degraded areas into biofuel sources. *Geotherapy: Innovative Methods Of Soil Fertility Restoration, Carbon Sequestration, And Reversing CO2 Increase*, 301.
- R Core Team (2023). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.
- Singh, M., Guleria, N., Rao, E. P., and Goswami, P. (2011). “A strategy for sustainable carbon sequestration using Vetiver (*Vetiveria zizanioides* (L.)): a quantitative assessment over India” in Project document CM PD-1101, CSIR Centre for mathematical Modeling and computer simulation (India).
- Sinore, T., and Dobocho, D. (2021). Effects of soil and water conservation at different landscape positions on soil properties and farmers’ perception in Hobicheka sub-watershed, southern Ethiopia. *Appl. Environ. Soil Sci.* 2021, 1–12. doi: 10.1155/2021/9295650
- Tefera, T., Yaziz, B., and Shimbir, T. (2019). Response of coffee genotypes (*Coffea Arabica*) for moisture stress condition at Tepi, south west of Ethiopia. *Int. J. Res. Stud. Agricul. Sci. (IJRSAS)* 5, 8–13. doi: 10.20431/2454-6224.0501002
- Tessema, B., Baldock, J. A., Daniel, H., Kristiansen, P., Adimassu, Z., and Wilson, B. (2024). Soil carbon fractions under Vetiver grass in Australia and Ethiopia relative to other land uses. *J. Soil Sci. Plant Nutr.* 24, 5680–5695. doi: 10.1007/s42729-024-01933-4
- Tessema, B. G., Daniel, H., Adimassu, Z., Wilson, B., and Ghimire, B. K. (2021). Soil carbon storage potential of tropical grasses: a review. *Botany-Recent Advan. Applications* 97835, 21–29 pp. doi: 10.5772/intechopen.97835
- Tuji, M., and Moges, A. (2022). Effects of Desho and Vetiver grass strips on selected soil physical and chemical properties: the case of kasha watershed, Southwest Ethiopia. *American J. Water Sci. Eng.* 8, 52–60. doi: 10.11648/j.ajwse.20220803.11
- Wakley, A., and Black, I. A. (1934). An estimation of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science.* 37:29–38.
- Wattanaprat, K., Meesing, K. K. I., and Nopmalai, P. (2006). Correlation between Vetiver root biomass with soil organic carbon and CO₂ emission in agricultural areas of the southern part of Thailand. Bangkok, Thailand: Land Development Department.
- Welle, S., Chantawarangul, K., Nontananandh, S., and Jantawat, S. (2006). Effectiveness of grass strips as barrier against runoff and soil loss in Jijiga area, northern part of Somali region. *Ethiopia. Agriculture and Natural Resources* 40, 549–558.
- Zena, H. L., and Abie, Y. (2023). Evaluation of biological measures and multipurpose adaptive grass on soil bund in Lasta district. *Ethiopia. Heliyon* 9:e18198. doi: 10.1016/j.heliyon.2023.e18198