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Optimal Vetiver Hedgerow Spacing for Mitigating Sediment and Runoff Erosion on Steep Slopes in Malawi

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Abstract

This study assessed the optimum vetiver hedgerow spacing capable of reducing sediment and runoff erosion on a 17% slope. Three treatments were used: 2-meter vetiver hedgerow spacing, 4-meter vetiver hedgerow spacing, and a control plot without vetiver. Erosion pins were strategically placed on the plots and measured periodically over a period of 6 months, accompanied by daily rainfall measurements. The findings revealed the effectiveness of vetiver hedgerows in reducing sediment erosion and runoff from the plots. Notably, the 2-meter vetiver hedgerow spacing proved more efficient in reducing erosion and minimizing soil accumulation within the plot, with an average change in erosional pin height of 1.2 cm, whereas the 4-meter hedgerow spacing exhibited higher erosion rates at 2 cm, which was statistically significant. These results underscore the importance of optimizing vetiver hedgerow spacing to effectively combat soil erosion and runoff on steep slopes.

Introduction

Land degradation encompasses a wide array of changes in ecosystems' capacity to provide essential biological, social, and economic services. Among the significant contributors to land degradation, water and wind erosion stand out as major causes of

topsoil loss (Fenta et al., 2020). The consequences of land degradation are particularly alarming for sustainable agriculture due to the depletion of soil nutrient capital (Mishra et al., 2021). This depletion not only jeopardizes soil quality and productivity but also poses a serious threat to the sustainability of agriculture, environmental stability, and overall land quality, thereby persistently affecting crop yields if proper soil management measures are not implemented.

Recognizing the critical importance of addressing land degradation, the Government of Malawi introduced and intensified campaigns focused on soil and water conservation. To ensure the continuity and cost-effectiveness of soil management programs, community participation has been emphasized. As a result of these initiatives, farmers adopted various soil management technologies, including the utilization of vetiver grass (*Vetiveria zizanioides*), constructing contour bunds, and implementing box ridges. Vetiver grass, owing to its unique morphological, physiological, and ecological characteristics, emerges as a promising and practical solution to combat soil erosion in both tropical and temperate regions worldwide (Islam et al.,2021). Its adaptability to diverse climatic and soil conditions, such as varying soil moisture, temperature, slope gradients, and fertility levels, makes it a versatile tool in soil conservation and stability efforts. When planted along contour lines or contour marker ridges, vetiver grass forms a dense hedge, effectively reducing soil loss and runoff by slowing down and dispersing concentrated flows of runoff water (Aziz & Islam, 2023).

However, despite the effectiveness of vetiver in mitigating soil erosion, the application of vetiver hedgerow spacing in agriculture fields is influenced by various factors, including slope, crop type, rainfall intensity, and soil type. These factors introduce variations in the required spacing of vetiver hedgerows across different landscapes, and if not properly considered, vetiver grass may not effectively reduce erosion. In Malawi, these factors, particularly on steep slopes, have challenged farmers to align their vetiver hedgerow spacing to effectively combat erosion. The varying effectiveness of vetiver on such slopes underscores the necessity to assess the optimum vetiver hedgerow spacing specifically suitable for reducing sediment erosion and runoff on slopes steeper than 12%. This study aims to provide valuable insights into the appropriate hedgerow spacing for farmers cultivating on steep slopes, thereby supporting the government's efforts to combat soil degradation and enhance crop productivity.

Methodology

The study was conducted in Lilongwe district at the Greenworld Nurseries Farm in Pondamali along S125 Bunda Road. The farm is geographically located between 14° 06’ 04.55’’ S, latitude and 33° 47’ 061’’ E longitude.

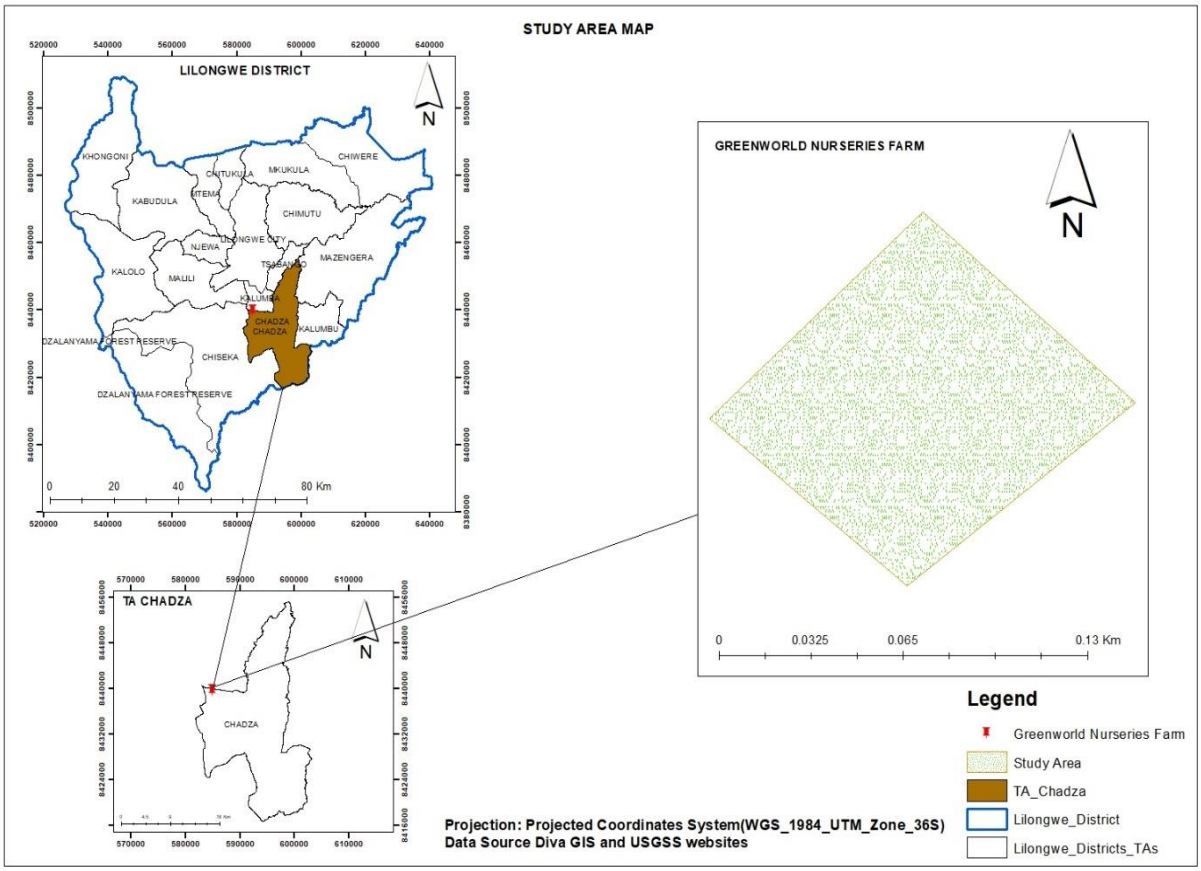

Figure 1: Map of the study area

The study was conducted for 6 months during the growing season of 2022 October to 2023 March. Vetiver grass was planted on 23 July 2022, early before the September-October-November rains. This early planting was done for the vetiver to be fully established in the field. All vetiver grasses were planted on the same day using the following process: a trench was dug, along the width of the plots about 15cm deep and they were pruned to 30 cm height. The vetiver grass strips were watered, so that they were able to survive and be established with the soil.

Other materials such as, a tape measure was used to measure the erosional plots area. An inclinometer and dumpy level were used to determine the slope. In addition, 12 erosional pins with a height of 40 cm were placed on the plot to study the erosion happening and evaluate the effectiveness of the vetiver hedgerows depending on the accumulation of soil occurring on the pins inside the plot. The pins were installed 10 cm in the ground while 30 cm was protruding to measure the accumulation occurring on the pin by subtracting the new distance from the known distance (30 cm). The pins were placed at 1-meter intervals that is before a vetiver hedgerow and after a vetiver hedgerow. Similarly, on the control plot the pins were placed with the same interval of 1 meter. At the end of plot, a bucket was placed to collect the runoff sediments for each month.

The vetiver hedgerow spacing, or treatments used were 2m, 4m spacing and control plot with no vetiver. The spacings were chosen by taking into consideration of previous studies on vetiver spacing in Malawi that recommends the use of not more than 5m

spacing on steep slopes of more than 12%. Similarly, according to Keyadi, (2021) elaborated that as the slope percentage increases, the potential for runoff and erosion normally increases hence recommended that the vetiver spacing has to be reduced. The assumption is that a narrower spacing is efficient in controlling erosion while a wider spacing of hedgerows is better in managing water runoff, however the effectiveness of the performance of the spacing chosen will vary and be affected by the slope, rainfall, crop and soil type of the region hence the need of this study to determine the best spacing.

Experimental designs

The experiment was laid out as a one-way factorial under a Randomized Complete Block Design (RCBD). The experiment had three treatments which were randomized and replicated three times (Table 1).

Table 1: Treatment codes and their description

Code	Treatment
T1	Vetiver Hedgerow planted at 2m spacing
T2	Vetiver Hedgerow at 4m spacing
T3	No vetiver

The collected Sediments and runoff water for each treatment were weighed and recorded to assess the mean soil loss between the treatments. The height of the erosion pins was measured by a tape measure and recorded to assess the difference in change of pin heights due to the erosion occurring within the plot. The analysis of the sediments and pin heights was done through Analysis of Variance (ANOVA) where the Turkey Test was used to compare the means at 0.05 significance level. A recording rain gauge was used at the experimental site to measure the amount of daily rainfall depending on the occurrence of the rains on the location. The runoff and soil loss were collected in the morning twice every month after an effective previous day's rain. The volume of runoff was estimated by multiplying the height of water in each funnel by the cross-sectional area of the funnel. Runoff amount (in millimetre) was estimated by dividing the volume of water received in the sedimentation drum by the area of the plot generating the runoff (eq. 1).

$$\text{Runoff (mm)} = \frac{volume\ of\ water\ (m)}{area\ of\ the\ plot(m)} \quad (1)$$

Results and Discussion

The Effect of Vetiver Hedgerow Spacing in the Collection of Sediment

As shown in Table 2, the mean collection of sediments for T1, T2 and T3 were 67.53g, 70g and 90.42g respectively. There was no significant difference between T1 and T2 on sediment collection.

Table 2: Differences in the mean sediments collected

Treatment	Average Sediments Collected (g)
2m VBS	67.53
4m VBS	73.46
No VBS (control)	90.42
F prob	0.003
LSD (0.05)	0.004
CV%	4.5

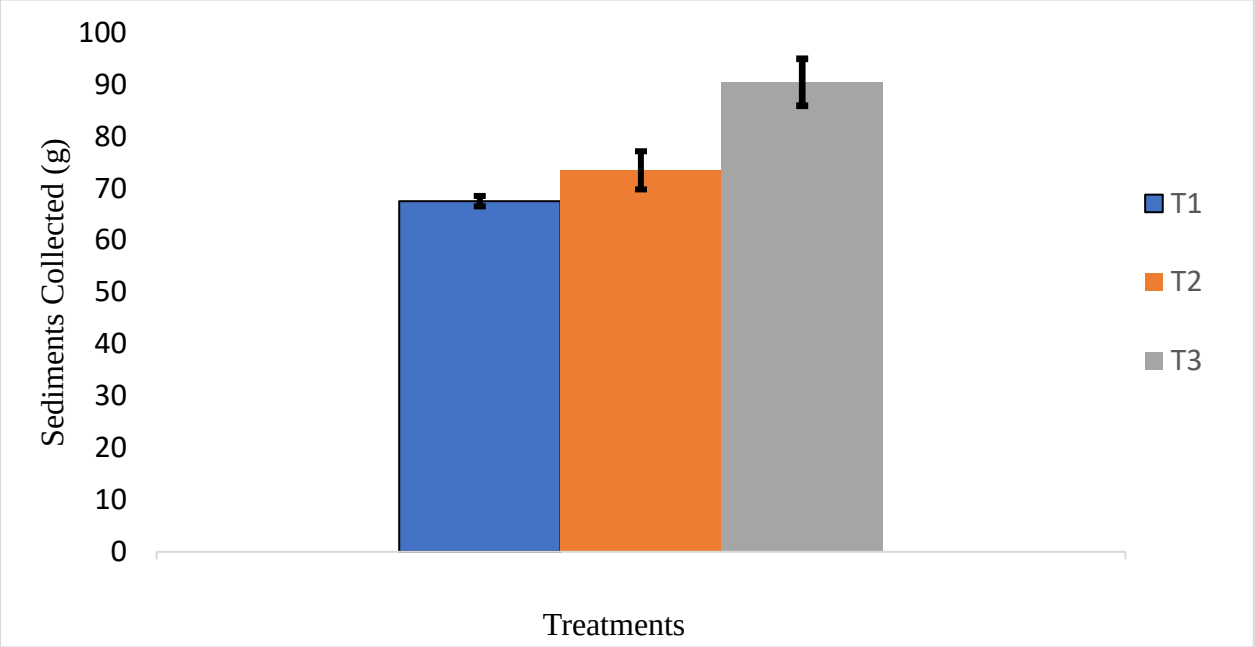

Figure 2: Sediments collection

Results presented in Figure 2 demonstrate the effectiveness of both the 2m and 4m vetiver hedgerows in reducing sediment erosion or soil loss from the plots, in contrast to the control plot without vetiver, which exhibited significantly higher erosion rates. The observed differences in soil loss can be attributed to the role of vetiver hedgerows acting as barriers that impede the movement of soil across the plot. The presence of vetiver grass restricts the runoff's ability to detach and transport soil particles, primarily due to its high retardance effect on runoff velocity and its physical protection of the soil from the impact of runoff (Garzón et al., 2020, Asima et al., 2022). Consequently, this led to the lowest sediment collection in the plots with vetiver grass, confirming its effectiveness in reducing erosion.

The Effect of Vetiver Hedgerow Spacing on Surface Runoff

The runoff reduction varied across the plots (Table 3). However, there was no significant difference between the 2m vetiver hedgerow and 4m vetiver hedgerow treatments concerning the amount of runoff. Both vetiver grass spacings proved effective in reducing runoff compared to the control plot without vetiver. These findings

align with similar reports by Islam et al., 2021 and Aziz & Islam, 2023 who observed significantly lower runoff depths on the vetiver grass plot compared to the control, attributing it to the higher roughness provided by the stems and leaves, which reduced the runoff velocity and facilitated increased soil infiltration.

Table 3: Different vetiver hedgerow spacing and runoff reduced

Treatment	Average Rainfall Amount (mm)	Runoff Amount (mm)
2m VBS	233.42	12.65_a
4m VBS	233.42	13.15_a
No VBS $_{(control)}$	233.42	15.90_b
F prob	-	0.015
LSD $_{(0.05)}$	-	1.326
CV%	-	6.1

The Effect of Vetiver Hedgerow Spacing on Erosional Pins

Accumulation of sediments on erosion pins varied widely across the plots (Table 4). The results indicate a significant difference in the effectiveness of reducing erosion and soil accumulation within the plots between the different vetiver hedgerow spacings, as evidenced by the average change in pin heights.

Table 4: Vetiver grass spacing and average change in erosion pin heights (cm)

Treatment	**Total average (cm)**
2m VBS	1.2
4m VBS	2
No VBS $_{(control)}$	3.5
F prob	0.005
LSD $_{(0.05)}$	0.865
CV%	16.3

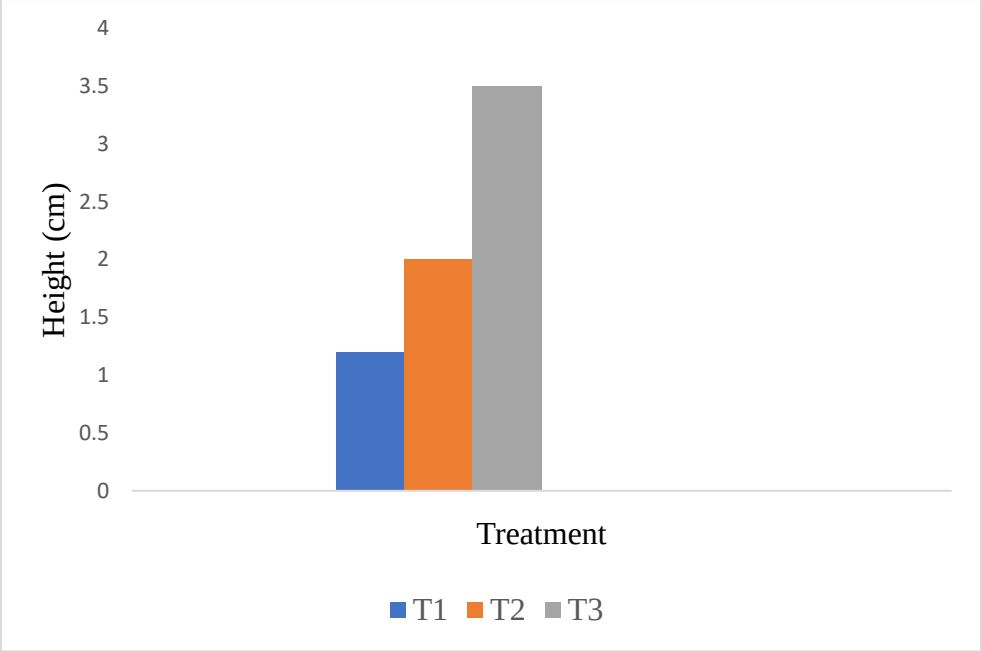

Figure 2: Change in erosional pin heights

The observed significant differences in erosion reduction within the plot among the treatments are in line with similar studies conducted by Garzón et al., 2020 who found comparatively lower and varying erosion levels on the vetiver-treated plots, whereas the control plot exhibited substantial erosion and deposition. Garzon (2020) discussed that the presence of vetiver acted as a barrier, leading to a minor amount of soil deposition on the hedgerows, while the control plot, lacking this barrier, experienced more significant soil accumulation. The narrow spacing of vetiver hedgerows, such as the 2m spacing in this study, effectively reduces runoff velocity by impeding its momentum within the alleys or between buffer strips due to the abundance of hedgerows or buffer strips available on the plot. Consequently, this limitation on runoff velocity results in decreased soil particle transport, leading to lower soil accumulation on the pins in the 2m vetiver hedgerow spacing plots. Similar significant differences in erosion reduction within the plot were also observed by Odutola Oshunsanya et al., 2023, who explained that the narrower spaced vetiver buffer strip (5m) more effectively reduced the velocity of rainwater running downslope on farmlands compared to the widely spaced ones (15m). The presence of multiple hedgerows at every 5m distance in the 5m spacing buffer strips contributed to the reduction in soil movement and accumulation on the pins, while the 15m spacing resulted in higher soil accumulation due to the greater distance between the vetiver barriers.

Conclusion and Recommendations

Vetiver hedgerows effectively reduce runoff and sediment erosion. The efficacy of vetiver hedgerows in trapping sediments and reducing runoff can be attributed to the stiff structure of vetiver grass, which lowers runoff velocity, promotes the dispersion of runoff water, and facilitates increased water infiltration into the soil. Notably, the 2m vetiver hedgerow spacing proved particularly effective in reducing erosion and soil accumulation within the plots, as indicated by the average change in erosional pin heights. Vetiver hedgerows as a valuable measure for mitigating runoff and sediment erosion, The utilization of vetiver hedgerows can thus be recommended as a practical

and environmentally friendly approach to enhance soil conservation and sustainable land management practices among farmers.

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