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Re-seeding on highly degraded rangeland as strategy for forage production, biodiversity, and carbon sequestration in Ethiopia

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Abstract

Rangeland degradation is becoming a serious problem in semiarid areas affecting rangeland productivity and hence the livelihood of the pastoralists. Degraded rangelands have low levels of soil carbon stock and diminished potential for biomass production. To overcome this problem, a re-seeding strategy is one option that needs to be considered. Accordingly, a study was conducted to examine the impact on biomass production, carbon stock, soil water content and biodiversity of re-seeding highly degraded rangeland with native grasses. Random sampling techniques using quadrats (0.5m x 0.5m) for biomass and species composition assessment were employed on re-seeded and non-seeded plots. Simpson's index of diversity was used to calculate the biodiversity of the vegetation. The soil organic carbon was calculated from soil samples taken at three depths (0-10 cm, 10-20 cm, and 20-30 cm) from re-seeded and non-reseeded plots. The results showed that vegetation composition recovered from the soil seed bank, forage biomass was higher, and carbon stock better on the re-seeded plot. There were sixteen species recovered in addition to *Chloris Gayana* and *Cenchrus ciliaris* on the seeded plots. The Simpson diversity of vegetation on the seeded plots was 0.78 compared with zero on the non-seeded ones. The dry matter yield for re-seeded plot and non-reseeded plots were 3.6, and 0.2 t/ha, respectively. Carbon stock was 15% higher under the restored rangeland compared to non-restored. The overall soil water content was 16.3 and 10.75% for re-seeded plot and non-re-seeded plots, respectively. Options to improve the productivity of highly degraded rangeland for multiple benefits could involve re-seeding with native grasses with integration of appropriate planning and continuous sourcing of grass seeds.

Introduction

Ethiopia's rangelands, covering 62% of the country's land area, provide essential feed for livestock and support the livelihoods of 12-15 million pastoralists (Gina 2015). However, like many other rangelands of the worldwide, Southern Ethiopia's dry land rangelands are facing degradation due to factors such as vegetation loss, increased abundance of unpalatable plants, bush encroachment, conversion to cropland, and overgrazing, exacerbated by climate change (Abdulahi et al. 2016).

Despite these challenges, protected vegetation can recover rapidly. Restoration methods, including reseeding, natural regeneration, and soil and water conservation practices, can address the underlying causes of degradation (Ouled Belgacem et al. 2019). Improved rangeland management can enhance ecosystem services, such as carbon sequestration (Henry B et al. 2024). By implementing appropriate rangeland management rules and successful restoration/rehabilitation practices, it is possible to slow and reverse land degradation, thereby increasing rangeland carrying capacity. This study aims to:

- Determine the capacity of reseeding native grasses on degraded rangelands to enhance ecosystem services, including carbon sequestration, forage production, and biodiversity.
- Raise awareness among development actors about the multiple environmental benefits of specific rangeland management practices.

Methods

Area description and site selection

The assessment was conducted in the rangelands of southern Ethiopia, specifically in the Dugda-Dawa district. This area, located between 4-6°N and 36-42°E, exhibits gentle slopes ranging from 1600 meters above sea level (masl) in the northeast to approximately 1000 masl in the extreme south, bordering Northern Kenya, and reaching 1780 masl in the central vicinity. Rainfall in this region is bimodal, with long rains occurring between March and May and short rains between September and November. The Dugda-Dawa district is a highly degraded rangeland where rehabilitation efforts, including reseeding with native grasses, have been initiated by the Yabello Pastoral and Dryland Agricultural Research Center. Local pastoralists reported that this specific area had been left degraded for over 33 years before the reseeding initiated began.

Data sampling procedures

Sampling was done for reseeded and non-reseed areas. The biomass was calculated using the 50 quadrats (0.5m X0.5m) that each taken from the reseeded area and non-reseeded area. Dry matter yield of grasses was determined after oven drying at 105 °C for 24 hours at Yabello Pastoral and Dry land Agriculture Research Centre.

Six samples of soil were collected from the depth of 0-10cm, 10-20cm and and 20-30 cm, from both reseeded and non-reseeded and bulked together for analysis of organic soil carbon by methods of Black and Walkely method used as described by Sahlemedhin and Taye (2000). Soil bulk density was analyzed following standard procedures (Bashour and Sayegh, 2007). The soil organic carbon stock was calculated using equation (Guo and Gifford, 2002). For soil water content, soil sampling was done using 5mm can from 10 point at depth of 0-10 cm and 10-25 cm within each area. Soil samples were covered and taken to laboratory for gravimetric moisture analysis (Michael 1978). Gravimetric moisture contents were calculated by expressing the percentage moisture on dry mass basis.

Simpson's diversity index was used to quantify the species composition. The data analysed and presented with descriptive methods, like percentage and average of the two areas.

Results

Dry matter yield

This result indicates a high potential for restoring degraded rangelands to support feed production. The previously barren, vegetation-deprived rangelands have shown promising signs of recovery. Although the initial seeding involved a mixture of two grass species with minimal tillage, the subsequent emergence of diverse vegetation has led to a significant increase in biomass in the reseeded area. It's important to note that the average dry matter yield for reseeded was 3.6 t/ha and for non-reseeded area was 0.2t/ha of a single cutting during the growing season. This suggests that the total annual dry matter yield for the reseeded area could potentially be double the value shown above if two cuts for the two seasons considered.

Soil organic Carbon and vegetation composition

Some differences were observed in soil organic carbon (%) content, particularly at the upper depth (0-10 cm) where 1.06 and 0.85 for reseeded and non-reseeded, respectively. The soil bulk density for reseeded and non-seeded areas were 1.21gm cm^{-3} and 1.3 1gm cm^{-3}, respectively. This may be due to the incorporation of root systems, organic matter and some tillage in the reseeded area. When calculating carbon stock (t/ha) for the upper depth (0-10 cm), the reseeded area exhibited approximately 15% higher carbon stock compared to the non-seeded area. This finding suggests that highly degraded pastoral areas can respond to climate change mitigation efforts through measures like reseeding. Such measures can improve rangeland resource management, minimize current vulnerabilities, and enhance resilience to future changes in rangeland degradation. The increased carbon stock in the reseeded area demonstrates the potential of such measures to improve the capacity to respond to climate change. The reseeded area, comprising two grass species, exhibited an increase in plant species diversity to eighteen, including twelve grasses and six non-grasses. Of the twelve grass species, eleven were perennial and highly desirable for livestock feed. The Simpson's Diversity Index calculated a biodiversity value of 0.78 for the reseeded area. The five dominant plant species in terms of percentage composition were *Digitaria melanjiana (*37.78%), *Chloris gayana (25.9%)*, *Indigophera spinosa (4.75%)*, and *Eragrostis capitulifera (3.77%)*.

Soil water content at reseeded and non-reseeded areas

Soil water content significantly influences plant growth and other soil properties. In this study, the soil water content of the reseeded area was found to be higher than that of the non-reseeded area at similar depths. The overall average of soil water content was 16.3 and 10.75% for re-seeded plot and non-reseeded plots respectively. Compared to the non-reseeded area, the reseeded area exhibited a 51.4% and 51.7% increase in soil water content at the 0-10 cm and 10-25 cm depths, respectively.

Discussion

The reseeded area exhibited increased biomass yield and vegetation composition. This improvement can be attributed may be to the long-term persistence of a soil seed bank, which was activated by minimal tillage on the highly degraded rangeland. In contrast, highly compacted, degraded rangelands have limited potential for aeration and water infiltration, hindering vegetation recovery. Amaha et al. (2009) found that degraded rangelands have the capacity to regenerate from existing soil seed banks, demonstrating their potential for recovery. Similar to our findings, Sahar Ezzat et al. (2013) reported enhanced biomass production through reseeding. While various factors influence soil organic carbon, the reseeded area showed promising results. As noted by Lal (2004), increased soil carbon content can improve soil properties and enhance adaptation capacity. Degraded rangelands, whether affected by overgrazing or fire, are susceptible to significant losses of soil organic carbon due to erosion and accelerated decomposition of soil organic matter. However, the increased vegetation cover in the reseeded area may have contributed to higher soil organic carbon content, biomass, and soil water content.

Suliman and Ahmed (2013) reported that reseeding with tillage can increase soil water content. Additionally, Duma (2000) noted that increased vegetation cover can lead to increased soil water content. The higher soil organic matter content in the reseeded area may also contribute to improved water retention

(Kimble et al., 2007). Several factors may contribute to the higher soil water content in the reseeded area, including reduced evaporation due to vegetation cover and increased infiltration rates, as the absence of plant cover in the non-reseeded area can lead to increased runoff and decreased soil moisture (Sadeghi et al., 2007).

Conclusion

It was concluded that reseeding on highly degraded rangelands have positive impacts on forage biomass productivity and protects the land from further erosion and degradation. The increased soil carbon stock and soil water content resulting from reseeding suggest that this practice may be a suitable option for highly degraded environments. The improved vegetation composition following reseeding indicates that this practice can enhance ecosystem stability and thus leading to increased livestock productivity and improved livelihoods in semi-arid environments.

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