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Pathways towards Miombo Restoration: A Lesson from Fire and Grazing Exclusion Plots at Kitulangalo Miombo Woodlands, Morogoro Tanzania

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Abstract

The current Tanzanian policy guidelines regarding ecological restoration encourage total protection (enclosure system) against grazing activities, fires and wood extraction to allow regeneration in state-based Miombo woodlands. However, there is little evidence on how such treatments would promote restoration. We fetched the pieces of evidence from studies that evaluated the impact of management treatments on the lightly degraded Miombo woodlands at Kitulangalo Forest Reserve in eastern Tanzania. Plot fencing and fire exclusion constrained woody species regeneration due to competition compared to unfenced plots. Adopting quota grazing policies and controlled burning systems can be the shortest and most eco-friendly pathways towards Miombo restoration. The results pointed out that stand disturbances and silvicultural practices can promote regeneration, which is crucial to promoting ecological restoration in Miombo woodlands.

Keywords

Natural Regeneration, Silvicultural Treatments, Conservation Policies, Miombo Woodlands, Ecological Restoration, Tanzania

1. Introduction

Miombo is the most extensive open woodlands dominated by three closely related genera of *Brachystegia*, *Julbernardia*, and *Isoberlinia*, covering at least eleven Eastern, Central, and South African countries [1]. Being part and centre for biodiversity

[2], Miombo woodlands also provide key goods and services that support over 100 million people across the region [3] [4]. In Tanzania, Mombo is the main vegetation type that covers over 90% of the entire forested land [5], providing timber and building materials, domestic energy involving firewood and charcoal [6] [7], plant medicines and forest foods such as honey, fruits and nuts, and game. Currently, Miombo woodlands are under a variety of severe threats from unsustainable human activities and the changing climate [8]. Studies suggest that the key drivers of deforestation and forest degradation include agriculture and fires, increased domestic energy needs (charcoal), and urbanisation [9] [10]. Overgrazing of Miombo woodlands, especially during the wet season, causes permanent habitat change, thus driving away species assemblages and reducing ecosystem functioning [11]. Reported deforestation and forest degradation rates in miombo woodlands are likely to profoundly impair their regeneration capacity to impair their regeneration capacity [12] [13].

The uniqueness of Miombo woodlands among other terrestrial ecosystems is the ability of its dominant tree species to regenerate mainly using coppices and root suckers when the upper part of the tree is removed, broken, or damaged [14]. Seed germination is, however, possible with miombo tree species, though usually limited due to adverse environmental conditions with frequent fires, flower and seed predation, limited seed dispersal, and extended droughts. Although Miombo woodlands tend to recover quickly when the disturbance drivers are controlled, over-grazing and especially frequent fires tend to damage saplings and diminish the regeneration capacity needed to replace the losses [15].

Tanzania completely prohibits all kinds of grazing activities and fire practices in all her state forest reserves [16]-[18]. This is the most common policy measure aiming to promote natural regeneration in forests and woodlands recovering from past abuse [19]. Although we tend to have better knowledge of how miombo ecosystems respond to various disturbances and silviculture actions, there is little long-term empirical evidence on how the exclusion of grazing and fires influences woodland recovery [20]. Understanding the short-term and long-term empirical impacts of excluding frequent fires and overgrazing is, therefore, essential for the sustainable management of miombo woodlands by formulating cost-effective pathways toward their restoration. From the social and economic points of view of sustainability, it is paramount to attain a working balance between conservation initiatives and utilization activities in Miombo woodlands. This policy brief presents empirical pieces of evidence on how fencing affected regeneration in the study forests. In addition, the highlights about ground-layer species diversity in the grassy and herbaceous plant community provide more evidence on how grassy competition affected regeneration.

2. Study Design, Data Collection, and Analysis

A set of studies was conducted at Kitulangalo Permanent Sampling Plots (PSPs) between 2008 and 2016. The study involved two sites within Kitulangalo Forest

Reserve (KFR). The KFR is a dry, lowland Miombo on Tanzania's Eastern coast, receiving about 500 to 700 mm of rainfall annually.

At each site, we installed two experimental blocks each measuring 30 m × 90 m with one half unfenced and one half fenced to eliminate animal grazing. Fire lines around the fenced blocks were also established and maintained during the study period.

Each block contained three adjoining plots measuring 30 m × 30 m with a grid of 25 smaller, circular subplots with a radius of 1 m where regeneration and vegetation cover were monitored for eight (8) years (Figure 1). The installed plots also had other research purposes.

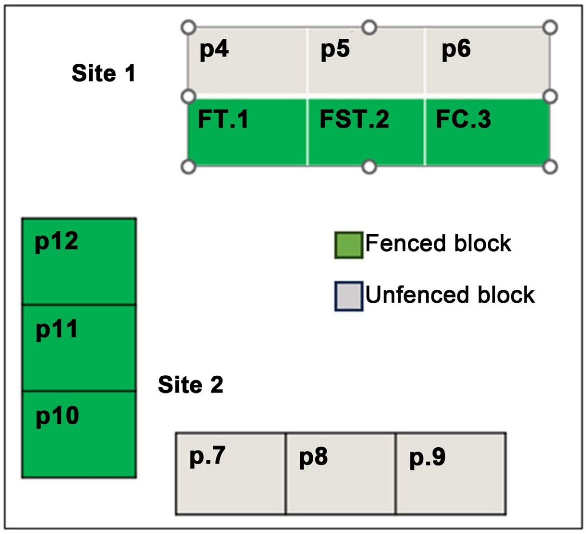

Figure 1. Study design and plot layout in the study area.

We counted all woody regeneration stems on each circular subplot in the first measurement (February 2008). Individually standing stems were counted separately as well as the number of clusters, which contained several stems originating from the same point. The total number of stems included the count of all stems (individual and within clusters), while the number of main stems comprised those standing alone and one principal stem in each cluster. Other variables in the subplot included the percentage of grassy and herbaceous cover which was visually assessed. We were also keen to observe the status of the empty subplots (no regeneration present) both at the beginning (2008) and the end of the study in 2016. The data collected were analysed through R Software (R Core Team, 2021). The change in the total number of stems and the number of main stems were finally calculated.

3. Discussion: The Implications for the Death of Regeneration

- A substantial drop in the total number of stems during the eight-year monitoring period involved the death of individual stems within clusters of stems or among single stems standing alone. The mortality of stems within the thick grassy cover is a result of severe growth competition between regeneration stems and grass layers within fenced plots (**Box 1**).

- Without animal grazing and browsing, trees tend to develop more single main stems and fewer clusters and sprouts through the self-thinning process. We considered these areas as regeneration "hot spots", areas where the saplings develop rapidly from a multi-stem shrub-like tree into single-stem individuals (**Figure 2(A)** & **Figure 2(B)**).
- Fencing can promote quick colonization of the empty subplots by new regeneration stem.
- The observed change in the number of stems (total number of stems and number of main stems) agreed with the predicted change by the model (GLM) in the total number of stems between 2008 and 2016 (**Figure 3(A)** & **Figure 3(B)**).
- The initial stocking parameters (stand basal area, $m^2 \cdot ha^{-1}$, and Volume, $m^3 \cdot ha^{-1}$) were also negatively correlated to the change in the number of stems (regulating regeneration and thus delaying stem recruitment into bigger trees).

Box 1. Key results.

The impact of fencing and fire exclusion on the number of regeneration stems

1) Fencing prompted thicker grassy and herbaceous plant communities with more open grass cover in unfenced plots at the end of the study (2016).

2) The total number of stems dropped from 29,800 to 19,100 $N \cdot ha^{-1}$ (equivalent to 35% fenced compared to unfenced plots between 2008 and 2016).

3) However, there was a significant increase in the number of main stems (from 9300 ha^{-1} to 11,100 $N \cdot ha^{-1}$) in unfenced plots (equivalent to 16%) between 2008 and 2016.

4) The proportion of empty subplots (without seedlings at the start of the study) also decreased from 7.3% to 5.3% at the end of the study (2016).

5) species like *Julbernardia globiflora* and *Combretum molle* (dominant species) were more prominent than other species with a high number of regenerations in each case.

Figure 2. Variation in grassy cover between fenced plots (A) and unfenced plot (B): Photo: Pentti Niemisto (2007).

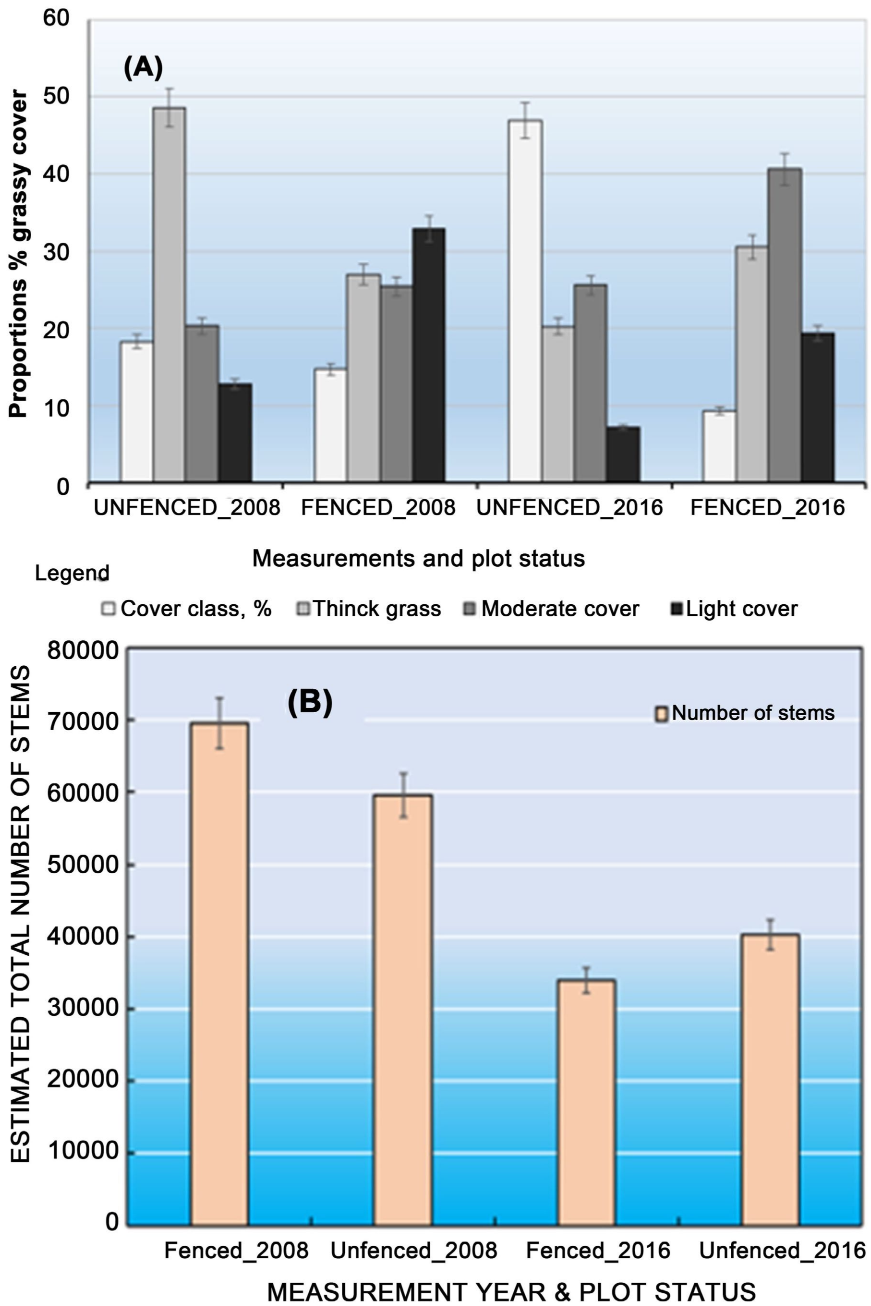

Figure 3. Proportional change in grass cover (A) and the total number of stems (B).

4. Key Policy Implications on the Management of Miombo Woodlands

1) The fencing experiment imitated a management system whereby Miombo woodlands are securely protected against grazing and fire outbreaks. The formation of the thick grassy and herbaceous layer in the fenced plots tends to limit regeneration through increased stem mortality, which could affect the future species composition structure and sustainability.

2) Although the fire and grazing were controlled, a thick grassy and herbaceous

layer is known to increase the likelihood of fire intensity, severity and frequency which are more harmful to restoration initiatives.

3) A controlled animal movement and gathering of dead wood tend to reduce fire frequency and severity, enhancing the resilience and sustainability of miombo.

4) Although the current study did not record the frequencies and intensities of fire and grazing in unfenced plots, yet, these activities had no significant effect on the number of regeneration stems.

5) Reducing stand canopy cover (through selective cutting or thinning) can increase the diversity and thus the productivity of herbaceous and grassy cover prompting more intensive competition with tree regeneration.

6) Grazing and fire can be an ideal solution for reducing the aggressive competition for nutrients, water and space induced by grassy and herbaceous cover against tree regeneration. Promoting quota systems, controlled burning and periodic complete enclosure of the miombo reserves can enhance quicker ecological recovery and induce resilience and the changing climates and human disturbances.

5. Conclusion

The proliferation of grassy and herbaceous cover in the absence of grazing and fire may tend to discourage the emergence of new tree seedlings in the long run. The introduction of a quota grazing system and controlled burning in Miombo could be an alternative way to reduce intensive competition between grass cover and regeneration stems, and destructive fire risks. This can be done with maximum care and in a controlled manner under relevant authorities in Tanzania.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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