Regeneration of miombo woodlands: Effects of herbivory, management and competition

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Miombo-woodland area has decreased substantially because of unsustainable management practices. However, not enough is known about miombo dynamics making conservation and management difficult. Object of this study was to investigate the role of herbivores and tree-grass interactions in regeneration of miombo woodlands, if certain forest management practices can be used to enhance regeneration and if responses can be seen only after a short-term study. Research was conducted by setting up a permanent experiment in a natural miombo forest. Experiment was composed of two stands on which same treatments were conducted. Treatments were thinning, cultivation, fenced thinning and fenced cultivation. Fenced and unfenced control plots were established on both stands. Grass coverage was estimated, saplings were identified by species and measured for height and diameter, and sapling damage cause, damage severity and sapling vigour were estimated. Exclusion of grazers led to increase in grass coverage. Some indications that silvicultural measures might play a role were visible but study period was too short to determine their usability. A longer study is needed to uncover the impacts of herbivore exclosure and silvicultural measures. Competition between trees and grasses is one determinant of miombo-forest structure. Conducted measures might alter the interaction and therefore influence tree regeneration indirectly.

1 Introduction

Climate, especially precipitation determines the vegetation type of savannas but it is also heavily influenced by herbivory and fires (Shorrocks 2007). Due to unsustainable forest practices miombo woodlands are diminishing and many tree species are facing local extinction (Chidumayo and Frost 1996). Grazing and especially frequent fires damage saplings and regeneration is not fast enough to cover losses (Dirninger 2004). Natural regeneration may be a better alternative to planting in the tropics for certain ecological purposes (Moura-Costa 1996) but knowledge on regeneration of miombo forests is insufficient (Dirninger 2004). More research is needed in order to develop effective silvicultural practices to promote natural regeneration.

Kitulangalo has very few natural mammal herbivores but cattle are fairly common. Natural herbivores are both grazers and browsers but cattle mainly feed on grasses (Taylor and Walker 1978).
Grasses are easier to digest where as trees contain high concentrations of lignins and metabolites. However, occasionally cattle also browse in which cases it has been observed to significantly restrict regeneration of trees (Lehmkuhler et al. 2003, Allcock and Hik 2004). 

Trees and grasses compete for living space, light, nutrients and water (Scholes and Archer 2006). Interactions are diverse and influenced by abiotic and biotic factors of surrounding environment and species in question. Trees might improve nutrient and humidity conditions under canopy and thus promote growth of grasses. On the other hand grasses might also suffer from lack of light and increased resource competition. Grasses in turn might compete with saplings for light, water and nutrients. Grasses also regulate fire frequency and intensity. Denser grass coverage leads to more intense fires which in turn cause more damage to saplings and might hinder their growth.

Fires have significant role in miombo dynamics (Dirninger 2004). Frequent fires suppress saplings thus slowing down growth and regeneration. Grasses on the other hand recover from fires fast. Fires hence maintain the landscape open. Grazing reduces grass coverage thus reducing the amount of combustible plant material (Mwendera et al. 1997). This will lead to lower frequency and intensity of fires (Roques et al. 2001, Savadogo et al. 2007).

Object of this study was to examine interactions between tree saplings and grass coverage and study how the interaction is regulated by silvicultural practices and exclusion of grazers. Effects of silvicultural practices and exclusion of grazers on sapling numbers, growth, vigour and sapling species composition were examined. Level of insect herbivory was evaluated and its effect on regeneration was studied. Tree competition effect on saplings and grass coverage was also examined. Aim was to examine if certain silvicultural practices can be used to enhance regeneration of miombo forests, define the role of mammal herbivores and evaluate how competition between trees and grasses should be taken into consideration when designing forest management.

2 Materials and methods

Permanent experiment was established into a natural miombo forest in Kitulangalo, Tanzania. Experiment consisted of two stands with six 30 m x 30 m plots. Treatments conducted were cultivation, thinning, fenced cultivation and fenced thinning. Fenced and unfenced controls were established. On cultivated plots soil under canopy of big trees (breast height diameter (dbh) > 20 cm) was hoed in depth of 15–20 cm to increase humidity, reduce competition and promote sprouting. On thinned plots trees and shrubs were cut or pruned in order to promote economically important species. On control plots no silvicultural measures were executed. Fencing was conducted to exclude mammal herbivores.

On each plot 25 subplots with radius of 1.1 meter were established. From each subplot grass coverage was estimated. All saplings with minimum height of 20 cm were identified and measured for height. Saplings above 130 cm were also measured for breast height diameter if it was below 5 cm. From groups of similar saplings only the highest was measured and others just counted in total number. Vigour, stem quality and damage severity were estimated and cause of damage was defined. If saplings were regenerating from a visible, single stump, also the diameter of the stump was measured. Seedlings from seeds above 20 cm in height were counted. All trees (dbh > 5 cm) were measured for dbh and data was used to calculate competition indices; Cls = Σd / (sj + 1), where s is the distance between centre of the subplot and tree and d is dbh.
Data was analysed with SPSS using split-plot Anova and Spearman’s correlation.

## 3 Results

Grass coverage increased on all treatments during study period but the increment was more distinct on fenced treatments (Fig. 1). Effect of fencing on grass coverage was significant (Anova; $F = 862.22, p = 0.02$) but thinning or cultivation did not have a significant effect.

![Figure 1](image1.png)

**Figure 1.** Change in grass coverage (% ±SD) between first and third (one year after) measurements.

Number of saplings showed decrease on all treatments but treatments had no significant effect (Fig. 2). No seedlings from seeds were detected during measurements although exclusion of grazers was tentatively significant (Anova; $F = 59.08, p = 0.08$). Number of sapling species and species composition was similar on all treatments and showed no major changes over the study period, treatment effects being insignificant. Sapling height increased on all treatments and sapling diameter increased on all but fenced control, where it stayed constant. Treatment effect was not significant for either sapling height or diameter. Overall herbivore damage increased on all but thinned treatment and fenced control. Stem vigour both increased and decreased but neither treatments nor herbivore damage had effect on this.

![Figure 2](image2.png)

**Figure 2.** Mean number of saplings (±SD) on different treatments on first and third (one year after) measurements.
Grass coverage correlated mainly negatively with number of saplings. However correlation was negatively significant only on fenced and thinned treatment on first stand (Spearman’s correlation; $r_s = -0.44$, $p = 0.03$) and positively significant on cultivated treatment on first stand (Spearman’s correlation; $r_s = 0.58$, $p = 0.01$). No differences between treatments could be found, however, due to dissimilarity of stands. Grass coverage also correlated mainly negatively with number of sapling species and correlation was significant though not linear on fenced and thinned treatment (Spearman’s correlation; $r_s = -0.53$, $p = 0.001$) and on fenced control (Spearman’s correlation $r_s = -0.49$, $p = 0.01$). On all cultivated treatments, however, grass coverage and number of species correlated positively, though not significantly. Grass coverage was not found to correlate significantly with sapling height or diameter.

Tree competition indices correlated mainly negatively with grass coverage but there were differences between the two stands. Correlation was positively significant only on control on first stand (Spearman’s correlation $r_s = -0.53$, $p = 0.01$) and negatively significant on fenced and thinned treatment on second stand (Spearman’s correlation $r_s = -0.55$, $p = 0.01$). Effects of tree competition on sapling numbers had no general trend, effect being significant only on fenced and cultivated treatment on first stand (Spearman’s correlation $r_s = -0.50$, $p = 0.01$). Competition had no significant effects on number of sapling species nor did the correlation have any conformity. Tree competition correlated both negatively and positively with sapling height and diameter on different treatments without having conformity. Some significance was detected but there were differences between stands.

Intensity of browsing was low throughout the study period. Exclusion of mammals prevented browsing but otherwise treatments had no effect on browsing intensity nor did browsing have effect on sapling vigour or regeneration. Insect herbivory was intense and evenly distributed throughout the treatments but no effects on sapling vigour or regeneration were found.

### 4 Discussion

Absence of seedlings regenerating from seeds supports observations that miombo trees mainly regenerate from root suckers (Trapnell 1959). This is thought to result from frequent fires which inhibit development of seedlings (Pomeroy and Service 1986).

Mammal herbivores on study area were discovered to be mainly grazers. Intensity of browsing was low and herbivore exclusion had visible effects on grass growth. Exclusion of grazers was seen to result in increase of grass coverage already in short term. Effects of exclusion to sapling growth and number of saplings were not detected.

Correlation between grass coverage and number of saplings was mainly negative, as was correlation between grass coverage and number of species. Grass cover had no effect on sapling growth. Negative correlation between grass coverage and sapling numbers was also discovered by Obiri et al. (2002) on their study of tree composition in Kitulangalo. Denser grass coverage was noticed to lead into decrease in sapling numbers. Exclusion of herbivores might thus influence regeneration in longer term since grass coverage increased on fenced treatments.

Management practices were not observed to have effect on regeneration over the one year study period. Number of saplings decreased on all treatments but treatments had no effect on this.
ling height and diameter increased constantly on all treatments but again, no significant effect of treatments was found.

Negative correlation between tree competition and grass coverage was found. There was also negative correlation between tree competition and sapling height and diameter but not between competition and sapling numbers nor species numbers. Increase in tree numbers and diameters will thus reduce grass coverage but it might also hinder sapling growth. Thinning as a management practice might in a longer term enhance regeneration. According to Mugasha and Chamshama (2002) number of saplings increased on disturbed areas of miombo forests because disturbance creates canopy gaps thus increasing light intensity and soil temperature and enhancing natural regeneration. On the other hand thinning has been noticed to enhance grass growth and increase grass coverage (Gambiza et al. 2000, Barnes 1979). If grass coverage increases substantially due to reduced competition the effect of thinning on tree regeneration might be negative. When conducting measurements, thinning was noticed to have strongly enhanced coppicing but due to lack of thinned trees on regeneration plots the effect was not uncovered in data.

No fires occurred in the forest during study period. Due to high fire frequency of the area, fire will however eventually become inevitable as the amount of burning material increases. If grazing is excluded denser grass coverage will lead to more intense fires which in turn could be more destructive to saplings. Cultivation did not have any short term effects on tree regeneration. Effects however might not be recovered yet for only saplings above 20 cm were counted and measured. Also not all regeneration plots under cultivation were hoed because cultivation was only done under big trees. This might as well lessen the effects of cultivation in collected data. Grass coverage was noticed to regenerate shortly after cultivation. Cultivation might promote tree regeneration in long term indirectly when in absence of dense grass coverage fires would become rare and low in intensity. This would however require cultivation to be conducted repeatedly before grass cover regenerates.

No noticeable changes in sapling species composition were detected during the study. *Julbernardia globiflora* continued to be the most prevalent species and treatments had no effect on species distribution. Lack of responses might also result from short time period of experiment.

Changes in grass cover can be seen after only a short term study but longer time is needed for possible effects of silvicultural measures and exclusion of mammal herbivores on tree regeneration to develop detectable. This is especially integral since tree-grass interactions are major determinant of savanna structure. However, it seems that intermediate grazing favours tree regeneration by suppressing grass growth. Hence exclusion of mammal herbivores might lead to more open savannas.

**References**


