Effects of Fire Disturbance and Grass Removal on Tree Growth in Mesic Savannas

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Introduction

The explanation for the coexistence of trees and grasses in the savanna landscape has confounded scientists for decades. In contemporary research, the mechanisms for codominance are usually explained through two different hypotheses depending upon precipitation level: rooting-niche-based and disturbance-based. The rooting-niche hypothesis states that grasses and trees have different root depths, and thus occupy different competitive niches. The disturbance-based hypothesis argues that life disturbances are what limit tree growth and survival, thus maintaining the grass-tree coexistence. Fire has been shown to be a major life disturbance, as the role of fire in savannas can affect the potential for tree growth. A key principle in savanna ecological models is that the fire regime is a major determinant of vegetation cover in a savanna, where late dry season fire burns are more damaging to trees than early fires, This is indirectly linked to the tree-grass coexistence, as less grass would provide less competition for resources, meaning more trees may grow faster in order to escape fire. Thus, disturbances like fire and grass removal may have the ability to alter the growth rate and height of juvenile and adult trees. This study analyzed the effects of fire disturbance and grass elimination on tree growth in a mesic savanna in Mali, West Africa for a period of two years. We divided two study sites into 8 experimental plots, 4 were subjected to grass reduction treatments (clipping, hoeing, herbicide, and grazing), 3 were subjected to fire treatments (early, middle, and late season), and 1 plot was set as the control variable. Preliminary results using a one-way analysis of variance (ANOVA) suggest that all grass removal mechanisms cause trees to grow taller while burns only in the early and late dry season stimulate more tree growth with most tree deaths occur in the late fire season. Ongoing research includes tree size in the analysis.

Background & Geographic Setting

The tree-grass-fire relationship in savanna systems differs from one savanna to the next depending on location, precipitation amount, tree species, and tree stage of life. Other studies have tested grass competition's affect on trees in different demographic stages in savannas such as Riginos (2009), but more research on this subject is needed in mesic savannas, where precipitation levels are high enough to sustain both trees and grasses. Some believe mesic savannas are unstable systems that can turn into a forest if tree growth is not suppressed by disturbances such as prescribed fires to burn back trees. The purpose of this study is to investigate how fire seasonality and grass elimination affects tree growth in different stages of life, and if grass removal may help small trees escape being perpetually burned back in a juvenile life stage, or "Gulliver syndrome" (Bond and Van Wilgen 1996).

This study took place in two villages, Tabou and Faradiele, located in the southwestern region of Mali, West Africa within the southern Sudanian belt. Both sites are considered mesic savannas, but Faradiele receives about 1200 mm of precipitation per year whereas Tabou receives only 1000 mm per year. Both villages contain a variety of small, African trees native to the Sudanian and Guinean savannas that grow to about 7-12 meters high. The grasses mainly consists of tall, perennial grasses that reach 1.5 - 3 meters high.

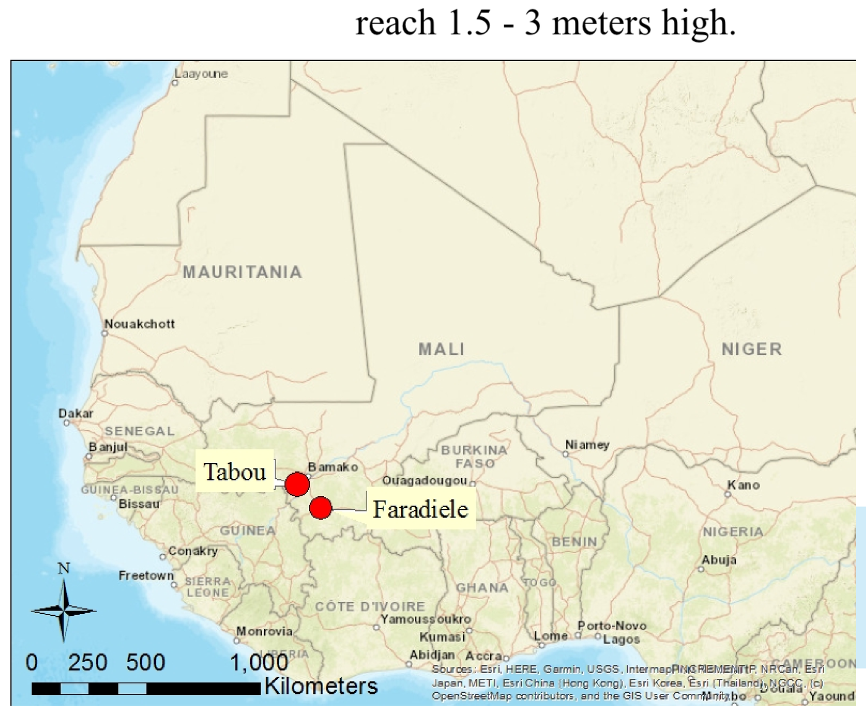


Figure 1. Location of study areas

Method

Trees were tagged in 20 m by 20 m plots, each with a grass removal disturbance, fire disturbance, or no disturbance. Trees were measured each year starting in 2016 and ending in 2018. Disturbances and tree stages were assigned as follows:

- **Fire Disturbance:**
  - Early Season: November - December
  - Middle Season: - January
  - Late Season: - Mid-February
- **Grass Disturbance:**
  - Grass Clipping
  - Hoe-Farming
  - Herbicide
  - Grazing
- **Tree Size:**
  - Small Juvenile: ≤ 2 m (below fire height)
  - Large Juvenile: 2 - 3 (within flame Zone
  - Adult: >3 m (above flames)

Figure 2. Small juvenile tree in dry grasses

Associations between treatment/tree size and growth rate were analyzed using a one-way ANOVA using treatment or tree size as a fixed factor. Growth rate data was transformed using a base-10 log transformation to make the data more normally distributed. The groups were then analyzed on a pairwise basis using a Tukey-Kramer test. All tests used an alpha value of 0.1 due to the exploratory nature of this experiment.

Results and Discussion

Fire Disturbance Results

ANOVA (Fire Disturbances)					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.348	3	0.783	8.084	0.000
Within Groups	16.653	172	0.097		
Total	19.001	175			

Table 1. One-way ANOVA of fire disturbance affect on tree Data. $P < 0.000$; There is a significant difference for at least one of the groups for fire disturbances

Fire Season	Mean Tree Growth	Tukey-Kramer
Early	0.844	a,c
Middle	0.563	b,c
Late	1.071	a
Control	0.510	b

Table 2. Tukey-Kramer test of Fire Disturbance groups. Means with the same letter are not significantly different from each other. The late and early season fire trees grew significantly more than the control trees. Middle season, when most fires are prescribes by locals, had the least amount of impact on tree growth.

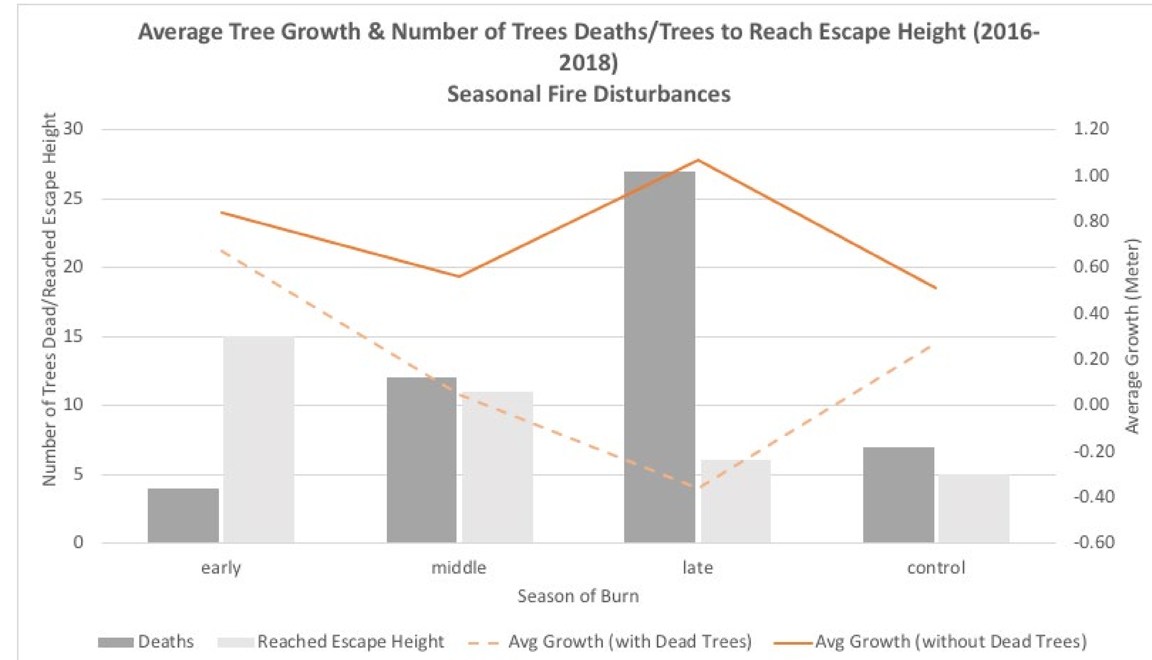


Figure 3. Average growth rate by fire disturbance next to amount of dead trees in each plot. Although Late season fire trees grew the most, they had the most deaths

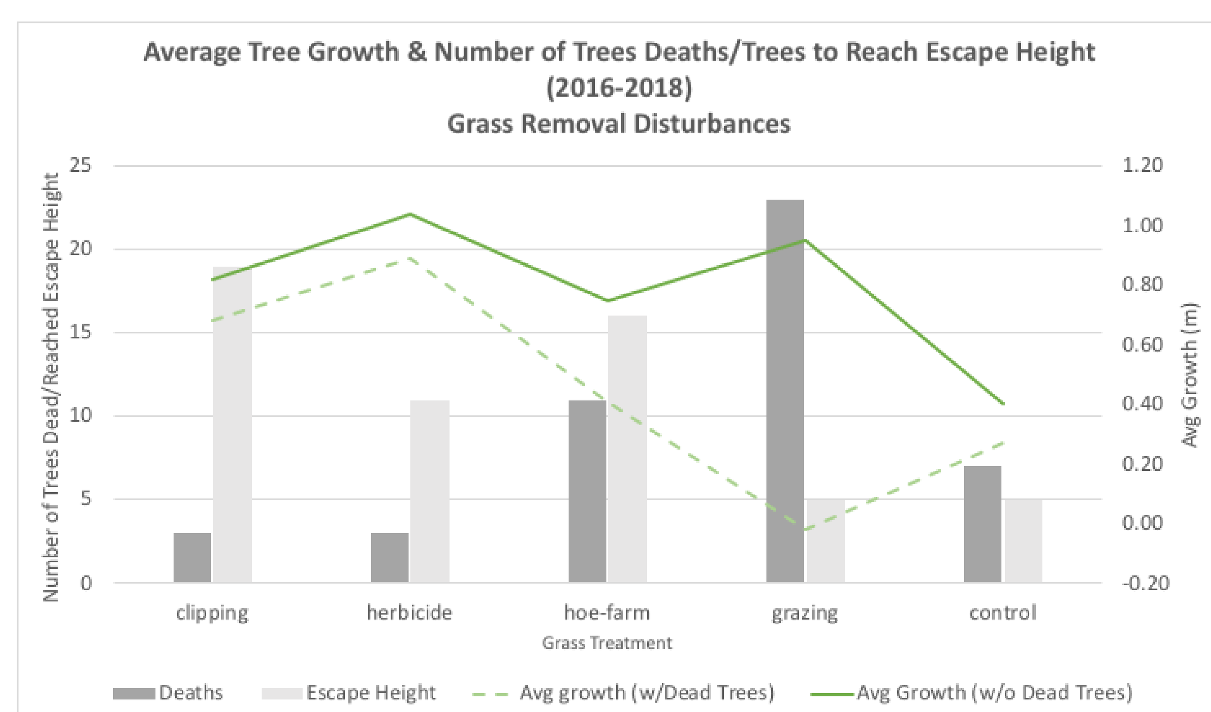
Grass Removal Results

ANOVA (Grass Removal Disturbances)					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.577	4	0.894	8.995	0.000
Within Groups	22.965	231	0.099		
Total	26.542	235			

Table 3. One-way ANOVA of grass disturbance affect on tree Data. $P < 0.000$; There is a significant difference for at least one of the groups for grass removal disturbances

Grass Disturbance	Mean Tree Growth	Tukey-Kramer
Clipping	0.822	a
Herbicide	1.044	a
Hoe-Farm	0.752	a
Grazing	0.947	a
Control	0.510	b

Table 4. Tukey-Kramer test of Grass Disturbance groups. All grass removal treatments grew significantly more than the control trees



Graph 4. Average growth rate by grass disturbance and dead trees in each plot. Grazing seems to cause a large number of tree deaths due to tree trampling and browsing.

Preliminary Results of Tree Size Analysis

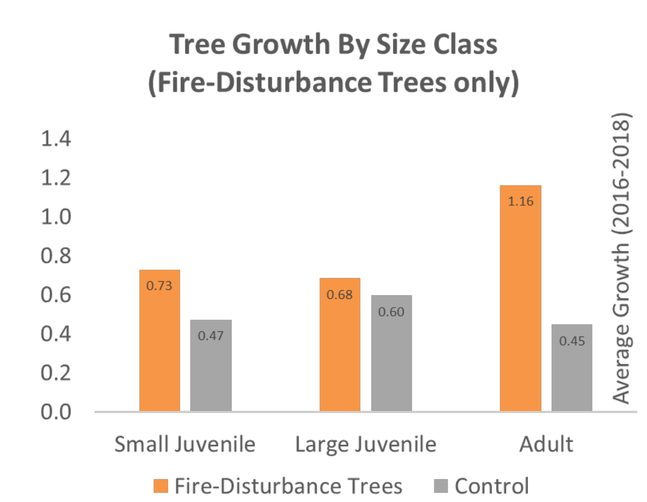


Figure 5. Average growth rate of fire disturbance trees by size class. All tree sizes grew more when they were burned. Adult trees grew the most as they were tall enough to escape the flames.

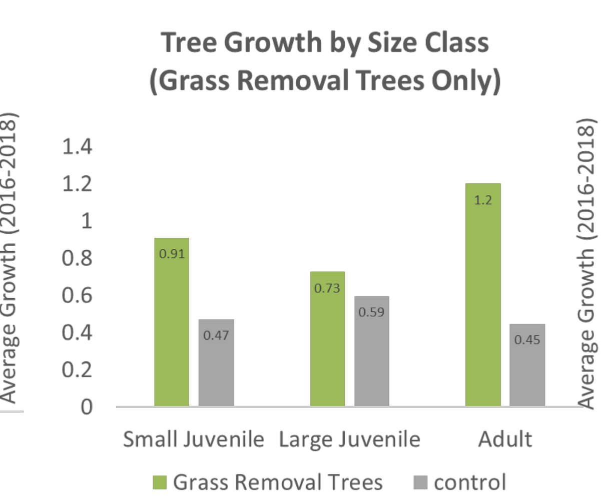


Figure 6. Average growth rate of grass disturbance trees by size class. All tree sizes grew more when grass competition was removed. However, small juveniles grew much more then large juveniles, suggesting small juveniles are under more grass competition.

Conclusion

The results of the statistical analysis suggests that trees and grass are still in competition in a mesic savanna, but removal of grass competition may help assist small trees to grow to escape height instead of being perpetually burned back by the fires. All methods of grass removal increased the growth rate while only early and late season fires grew significantly more than the control group.

One of the reasons prescribed burns are utilized in savannas is to burn back trees to maintain the savanna landscape, results suggest that early season fires and late season fires may encourage trees to grow more. However, late season fires also caused the most amount of tree deaths. Many of the trees that grew more in the late season fires were large juvenile and adult-sized trees that possibly grew taller due to long-term affects effects of life history disturbance interactions between the trees and fires. Further research will include more analysis of life history disturbance interactions on demography.

Other studies have also found that early season fires have a positive effect on tree growth rate. This may be explained by reduced competition from grasses, as they are burned in the fires, and release of nutrients from burnt biomasses. In larger trees, a "fertilization effect" causes trees to quickly recover from fires by rapidly releasing nutrients stored in a below ground carbon storage (Prior et al. 2006, Werner 2011). As most trees in this study were at least one meters tall, most trees likely released a "fertilization response" to quickly recover from the fires..

Removal of grass competition may also assist in shifting the savanna landscape to one of a forest. This would help with carbon sequestration and tree production, but may also affects many farmers and cattle ranchers that live locally in the area. This is because more trees will take nutrients from grasses and herbs will start to die, losing food supply for cattle.

References

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