

Full Length Research Paper

Effect of scattered tree species on the diversity, abundance and biomass of pastures in a sedentary grazing system in South-western Uganda

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Tree species play a significant role in sustaining the productivity of grazing lands. However, information on appropriate species to use in restoring degraded grazing areas is limited. This study used 120 trees to assess the effect of 8 tree species on pasture diversity, abundance and biomass. This was done in a total of 960 quadrats of 1 m² established under tree canopies and 5 m away from the edge of tree canopies. In each quadrat, the different pasture species and their ground cover were recorded. The pastures were harvested, weighed and their biomass recorded. Results of analysis by Shannon–Wiener’s index indicated that pasture diversity was almost the same under and outside tree canopies ($H = 1.8$ and $H = 1.78$ respectively), but pasture abundance was significantly higher under tree canopies ($p < 0.05$). *Ficus natalensis* and *Albizia coriaria* had the highest pasture abundance under their canopies. Pasture biomass never varied significantly under and outside tree canopies but between tree species, *F. natalensis* had a significantly higher positive influence on pasture biomass than other species. It was discovered that *F. natalensis* and *A. coriaria* have a higher potential for restoring degraded grazing areas in South-western Uganda.

Key words: *Brachiaria* spp., *Ficus natalensis*, livestock, Shannon-Wiener, tree canopy.

INTRODUCTION

In the livestock dominated farming communities of South-western Uganda, natural pastures constitute the major feed resource for livestock throughout the year (Tibezinda et al., 2016). However, lack of sufficient pastures remains one of the leading constraints of the low livestock productivity in the area (Creemers and

Aranguiz, 2019). Other than climate related effects such as prolonged droughts which have reduced the abundance of pastures, the predominant and intensive sedentary practice of livestock grazing can hardly favor sustainable production of natural forage (Selemani et al., 2012). Nonetheless, increasing the productivity of

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existing grazing space by increasing the quantity of pasture species remains one of the key options available for livestock farmers engaged in sedentary grazing.

In an effort to address the challenge of pasture shortage, livestock farmers in South-western Uganda resorted to indiscriminate cutting of trees; a practice which is increasingly being adopted by sedentary pastoralists in the current decade (Roba and Oba, 2013). Livestock farmers have hoped that by clearing trees, more pastures will grow in the created spaces and therefore increase availability of adequate forage for their animals. Unfortunately, the act only exacerbates the declining productivity of grazing sites (Mganga et al., 2019) and in the sedentary grazing areas of South-western Uganda, the diversity and quantity of forage pastures is increasingly declining (de Vries, 2019).

Globally, several studies have documented integration of trees in grazing lands as one of the remedies recommended to enhance the quantity of pasture species (Murgueitio et al., 2011). This is based on the fact that scattered tree species in grazing lands are reported to improve the microclimate below their canopies (Siqueira et al., 2017) for the benefit of the underlying community. In a study by Abdulahi et al. (2016), it was revealed that trees scattered in grazing lands modify light intensity, temperature and can influence mineralization of nutrients, which factors support growth and biomass yield of pasture species. Therefore, in degraded grazing areas where pasture productivity and associated grazing operations are constrained, restoration of tree cover will contribute towards improving the productivity of such lands.

However, despite the facilitative effect of trees towards pasture productivity, in some cases tree species in grazing lands have suppressed pasture growth and biomass accumulation under their canopies. This has been through reduction of light intensity and competition for soil moisture (Whitecross et al., 2017; Lozano-Parra et al., 2018; Castillo et al., 2020). With such inhibitory evidence, identification of tree species with a complimentary effect on pasture diversity and quantity and therefore be used in restoration initiatives can only be established through localized scientific investigation. Therefore, this study sought to identify tree species with potential for restoring the productivity of degraded grazing lands in South-western Uganda, by assessing the effect of selected scattered tree species on the diversity, abundance and biomass of natural pastures.

MATERIALS AND METHODS

Study area

This study was carried out in Ruborogota and Masha sub-counties in Isingiro district (0.8435° S, 30.8039° E) and Kenshunga and Kikatsi sub-counties in Kiruhura district (0.1928° S, 30.8039° E) in South-western Uganda (Figure 1). This was between February and March, 2019; a period which marks the onset of the first rainy

season. In particular, the study districts experience a semi-arid type of climate with average annual rainfall of 750 - 800 mm distributed in a bimodal pattern (Nagasha et al., 2019). Average temperatures range from 17° - 30°C, with highest peaks recorded in January and July. Soils are sandy loamy and are predominantly covered by savannah grassland type of vegetation with scattered Acacia tree species. Livestock farming dominated by cattle is the major livelihood activity; characterized by Ankole Longhorn, Holstein Friesian and crosses as the major breeds usually grazed in a sedentary practice (Tibezinda et al., 2016).

Data collection

Selection of the study tree species and data collection sites

This study used eight indigenous tree species which included; *Acacia abyssinica* Benth., *Acacia campylacantha* A. Rich., *Acacia gerrardii* Benth., *Acacia hockii* De Wild., *Albizia coriaria* Oliv., *Allophylus africanus* Davies. & Verdcourt., *Ficus natalensis* Krauss ex Engl., and *Grewia mollis* Juss. Selection of the tree species was through focus group discussions with livestock farmers in two livestock dominated sub-counties in each study district. In every sub-county, 15 livestock farmers who had a representative number of the prioritized tree species and had greater uniformity in terms of sedentary grazing were selected for field assessments.

Study design and data collection

At every farmers field, mature (>20 cm DBH) and healthy trees of the respective species were considered. Canopy radius of each study tree species was taken with a measuring tape to determine the canopy size of tree species. Using wooden square frames, four quadrats of 1 m² were established in four directions under the tree canopy. A distance of 5 m away from the outer most edge of the tree canopy was measured and corresponding quadrats of 1 m² were established and demarcated (Figure 2). In each quadrat, data was collected on the different types of pasture species encountered and their proportional ground cover (%). To determine pasture biomass, all growing plants in a quadrat were manually harvested to ground level and sorted to remove non-pasture plants. The sorted pastures were collected in a polythene bag and weighed using a sensitive digital weighing scale. A total of 120 trees and 960 quadrats were covered in this study.

Data analysis

The data collected was entered in MS Excel computer package where descriptive statistics in form of tables and graphs were generated. Within Excel package, Shannon-Wiener's species diversity index (H) was used to determine pasture diversity under and outside tree canopies and between tree species, as described by Sagar and Sharma (2012);

$$\text{Shannon index (H)} = -\sum si = 1 \pi i \ln \pi i$$

Where; p = Proportion (n/N) of individual species found, ln = Natural log, Σ = Sum of calculations, s = Number of species.

To identify the dominant pasture species under and outside tree canopies, MS Excel was used further to compute the Simpson dominance index (D) of pastures following the formula described by Sagar and Sharma (2012).

$$D = \sum si = 1 \pi^2, \text{ with components described as above.}$$

To obtain statistical information on abundance and biomass of pastures, the data was imported into Minitab.19.0 software where it was subjected to Ryan-Joiner (similar to Shapiro-Wilk test) technique to test for normality. Any deviation from normal distribution was corrected using Johnson transformation technique. Analysis for differences in abundance and biomass of pastures under and outside tree canopies and between tree species was undertaken using Generalized Linear Models (GLM) at 95% CI. Fishers Least Square Difference (LSD) test at 95% CI was used to separate the means where significant differences existed. More so, the data was imported into R software and using the vegan package (Oksanen et al., 2019), rarefaction curves were generated to display pasture species richness under and outside tree canopies. Non-Metric Multidimensional Scaling (NMDS) analysis was as well undertaken to display the spatial relationships between tree canopy effects and pasture abundance.

RESULTS AND DISCUSSION

Canopy size characteristics of the study tree species

The tree species in this study were of significantly varying canopy size ($p < 0.05$). *A. campylacantha* had the widest canopy of 7.6 m while the shortest canopy was displayed by *A. hockii* (2.4 m) Table 1. Statistically, canopy radius of *A. abyssinica*, *A. campylacantha*, *A. coriaria* and *F. natalensis* was significantly wider than the canopy radius of *A. gerrardii*, *A. hockii*, *A. africanus* and *G. mollis* (Table 1).

Effect of scattered tree species on the diversity and abundance of pastures

A total of 14 different naturally growing pasture species were identified in the study, with two pasture species exclusive to under tree canopies. Analysis of diversity by Shannon-Wiener's method showed that pasture species diversity was almost the same under and outside tree canopies ($H=1.8$ and $H=1.78$ respectively). The dominant pasture species under and outside tree canopies were *Brachiaria ruziziensis*, *Cynodon dactylon*, *Brachiaria brizantha* and *Brachiaria decumbens* (Table 2). An exception existed in *B. decumbens* whose dominance index outside tree canopies was far lower than the other dominant pasture species.

The close uniformity in the diversity index of pastures under and outside tree canopies could be attributed to the dominant sedentary practice of grazing in the area. During grazing more so under sedentary practice, previous studies have documented that the intensive and non-selective grazing exerts excessive pressure on natural pastures thus limiting species recovery (Kavana et al., 2019). As an adaptation strategy therefore, pasture species that can withstand the resultant grazing pressure have ended up colonizing the pastoral communities (Souther et al., 2019). Such findings could explain the uniform diversity and dominance of certain pasture species under and outside tree canopies in this study.

From the rarefaction plot in Figure 3, visual displays of pasture species richness revealed existence of variation under and outside tree canopies and between tree species. At a standardized sampling depth of 20 pastures under and outside canopies of each tree species, *A. hockii*, and *F. natalensis* displayed the highest number of pastures ranging from 6 - 8 for both canopy sites. *A. campylacantha* had the lowest species richness ranging from 2 - 4 pastures under its canopies where beyond a sample of 10 pastures, the tree species had no more new pastures recorded under its canopies. For most tree species, it was revealed that no more new pastures would be encountered under and outside tree canopies beyond an approximate sampling depth of 50 pastures. More sampling would only favor *F. natalensis* and *A. coriaria* whose species richness increased to more than 10 pastures with a batch of 80 - 100 samples. Nonetheless, as revealed from the curves, beyond 100 pasture samples the two tree species would as well not register any more new pasture species under and outside their tree canopies.

The use of rarefaction curves is an important tool in assessing species richness which aspect gives one of the simplest and most popular measure of diversity (Bacaro et al., 2016). From the rarefaction curves displayed, the varying species richness under and outside tree canopies as well as between tree species reveals some level of association between certain tree species and pastures. Within grazing lands, a study by Li et al. (2017) revealed that plant species richness is positively correlated with availability of soil nutrient resources. This implies that under tree canopies of *A. hockii* and *F. natalensis* soil nutrient concentrations could have favored the growth of several pastures compared to other tree species. Such findings could as well explain the higher pasture species richness under *A. coriaria* at a higher sampling depth.

However, whereas *A. hockii*, *F. natalensis* and *A. coriaria* displayed higher pasture species richness under their canopies compared to other tree species, the relatively higher pasture richness outside tree canopies for most species implies that in the sedentary grazing areas of South-western Uganda, presence of tree species did not change the composition of pasture species. Interestingly, a study by Lopes et al. (2016) revealed that presence of trees in grazing areas changes the feeding behavior of cattle, leading to higher time of grazing and rumination under tree canopies compared to open pastures. With such findings, it could be true that tree canopies for several species favored grazing activities for livestock and partially influenced pasture species richness under their tree canopies (Figure 3).

Complementary to rarefaction curves, pasture diversity varied significantly under and outside tree canopies and between tree species ($p < 0.05$). As shown in Figure 4, significant variation in pasture diversity under tree canopies was between *F. natalensis* ($H = 0.32$) which had the highest diversity and *A. campylacantha* ($H = 0.17$),

Table 1. Canopy size (m) of the study tree species.

Tree species	n	Mean	Std Dev
<i>A. abyssinica</i>	16	7.4 ^a	2.19
<i>A. campylacantha</i>	14	7.6 ^a	1.50
<i>A. gerrardii</i>	16	5.2	1.24
<i>A. hockii</i>	14	2.4	0.65
<i>A. coriaria</i>	14	6.6 ^a	2.45
<i>A. africanus</i>	16	3.6	0.73
<i>F. natalensis</i>	15	6.1 ^a	1.32
<i>G. mollis</i>	15	4.8	1.06

Canopy size of means which do not share a letter is significantly different at 95% CI.

Table 2. Composition of pastures and their dominance levels under and outside tree canopies.

Pasture species	Dominance index under canopies	Dominance index outside canopies
<i>Brachiaria ruziziensis</i>	0.13	0.17
<i>Cynadon dactylon</i>	0.04	0.02
<i>Brachiaria brizantha</i>	0.02	0.02
<i>Brachiaria decumbens</i>	0.02	0.00
<i>Panicum maximum</i>	0.00	0.00
<i>Neonotonia wightii</i>	0.00	0.00
<i>Hyparrhenia rufa</i>	0.00	0.02
<i>Pennisetum clandestinum</i>	0.00	0.00
<i>Chloris guyana</i>	0.00	0.00
<i>Setaria anceps</i>	0.00	0.00
<i>Desmodium intortum*</i>	0.00	0.00
<i>Setaria sphacelata</i>	0.00	0.00
<i>Microptilium atropurpureum*</i>	0.00	0.00
<i>Themeda triandra</i>	0.00	0.00

Pasture species with an asterisk (*) were recorded under tree canopies only.

A. hockii (H = 0.16) and *A. africanus* (H = 0.23) which species had low pasture diversity.

In grazing lands, the contribution of tree species towards improving the productivity of below ground vegetation is attributed to the reduction in incoming solar radiation, decreasing sub-canopy evapotranspiration and enhanced mineralization of nutrients (Abdulahi et al., 2016). Such factors positively influence establishment and growth of different types of pastures. Banking on previous studies it could be true that the micro climate under the canopy of *F. natalensis*, led to a higher facilitative effect towards growth of different pasture species compared to other tree species especially *A. campylacantha* and *A. hockii*.

In terms of abundance, there was significant difference in pasture abundance under and outside tree canopies and between tree species especially for under the tree canopy site ($p < 0.05$). As displayed in Figure 5, the distinct patterns in the alignment of pasture abundance under and outside tree canopies and in relation to tree

species reveal existence of significant differences. Most importantly, the relatively wider distance between pasture abundance positioning under the tree canopies of *A. campylacantha*, *A. coriaria*, *F. natalensis* and other tree species gives insights into the source of variation. More so, like in the case of pasture species diversity, higher pasture abundance was recorded under tree canopies of *F. natalensis*, *A. coriaria* while lower abundance was recorded under canopies of *A. hockii* and *A. campylacantha* (Figure 5).

Basing on the results of this study, it is evident that presence of tree species enhanced colonization of pasture species in the sedentary grazing areas of South-western Uganda. Besides, the significant differences in pasture abundance under the canopies of different tree species reveal that some tree species had more complementary support towards pasture growth and ground coverage. This is true especially for *F. natalensis*, *A. coriaria* under whose canopies highest abundance of pastures was recorded.

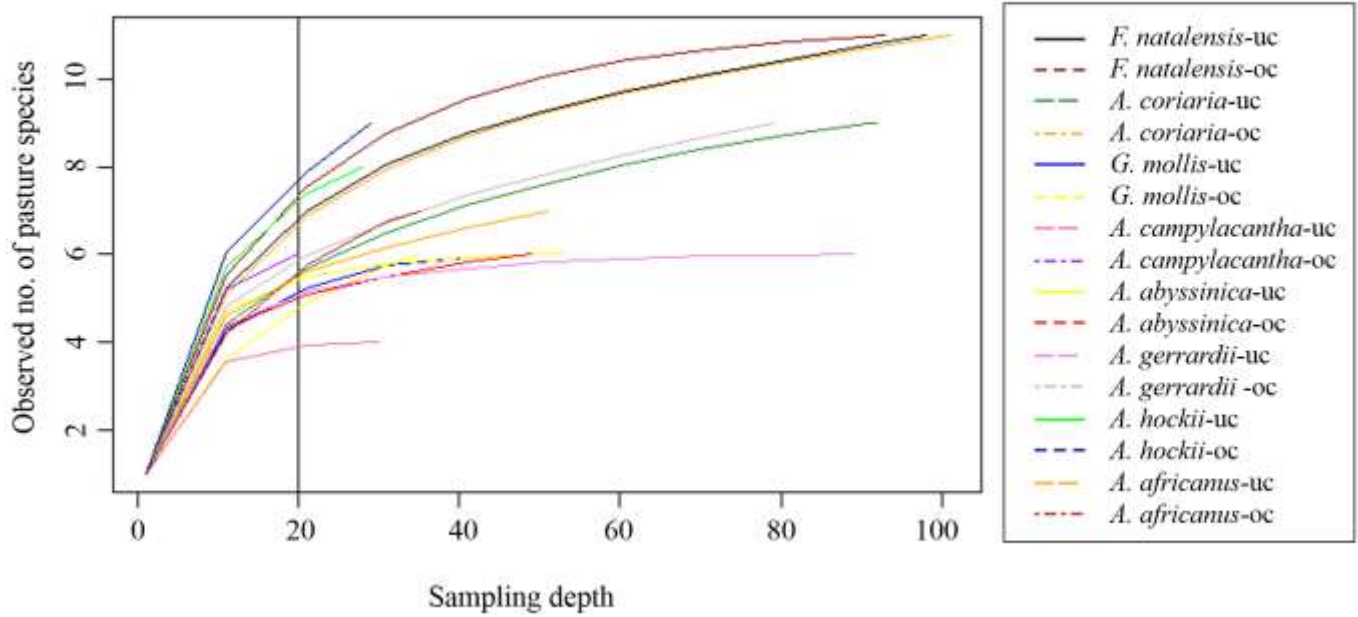


Figure 3. Rarefaction plot for pasture species richness under (uc) and outside (oc) tree canopies.

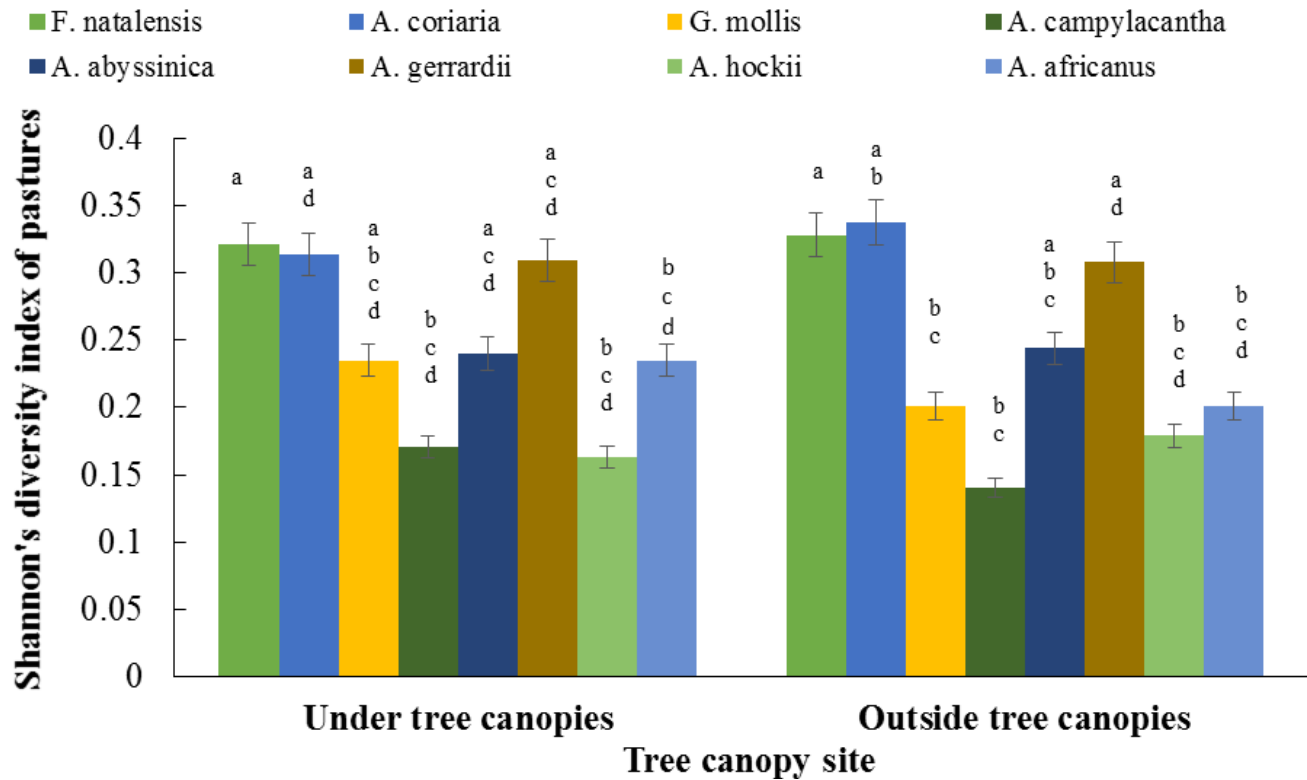


Figure 4. Pasture diversity under and outside canopies of the different tree species. Pasture diversity of bars which do not share a letter is significantly different at 95% CI.

The findings revealed by the results above could be explained by differences in plant traits between tree species. An earlier study by Castillo et al. (2020) revealed

that differences in tree traits such as canopy structure, nutrient uptake and litter quality can affect soil processes thus impacting on the growth and colonization of pasture

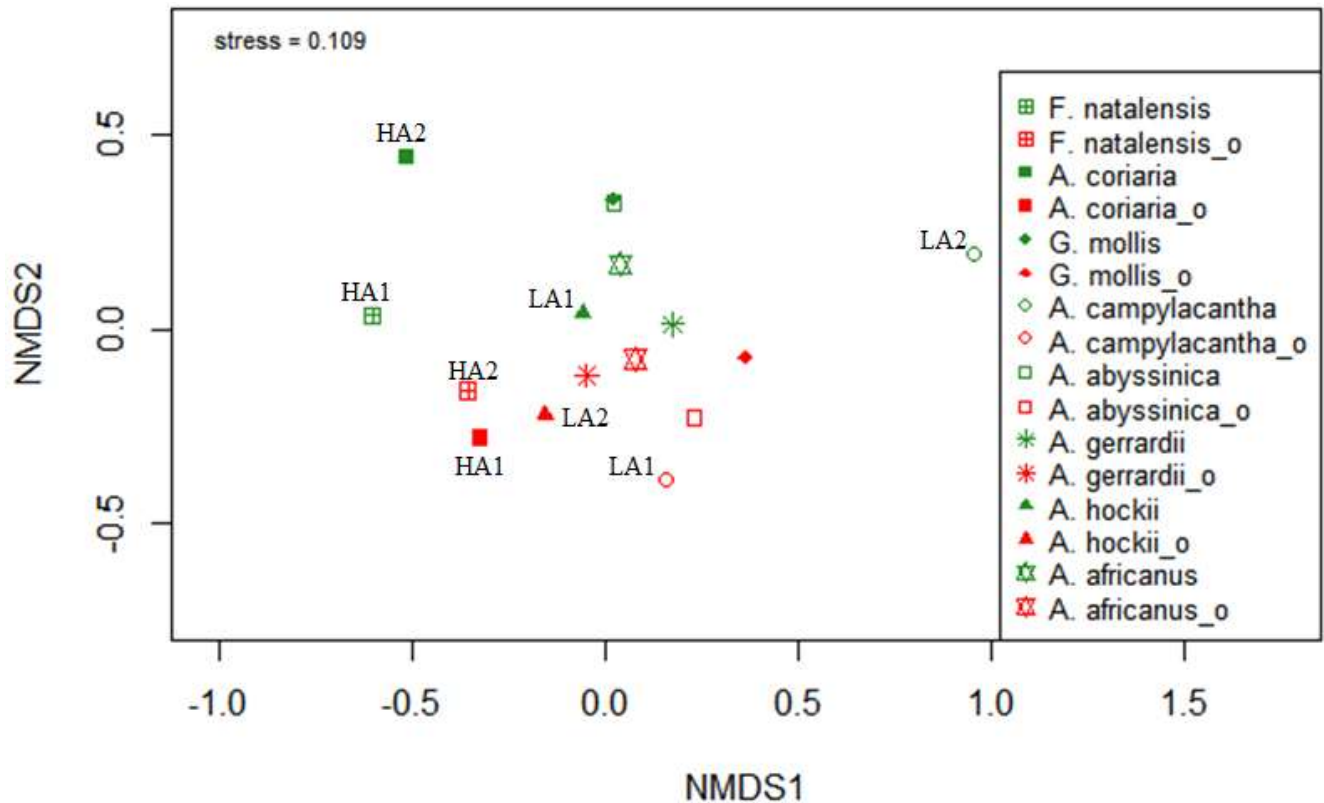


Figure 5. NMDS ordination plot displaying the canopy effects of different tree species on pasture abundance. HA= High Abundance; LA=Low abundance; o = outside tree canopy.

species. In a study by Ssebulime et al. (2018), it was discovered that the leaf litter of *A. coriaria* and *F. natalensis* comprise a high concentration of nutrients which factor could have improved soil fertility under these tree species and supported growth and greater ground coverage of the pastures. More so, a study by Fujita (2014) reports that below tree canopy ground conditions of *F. natalensis* tend to favour germination and seedling survival of plants compared to the open environment. Therefore, since *A. coriaria* and *F. natalensis* never had the widest canopies as reflected in Table 1, enhancement of soil fertility linked to these tree species could justify the findings of this study.

Worth noting, *F. natalensis* and *A. coriaria* which had higher pasture diversity and abundance under tree canopies compared to other tree species still recorded higher pasture diversity and abundance outside tree canopies. Whereas in some studies tree species have been reported to have negative effects on below ground grass community (Abate et al., 2012), in this study such results could imply that the extent of positive influence on pasture growth and ground coverage by the two species extended beyond their tree canopies.

Much as the physiological attributes of tree species was an aspect beyond the scope of this study, the deciduous nature of *F. natalensis* and *A. coriaria* gives

the closest factor to explain the observed results. Probable reasons could be that during leaf shedding, some of these high nutrient rich leaves, could have been deposited in a close distance outside the tree canopies and improved the soil fertility conditions for the benefit of the pastures (Ssebulime et al., 2018). More so, in a study by Buyinza et al. (2019), it was revealed that as *A. coriaria* sheds its leaves between late January and February, the species increases its water use about one month prior to the start of the wet season, between mid-February and early March. Such results could be banked on to ascertain that in the phase of this study, there was higher water use by the two tree species under their canopies which lowered pasture growth and subsequent ground coverage compared to outside their canopies.

Effect of scattered tree species on pasture biomass

Above ground biomass of pastures never varied significantly under and outside tree canopies ($p > 0.05$). Nonetheless, six out of the eight tree species studied had slightly higher pasture biomass under tree canopies. This was under *A. coriaria*, *A. africanus*, *A. gerrardii*, *A. campylacantha*, *A. abyssinica* and *G. mollis* (Figure 6). Similar to pasture diversity, the uniformity of pasture

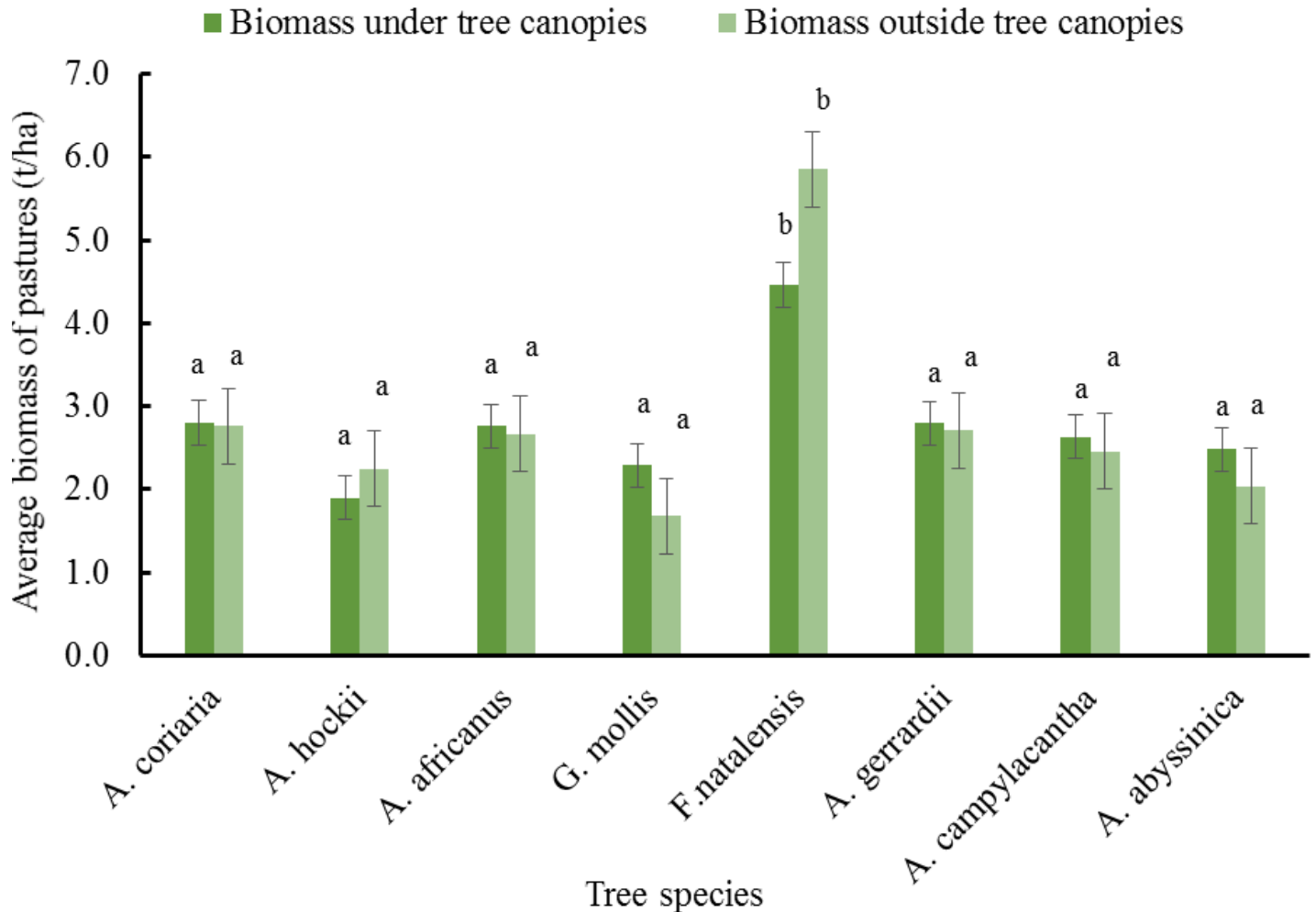


Figure 6. Average biomass of pastures under and outside canopies of the study tree species. Biomass in bars that do not share a letter is significantly different at 95% CI.

biomass under and outside tree canopies could be attributed to the non-exclusive foraging pattern of livestock in the area. In such unprotected sites, overgrazing which accrues from continuous pasture utilization has been documented to hinder biomass productivity (Hassan et al., 2017).

However, irrespective of the canopy size, the slightly higher pasture biomass under the canopies of most species reveals that probably there was a more favorable micro-climate under tree canopies of the respective species which enhanced nutrient uptake and subsequent biomass accumulation. Although the physiological attributes of tree species were not covered in this research, the aspect presents a probable insight into the findings of this study. In a study by Mazía et al. (2016), it was revealed that most deciduous and leguminous trees enhance the biomass of grasses growing beneath them. In this study 3 tree species out of the 6 species where higher pasture biomass under tree canopies was

recorded are leguminous while *A. coriaria* is deciduous. Between tree species, pasture biomass varied significantly under and outside tree canopies ($p < 0.05$). Under the canopies, the highest and statistically significant pasture biomass was 4.5 t/ha which was recorded under *F. natalensis* while the lowest pasture biomass was 1.9 t/ha which was recorded under *A. hockii* (Figure 6). In comparison with previous studies, biomass of natural pastures in grazed areas has been documented in values of 0.596 - 1.59 t/ha as the lower range and 0.7 - 2.83 t/ha as the higher range (Oñatibia and Aguiar, 2016; Ishaq et al., 2019). Basing on the previous findings elsewhere, this study has revealed that presence of *F. natalensis* in the sedentary grazing areas of South-western Uganda has a higher complementary support towards pasture biomass for the benefit of livestock. Since above ground plant biomass is linked to soil nutrient levels (Li et al., 2017), it is highly likely that the leafy litter of *F. natalensis* contains a high

concentration of nutrients which improved soil fertility and led to higher pasture biomass.

Surprisingly, the highest and statistically significant pasture biomass outside tree canopies (5.9 t/ha) was still recorded in pastures away from tree canopies of *F. natalensis* (Figure 6). It is probable that the positive effect of *F. natalensis* trees on pasture biomass stretched to more than 5 m beyond their canopies. However, the fact that the biomass outside tree canopies was higher than under the canopy calls for detailed analysis. Since no previous literature has been documented in relation to the findings, such observation warrants scientific investigation.

Conclusion

This study has shown that in the sedentary grazing lands of South-western Uganda, scattered tree species especially *F. natalensis* and *A. coriaria* improve the abundance of forage pastures. Whereas most tree species did not lead to significance increase in pasture species diversity and biomass, *F. natalensis* had a significantly higher positive influence on pasture diversity and biomass. Therefore, this study recommends that *F. natalensis* and *A. coriaria* can be used to restore degraded grazing lands in South-western Uganda. Further research on the effect of deciduous attributes of the two tree species on pasture productivity is needed.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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