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Assessment of the influence of livestock grazing and soil moisture on tree sap flow in savannah, Lambwe valley, Kenya

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Abstract

A Kenyan humid savanna in Lambwe Valley is dominated by trees of the genus *Acacia* and *Combretum.* The ecosystem is subjected to livestock grazing at varied intensities and fluctuating rainfall amounts. Notable increase in livestock densities and declining rainfall amounts are raising concerns regarding the sustainability of the humid savanna. Sap flow measurements in mature representative trees of *A. ancistoclada* and *C. molle* were carried out to assess tree responses to varying intensities of livestock grazing and the compounding effects of fluctuating soil moisture in their natural conditions. On average, trees in the grazed fields (grazed plots) exhibited significantly higher ($P>0.05$) mean daily sap flux densities (SFD) compared to those excluded from grazing (fenced plots), amounting to 20.17 ± 2.32 g $m^{-2}s^{-1}$ and 16.9 ± 0.71 g $m^{-2}s^{-1}$, respectively. The peak daily sap flux densities were recorded around midday in both species. For both species, daily SFD was correlated ($R^2=0.77$) with vapor pressure deficit. Seasonal changes in SFD were however positively influenced by the amount of rainfall, through changes in soil moisture. Higher SFD in the grazed plots was attributed to higher projected crown area. The diurnal variation in SFD showed that sap flow was coupled to the atmosphere with relatively low boundary layer resistance and the seasonal variation in sap flow was controlled by stomatal regulation. These findings point to the possibility that the dominant tree species in Lambwe are isohydric species.

Key words
sap flow; trees; grazing; savanna; *Combretum molle*; *Acacia ancistroclada*

Introduction

In Africa, transitions in the structure and function of the savanna are being observed and are attributed to changing climate and land use (Hill and Southworth, 2016; Sankaran, 2019). In the tropical Africa, where most savanna ecosystem is located, the rainy seasons have become shorter while droughts have become more frequent (Sillman et al., 2013; Sankaran, 2019). Traditionally, the African savanna has played host to large herds of free-ranging mega herbivores. Recently however, an increasing number of sedentary livestock, confined to relatively small grazing areas, has been witnessed. The occurring changes in the environment are affecting the structure and function of the ecosystem but they are less studied (EKgosikoma et al., 2015; Ondier et al., 2019; Ondier et al., 2021). An understanding of the mechanisms that underlie plant responses to the increased livestock grazing and altered rainfall regime is important in comprehending how the ecosystems respond to these environmental changes.

Existing evidence shows that increase in livestock grazing and declining rainfall amounts negatively affect vegetation physiological processes, especially plant water uptake, water transport and carbon assimilation (Baudena et al., 2015). Trees, which form a significant proportion of the savanna vegetation, tend to be quite sensitive to environmental changes (Wu et al., 2017). Wang et al (2010) observed that certain tree species adjust physiologically and survive changes in grazing intensity and increasing drought stress. However, the tree survival may be dependent upon the intensity and length of the environmental change process and the versatility of the tree species considered (Wang et al., 2010; Midgley et al., 2010a and b).

The sap flow measurement methodology, an important tool in investigating the movement of water in the stem of plants can mirror the physiological attributes and transpiring responses of trees to environmental factors (Mapeto et al., 2018). Some studies have reported increased tree sap flow with increasing soil moisture levels (Zepp et al., 2007; Eliades et al., 2018) whereas others have revealed contradictory results (O'Grady et al., 1998; Plaut et al., 2013). The influence of soil moisture on sap flow may be related to multiple factors such as tree species (Cheng et al., 2006), rainfall amount, vapor pressure deficit, soil characteristics, social position of the tree, etc (Ivans et al., 2006). For example, deep rooted Australian *Eucalyptus miniata* and *E. tetrodonta* exhibited increased sap flow during the dry seasons due to increased evaporative demand and exploitation of the belowground water aquifers by the tree roots (O'Grady et al., 1998). On the other hand, shallow rooted *Isopogon gardneri* exhibited increased sap flow in response to improved moisture levels in Southern Australia (Burgess, 2006), a tendency which was linked to efficient utilisation of available soil moisture. Trees with broad leaves show the greatest increase in sap flow with increasing vapor pressure deficit compared to narrow-leaved. (Komatsu et al., 2007). Leaf area and stomatal regulation may account for the varying behavior in response to the changes in environmental and water conditions (Solari et al., 2006; Rodriguez-Gamir et al., 2016).

Based on the stomatal regulation of sap flow, savanna trees may be categorized as either isohydric or anisohydric species (Roman et al., 2015; Zhang et al., 2017). Isohydric species reduce stomatal conductance and sap flow as soil water decreases, hence maintaining constant leaf water potential (Roman et al., 2015). However, a consequence of this strategy is that the trees shut their stomata in response to even mild water stress, a process which though reduces tree water loss, often results in carbon shortage (Cheng, et al., 2014; Sankaran, 2019). On the contrast, anisohydric species allow large fluctuations in leaf water potential, maintaining high stomatal conductance and sap flow even during periods of water stress (Konings and Gentine, 2017). This strategy incurs a risk of xylem cavitation, which could ultimately lead to a decline in leaf water supply and tree mortality (McDowell *et al*., 2008; Yoshimwa *et al*., 2013).

Savanna trees have evolved with grazing, predominantly by mega herbivores, that normally occur at an ecologically sustainable level (Kioko and Seno, 2012; Mureithi et al., 2014; Mojeremane, 2015). However, with expanding livestock numbers, the ecosystems have experienced increased grazing pressure, which likely influences soil water infiltration and tree water transport (Sankaran 2019). At high grazing intensities on steep slopes, prolonged trampling by grazers may result in surface runoff and reduced soil water infiltration (DeLonge and Basche, 2018), thus reducing the water reaching the root zones of trees. Such conditions induce tree water stress and result in reduced sap flow and increased tree mortalities. Nevertheless, most savanna tree species have well developed deep rooting systems that access below ground water reservoirs (Miller et al., 2010) and can, therefore, overcome the induced water stress. Alternatively, grazing may increase the availability of soil water by reducing competition from the herbaceous layer, as suggested by models of savanna tree-grass coexistence (Sankaran *et al*., 2004; Baudena *et al*., 2010). In such scenarios, grazing would, therefore, contribute to the maintenance of water transport in savanna trees.

Lambwe Valley in western Kenya is a relatively humid savanna dominated by *Acacia ancistroclada* and *Comberatum molle* trees. In the recent years, both *Acacia ancistroclada* and *Comberatum molle* have been reported to be on a declining trend, raising concern over the stability of the valleys woody vegetation (Ondier *et al*., 2021). The region has experienced significant reduction in rainfall with extended dry periods and short episodes of intense rainfall and increased livestock density in the last decade (Njoka *et al*., 2003; Muriuki *et al*., 2005; Otieno *et al*., 2011; Ondier et al., 2019). There are reports of declining forest cover in Lambwe valley from 5% to less than 1% (Njoka *et al*., 2003; Scharsich et al., 2019), which could be linked to the environmental change, however, scientific evidence is lacking. This study used tree sap flow measurements to examine the responses of dominant tree species to livestock grazing and seasonal changes in soil moisture. The understanding of water use strategies of the savanna trees under the environmental change scenario will help in decision making aimed at conserving the savanna and other similar ecosystems.

Materials and Methods

Study site

The experiment was conducted in Ruma, Lambwe valley (00° 35’ S & 34° 12’E). The valley which sits inside a humid savanna in western Kenya has an elevation of around 1300 m above sea level. The valley is surrounded by Gembe and Gwassi hills located to the west and Kanyamwa escarpment to the East. The average yearly rainfall here is 1100 mm and occurs in a bimodal pattern between April-June and September-December (Ondier et al., 2021, Figure 1). The climate is warm and humid with a yearly average air temperature of 22 °C. Other than the broad savanna with semi-natural vegetation, other land use types include a protected area under the Ruma National Park, human settlements, and open cattle (cows, sheep, and goats) grazing fields with animal stocking rate of 7.4 animal units ha^{-1} (Ondier *et al*., 2021). The soils at the valley base are black clays and are plentiful in minerals (Allsopp and Baldry1972). The higher elevations are covered with trees, while the sloppy grounds are dominated by herbaceous vegetation. Measurements were conducted on a slightly sloping area (slope=3°), 150 ha terrain mainly open woodland and thickets dominated by tree genera of *Acacia ancistroclada* and *Combretum molle*, and a wide diversity of herbaceous vegetation, dominated by the grass species *Hyparrhenia filipendula*. The experimental site had tree canopy cover of approximately 20%.

Microclimate

Between January 2014 and December 2015, an Automatic weather station (AWS-WS-GP1, Delta-T Devices, Cambridge, UK) installed in an open place within the study area, was used to measure rainfall and air temperature (T_{air}). Measurements were taken every 5 minutes and data averaged and logged every 30 minutes. Additional measurements of air humidity and temperature were conducted using FUNKY-Clima, (ESYS, Berlin, Germany), which was installed close to the studied trees. Soil temperature (within study plots) at −30 cm (HOBO- ware, SynoTech, Linnich, Germany) was measured every 5 min, and data averaged and logged half- hourly.

Soil water content

Within the grazed and fenced plots, continuous SWC in the upper 30-cm soil layer was monitored between January 2014 and December 2015 using Theta probes (type ML 2X, Delta-T Devices, Cambridge, UK). Data were collected every 30 min, averaged, and logged hourly using a data logger (DL 2e-Delta-T Devices, Cam- bridge, UK).

Plant root distribution

Analysis of plant root distribution was done by excavating the selected soil profiles down to a depth of about 1 m or a depth where concrete rock material was found. Soil profiles (~0.5 x 1 m) down to a depth of consolidated rock material were dug within grazed and fenced plots at locations under the tree canopies. Each profile was divided into individual soil horizons and subsequently analyzed for depth distributions of roots. Coarse (>2 mm diameter) and fine (<2 mm diameter) root densities for each horizon were determined by counting all roots and dividing the number by the area of the profile wall covered by the associated horizon.

Tree sap flow measurements

On the hill slope dominated by trees, grazed and fenced plots measuring 70 m by 50 m were randomly established at 100 m apart and each replicated three times. Fenced plots were set up by erecting 2 m high perimeter fence to exclude livestock whereas the grazed plots were open and subjected to livestock grazing. A minimum of 3 individuals belonging to the dominant trees species *Combretum molle* and *Acacia ancistroclada*, respectively, were identified for sap flux density SFD (g m^{-2} s^{-1}) measurements using custom-type Thermal Dissipation Probes (TDP) developed after Granier's (1987). Each sensor comprised a pair of 2-mm-diameter probes. The two probes were installed 20 cm into the sapwood and were vertically aligned ca. 10 cm apart. The two thermocouples were joined at the constantan leads, so that the voltage measured across copper leads provided the temperature difference between the heated probe and the lower reference. The heated probe was powered by 120 mA wet cells, which were charged from a solar panel.

In cases where the tree trunk was larger, with sapwood depth greater than 20 mm, a second sensor was placed deeper, 20-40 mm and15-20 cm circumferentially, away from the first sensor pair, on the same side of the stem to avoid azimuth differences. Temperature differences were measured every 5 minutes and 30 minutes mean value logged (DL2e with LAC-1 in single ended mode, Delta-T Devices, England). Sap flux density (SFD, g m^{-2} s^{-1}) for every sensor was determined from ΔT in accordance with Grainer (1987) assuming zero SFD (i.e. ΔT_{max}) at night and VPD close to zero:

$$SFD = 119\ K^{1.231} \quad \text{eq. 1}$$

where,

$$K = \frac{\Delta T_{max} - \Delta T}{\Delta T} \quad \text{eq 2}$$

Tree sap flux was calculated by multiplying SFD by the hydro-active xylem area described in equation 3.

Tree Allometries

The sample trees were selected according to species and tree size distribution within the experimental plots. To estimate the sap wood area (SA) of the sample trees, an increment borer was used to extract cores of sapwood at the sensor installation height (about 1.5 m height) on the same species, but different trees from those installed with sap flow sensors. The depth of the sap wood depth was visually determined at those cores, as wood and heartwood were clearly different. Sap wood area was determined from sapwood depth and tree DBH based on equation (Vertessy *et al*., 1995; Meinzer *et al*., 2005): $SA = \alpha \times DBH^{\beta}$..eq. 3

Where α is a constant and β is allometric scaling exponent, and both are species-specific coefficients.

The ground projected crown area (m^2) of sample trees was measured in eight horizontal directions using compass, crown mirror and a measuring tape. The octagonal area was determined as the whole of eight triangles (Schmidt, 2007).

Stomatal Conductance

Monthly measurements of diurnal courses of stomatal conductance was carried out using steady state porometer, model LI-1600, (LI COR, Nebraska, USA). On each measurement day, three different trees of the same species were selected for measurements. Well-exposed leaves were identified from each of the trees, and measurements conducted on the same leaves between 08:00 and 17:00, local time, to avoid wet canopy conditions caused by morning and late evening dew. Tree crowns were accessed using a ladder. Care was taken not to damage the leaves during measurements by using a soft air tight pad placed over the mouth of the cuvette. Each leaf was mounted in the cuvette so that it received full illumination during measurement. Every turn of measurement lasted one to two minutes to allow the chamber to equilibrate. Alternate measurements were conducted between species throughout the day.

Statistical Analysis

SFD and environmental variables were recorded as half hourly averages. These variables, including stomatal conductance (Gc) were converted into daily and monthly averages. Data are presented as mean ± standard deviation (SD). Sap flux density (SFD), Air temperature (T_{air}), vapor pressure deficit (VPD) and Gc were compared between grazed and fenced plots, within months and among tree species using factorial ANOVA. All statistical analysis were based on 0.05 significance level and performed with SAS version 9.1 (California, USA).

Results

Microclimate of the study site

The total rainfall amount in 2014 and 2015 were 1148.4 mm and 1169.5 mm, respectively. Rainfall was bimodal, occurring in April to June and September to December. On average, monthly air temperature was 22.95±4 ^{0}C and 22.35±3.2 ^{0}C in 2014 and 2015 respectively. The hottest months were January, February and March while the coldest month were April, May and October (Figure 1).

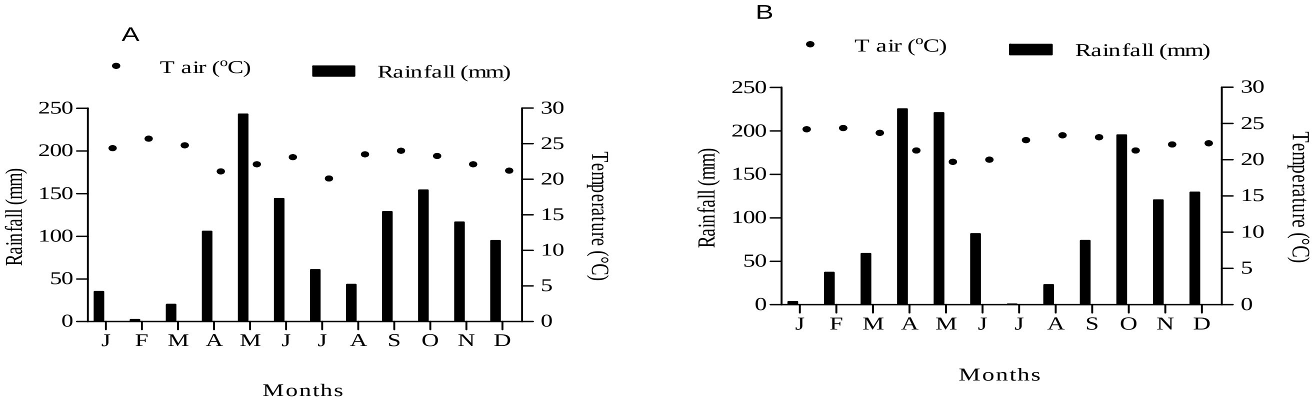


Figure 1. Mean monthly air temperature (T_{air}) and total monthly rainfall amounts recorded in 2014 (A) and 2015 (B) respectively.

Soil water content within Grazed and Fenced plots

In all the plots, soil water content followed seasonality in rainfall pattern, increasing and decreasing during wet and dry seasons respectively. April- June and September-December were wet periods while January-March and July and August were dry periods (Figure2).

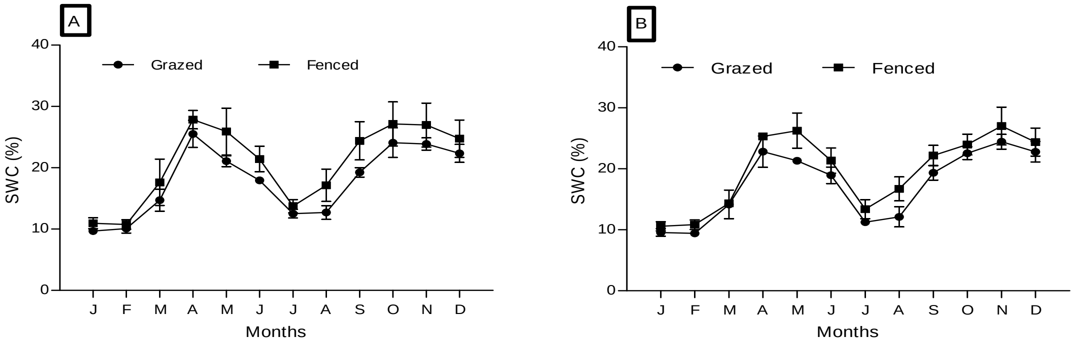


Figure 2. Mean soil water content (%) within grazed and fenced plots measured in 2014 (A) and 2015 (B) respectively. Bars are means with ± SD.

Root distribution patterns

The depth of soil on which the plots were established ranged between 50 and 70 cm below which there were strong presence of course rock fragments. Root distribution patterns were not different between the two locations (Fig 3). In all the plots, the densities of fine roots were highest at around 20 cm depth, most of which belonged to grass. Between 30 and 70 cm depths, coarse roots belonging to trees significantly increased.

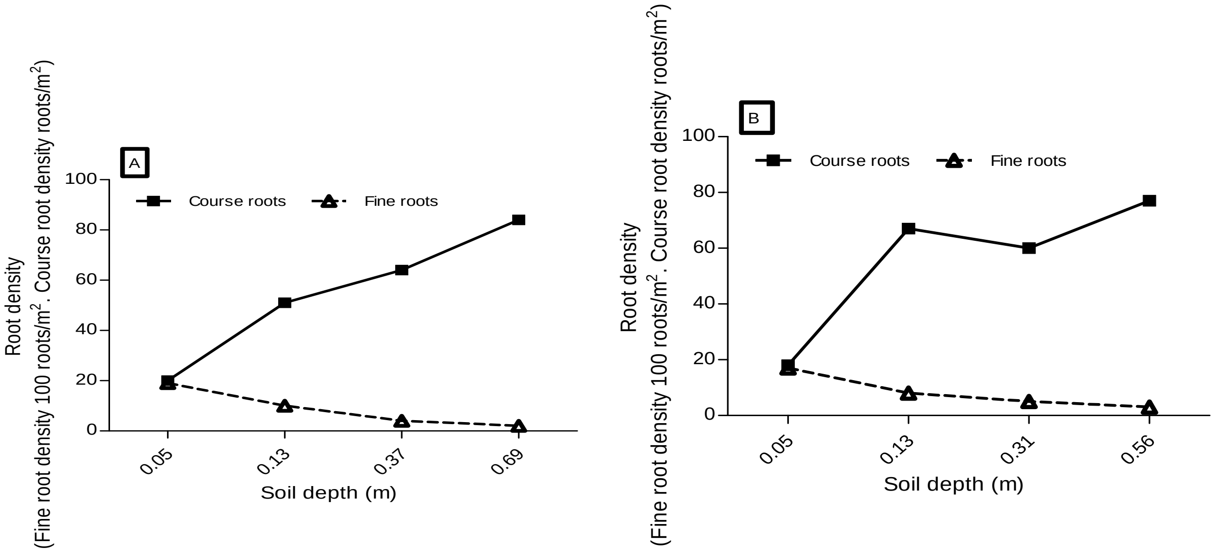


Figure3. Root distribution in the A) locations outside the tree canopies dominated by herbaceous vegetation and B) locations under the tree canopies.

Characteristics of the studied trees

Table 1 shows the morphological characteristics of the selected trees for sap flow measurements and their mean Sap Flux Densities. Mean sap flux density (SFD) between grazed and fenced plots were statistically different (P < 0.0001, F= 5.83) with grazed plots recording higher SFD (20.17 ± 2.32 g/m^2/s) than fenced plots (16.96 ± 0.71 g/m^2/s). As SFD is related to DBH, wood area, and crown projected area (Liu et al., 2008; Sevanto et al., 2008), we also determined coefficients between SFD with DBH, wood area and crown projected area from table 1. The statistically significant R and P values were determined with R^2 = 0.60, P < 0.0001; R^2 = 0.61, P < 0.0001 and R^2 = 0.40, P = 0.0022 respectively. The coefficient of determination between SFD and tree height (R^2 = 0.058, P= 0.2912) was statistically insignificant.

Table 1.
Characteristics of sampled trees in Lambwe, Kenya (January 2014 and December 2015)

Plot	***Tree code***	***Tree name***	***DBH (cm)***	***Wood area (cm^2)***	***wood area (m2)***	***Tree height (m)***	***Crown projected area (m2)***	***Mean sap flux density (g/m^2/s)***
Fenced	Cm1H	*Combretum molle*	16.4	97.97	0.009797	4.43	17.64	15.27±1.23
	Cm3H	*Combretum molle*	15	84.41	0.008441	6.4	12.43	16.47±0.97
	Cm4H	*Combretum molle*	13.3	67.94	0.006794	11	20.9	7.96±1.05
	Cm5H	*Combretum molle*	17	103.78	0.010378	5.28	19.78	28.09±6.02
	Cm6H	*Combretum molle*	11.9	54.38	0.005438	5.51	4.08	10.45±2
	Ae1aH	*Acacia ancistroclada*	27.4	204.53	0.020453	5.45	58.6	25.27±0.78
	Ae1bH	*Acacia ancistroclada*	27.4	204.53	0.020453	5.45	58.6	23.19±0.89
	Ae2H	*Acacia ancistroclada*	16.2	96.03	0.009603	4.4	30.96	15.91±2

	Ae3H	*Acacia ancistroclada*	13.3	67.94	0.006794	3.88	22.55	10.05±0.73
							Mean 27.28±5.7	Mean 16.96±0.71
Grazed	Ae1F	*Acacia ancistroclada*	34.5	273.3	0.02733	10	56.7	27.04±2.88
	Ae2F	*Acacia ancistroclada*	20	132.84	0.013284	6.9	30.03	18.34±2.14
	Ae3aF	*Acacia ancistroclada*	17.4	107.66	0.010766	7	55.6	15.24±5.75
	Ae3bF	*Acacia ancistroclada*	25	181.28	0.018128	7.3	69.66	31.21±3.15
	Cm2F	*Combretum molle*	23.1	162.87	0.016287	10.3	33.37	25.96±7.16
	Cm3F	*Combretum molle*	15.5	89.25	0.008925	7	20.1	16.16±0.82
	Cm4F	*Combretum molle*	12.4	59.23	0.005923	6.2	29.21	19.73±3.41
	Cm5F	*Combretum molle*	13	65.04	0.006504	9	13.58	16.03±1.42
	Cm6F	*Combretum molle*	10.7	42.76	0.004276	6.01	48.99 Mean 39.69±8.21	11.84±0.1 Mean 20.17±2.32

Monthly patterns of sap flow

Fig 4 shows the mean monthly sap flow (Kg/hr) measured in different individuals of the two tree species in grazed (A) and fenced (B) plots, respectively. Sap flow increased between April and June and September and December. Moreover, sap flow decreased between January and March. The monthly increase and decrease of sap flow coincided with wet and dry seasons respectively. In all the plots, *Acacia ancistroclada* recorded significantly lower ($P< 0.05$) sap flow than *Comberatum molle*.

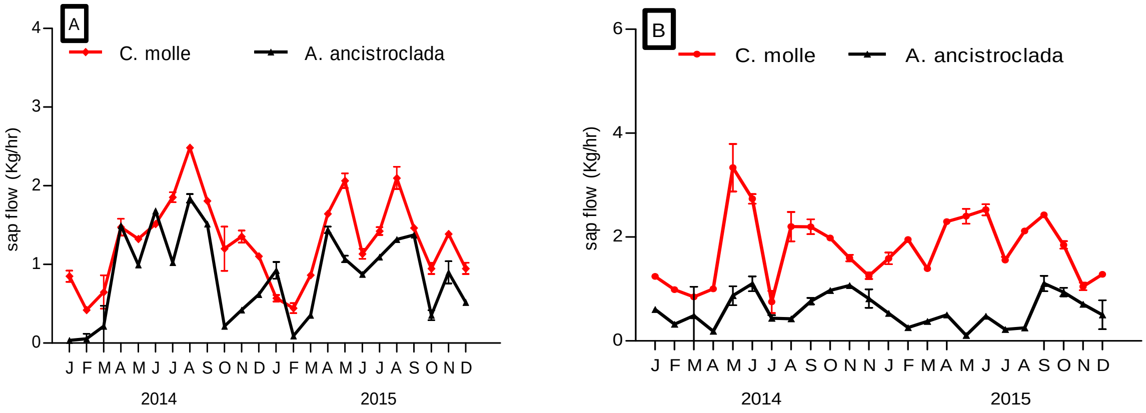


Figure 4. Monthly means of tree sap flow (Kg/hr) measured within grazed (A) and fenced (B) plots respectively. Bars are means with ±SD. Studied trees are *Comberatum molle*, and *Acacia ancistroclada.*

Influence of soil moisture on tree sap flow

Figure 5 shows the relationship between sap flow and soil water content measured within 0.3 m soil profile. There was a weak positive correlation between sap flow and soil water content in the grazed (Acacia $R^2 = 0.34$, *Comberatum* $R^2 = 0.16$) and fenced plots (Acacia $R^2 = 0.12$, Comberatum $R^2 = 0.07$).

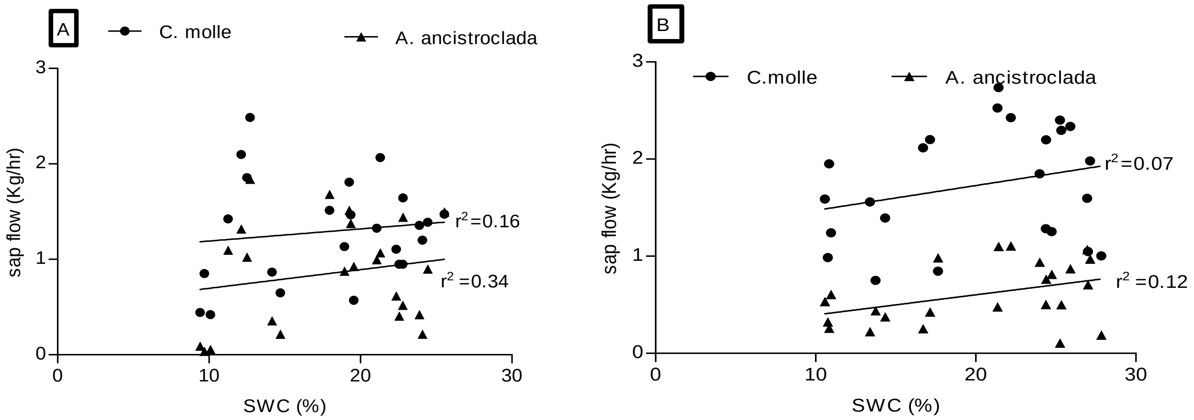
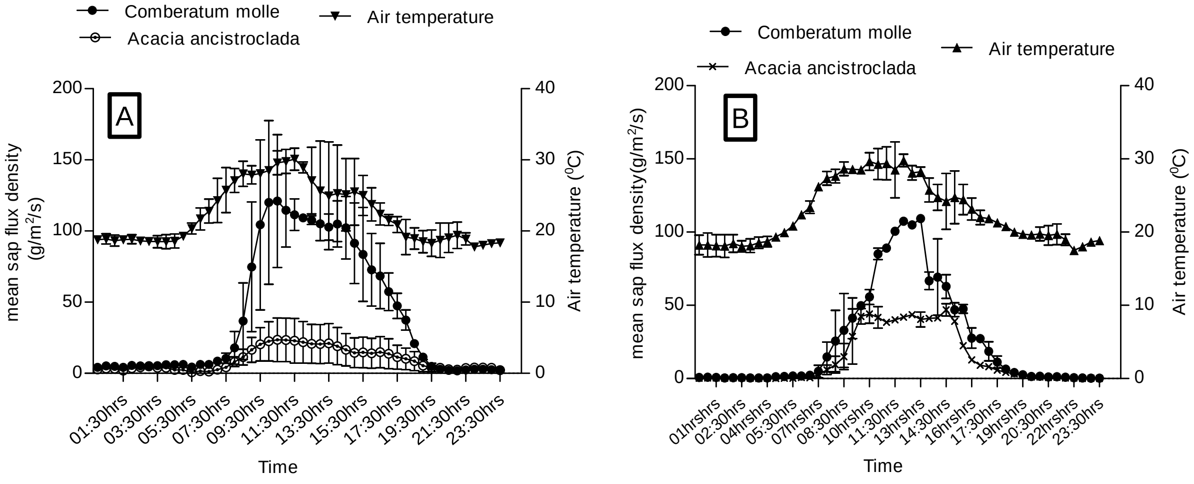


Figure 5. Relationship between sap flow and soil water content for studied trees within grazed (A) and fenced (B) plots

Diurnal courses of SFD, and T$_{air}$ and relationship between SFD and VPD

The diurnal pattern of sap flux density (SFD) on a representative day within grazed and fenced plots display typical diurnal patterns with maximum values occurring around noon. There was a linear relationship between SFD and air temperature in both grazed and fenced plots. In all the plots, Acacia species recorded significantly ($P< 0.05$) lower SFD in comparison to Comberatum species. Mean SFD was strongly correlated with VPD at both grazed (Acacia $R^2 = 0.82$ and Comberatum $R^2 = 0.74$) and fenced plots (Acacia $R^2 = 0.79$ and Comberatum $R^2 = 0.77$).



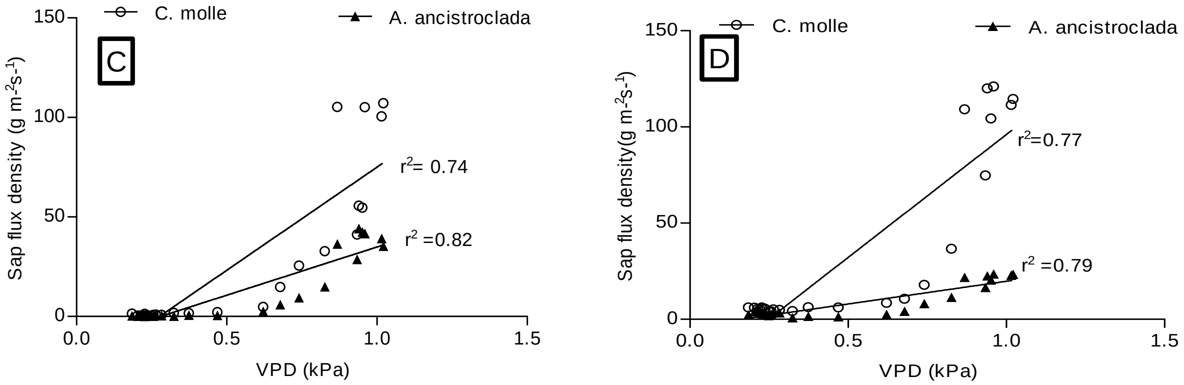


Figure 6. Mean SFD and air temperature in grazed (A) and fenced plots (B) plots under different times of the day, and relationship between mean SFD and VPD in grazed (C) and fenced (D) plots. Data are means ±SD.

Monthly trends of stomata conductance

Monthly variations in leaf stomatal conductance and relationship between conductance and soil water content in grazed and fenced plots are shown in figure 7a and b respectively. Stomatal conductance increased and decreased during wet and dry periods in all the plots (Fig 7 a and b).

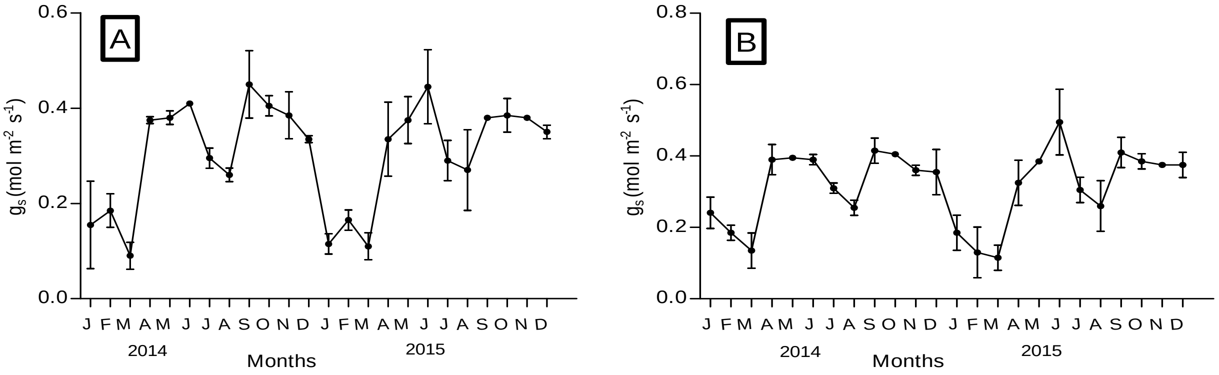


Figure 7. Variations in monthly mean stomatal conductance for *C molle* measured within grazed (A) and fenced (B) plots. The conductance of *Acacia ancistroclada* was not measured because the leaves were tiny and could not fit in the cuvette of the porometer used. Error bars are ±SD.

Discussion

Sap flow characteristics

This study demonstrated diurnal patterns of sap flux density (SFD) for the tree species (Figure 6a and b). The results are consistent with studies from other savannas (Du et al., 2011; Butz et al., 2018). Yin et al., (2011) and Chen et al., (2014) demonstrated a relationship between SFD and VPD and revealed that the daily changes of SFD for tree species displayed single peak curves that reached maximum values between 1200hrs and 1400hrs. Our results likewise revealed positive relationships between SFD and VPD (Figure 6 c and d). Further, SFD exhibited distinct curves that reached maximum values at about 1200hrs and 1400 hrs. The maximum SFD values coincided with peak values of both VPD and air temperatures (Figure 6 a and b). The results demonstrate that SFD within our plots is driven by VPD and air temperature. VPD and air temperature are known drivers of sap flow and transpiration attributable to the water potential gradient, and the ability of dry air to pull water from a source of higher water potential (Nadezhdina et al., 2019). Moreover, the correlation of SFD with VPD infers that SFD was coupled with the atmosphere with relatively low humidity (Gomenez et al., 2019). Similar findings were reported by Deng et al., (2015) who recorded a gradual increase in tree sap flux density with increasing vapor pressure deficit up to around midday. The linear increase in SFD with VPD was linked to increased evaporative demand that was necessitated by the increased air temperature. According to Deng et al., (2015) and Chen et al., (2022), SFD reached peak values when VPD was < 1.4 kPa, beyond which stomatal conductance and transpiration drastically reduced to avoid cavitation. This is true for our experiment where SFD peaked when VPD was around 1.0 kPa (Figure 6 c and d).

Although the patterns of SFD for *Acacia ancistroclada* and *Comberatum molle* were comparative in patterns, they were not synchronized (Fig 4 a and b, Fig 6 a and b). *Acacia ancistroclada* recorded significantly lower SFD than *Comberatum molle*. This finding could show the uniqueness in habitats to which every species is adopted (Wu et al., 2017). It might also be related to the differences in the leaf anatomical structure of the individual species. *Acacia ancistroclada*, is narrow-leaved compared to the broad-leaved *Comberatum molle.* Thus, under the same environmental conditions, Acacia is expected to transpire less compared to *Comberatum molle* due to the limited leaf area exposed to transpiration water loss. This could be the reason for the lower sap flow in Acacia observed within our plots. Moreover, in response to the increasing soil water deficit and evaporative demand, following dry periods within our plots, there was a significant reduction of the transpiring leaf surface through leaf shedding in Acacia. This could account for the decline in whole-tree sap flow in Acacia. Gomenez et al., (2019) linked lower transpiration in narrow leaved trees to lower stomatal conductance which was triggered by the accumulation of ABA (Abscicic Acid) in the leaves. In our study, however we did not determine the level of ABA in the trees leaves. Further, we could not determine the stomatal conductance of Acacia species due to the limitation of our equipment.

The linear relationship between SFD and DBH, wood area, and the crown projected area reported in our study (table 1) was also documented by other researchers (Kallarackal et al., 2012; Berry et al., 2017). The relationship between crown projected area and sap flow is explained by the pipe model theory (Shinozaki et al., 1964). According to the theory, the crown area and amount of leaves on a tree are supported by a proportionate of the crossectional area of the xylem vessels with equal hydraulic conductance. Consequently, the larger the crown area, the higher the transpiration and sap flow. Additionally, large projected crown areas are linked to higher leaf numbers and higher transpiration rates (Li et al., 2017). The relationship between DBH and sap flow is attributed to the positive relationship between DBH and sapwood area which directly transports sap flow. The report by Kallarackal et al., (2012) that large stems are linked with increased stem water storage and transport capacity agrees with the findings of this study.

Sap flux density responses to livestock grazing and seasonal changes in soil moisture

Mean sap flux density was higher in the grazed plots compared to the fenced plots (Table 1). We could link this to a higher mean crown projected area in the grazed (39.69 ±8.21m^2) compared to fenced areas (27.28 ±5.70 m^2). Higher crown area is linked to a greater transpiring surface and could be the reason for higher SFD (Liu et al., 2017). SFD within our plots was decoupled from soil water content at – 0.3 m (Fig 5a and b). This could be expected as tree roots within this study site are concentrated at a depth > 0.4 m (Figure3). Tree sap flow within our plots followed seasonality in rainfall pattern, increasing and decreasing during wet and dry seasons respectively (Figure 4a and b). Such results were also recorded for a seasonally dry and wet ecosystems (Tang et al., 2025; Kume et al., 2007) and were linked to seasonality in rainfall. For our plots, however, the fluctuation in sap flow in response to seasonality in the rainfall pattern was linked to stomatal adjustment (Figure 7 a and b) which limits water loss during dry seasons and maintain transpiration during wet seasons. Such a phenomenon is common in isohydric tree species. However, it is inherently difficult to establish a firm relationship between sap flow and soil water content mainly because of the large spatial variation in soil properties and soil moisture, but also because of sap flow’s strong dependence on other weather parameters.

Conclusion

The higher Sap flux densities in the grazed as compared to fenced plots were explained by the differences in tree crown area. The savanna trees showed a uniform response to the seasonality in the rainfall pattern. They exhibited an increase and decrease in SFD following increased and reduced rainfall which coincided with wet and dry seasons respectively. This is a phenomenon that characterizes isohydric species. *Acacia ancistroclada* which recorded significantly lower sap flow compared to the *Comberatum molle* could be distinguished as best suited species for survival in Lambwe Valley under prevailing environmental change processes. The species can then be used for reforestation of the ecosystem and other similar areas. However, additional measurements need to be conducted on the eligibility of the species to confirm the conclusion.

Conflict of interest

The Authors declared no conflict of interest

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Data availability statement

The dataset used and/or analysed during the current study are available from the corresponding author on reasonable request.

Authors' contribution

Joseph Ondier sourced for funding, designed experiment, collected data, analysed data, wrote and reviewed the manuscript; Dennis Otieno designed the experiment, analysed data reviewed the manuscript while Daniel Osieko collected data and reviewed the manuscript.

Licensing Statement

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