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Research article

Evaluation of rangeland condition in miombo woodlands in eastern Tanzania in relation to season and distance from settlements

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ABSTRACT

Miombo woodlands sustainability in east and south-central Africa is threatened by human activities, including overgrazing. This study investigated seasonal variations in rangeland condition in three grazed areas in miombo woodlands in eastern Tanzania. Transect lines were established across the grazing areas, sampling points were identified and marked at every 10% of the length of transect line. Sampling points were categorised in different distances with respect to settlement. The line intercept method was used to collect data on vegetation cover and forage distribution, while herbaceous forage biomass was estimated using a disc pasture meter. A total of 118 different plant species were observed and grasses comprised 40.6% of all herbaceous species. *Bothriochloa pertusa, Cynodon plectostachyus, Hyparrhenia rufa* and *Urochloa mosambicensis* grass species dominated miombo grazed areas in various seasons and distances. These perennial grass species are desirable and indicated moderate grazing activities in miombo. Season affected grass cover, herbaceous forage biomass and nutritional composition. Grass cover and forage biomass were at the lowest during late dry season while forage nutritional quality was best during early dry season. Distance from settlement had no effect on grass cover and herbaceous forage biomass. Rangeland condition was generally fair, livestock stocking rate in continuously grazed drylands should be set at the lowest monthly forage biomass in order to ensure grazing land sustainability.

1. Introduction

Miombo woodland is an important dryland biome in countries in east and south-central Africa. They are home to 100 million people and support another 50 million in the region's cities with forest products and environmental services (Ryan et al., 2016). These woodlands are dominated and defined by trees of the genera *Brachystegia*, *Julbernadia* and *Isoberlinia* (Backéus et al., 2006; Cauldwell et al., 1999). The extent and sustainability of miombo woodlands are now being severely threatened by agricultural expansion, charcoal extraction, illegal logging and increasing livestock grazing (Backéus et al., 2006; Lupala et al., 2015; Nduwamungu et al., 2009). Overgrazing in miombo is frequently reported as a cause of reductions in tree cover and tree regeneration (Gambiza et al., 2000; Mtimbanjayo and Sangeda, 2018; Nduwamungu et al., 2009). Moreover, continuous heavy grazing can change rangeland vegetation structure, by replacing palatable grass species with undesirable herbaceous plants (Pfeiffer et al., 2019; Tessema et al., 2011). Heavy grazing can also increase soil compaction and cause erosion, leading to reduced soil carbon levels and thus negative climate change impacts, i.e. reduced carbon sequestration potential (Angassa et al., 2012; Dunne et al., 2011; Walker and Desanker, 2004).

The increased deforestation rate in Tanzanian woodlands due to human activities and its possible consequences led to implementation of a land use plan in Kilosa district, eastern Tanzania in 2012 (Gmünder et al., 2014; TFS, 2015). This initiative brought together various stakeholders for the purpose of community-based forest management (Gmünder et al., 2014). However, the main objective of this land use plan was to facilitate sustainable charcoal production, so, little attention was directed towards improvement of livestock production on marginal land allocated for grazing (Gmünder et al., 2014; Kilawe et al., 2018). Empirical information on condition of grazed miombo land is limited, but the perception of traditional herders (pastoralists and

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agro-pastoralists) in the area is that forage quantity is in decline (Ruvuga et al., 2020).

Forage quantity and rangeland condition vary spatially and temporally as they are affected by seasonal changes, topography, soil quality and grazing activities (Gersie et al., 2019; Odadi et al, 2009, 2017). Rangeland areas frequently used by grazing animals, such as watering points, tend to be eroded and dominated by undesirable herbaceous species (Egeru et al., 2015; Tefera et al., 2007; Van Der Westhuizen et al., 2005). Livestock congregation areas such as resting places and *bomas* (overnight livestock holding facilities) are also usually in poor condition, due to regular trampling and heavy grazing (Dorji et al., 2013; Dunne et al., 2011; Enri et al., 2019). These trends are common at most grazing hotspots, unless there are managerial interventions such as resting periods between grazing bouts, rotation of watering points and uses of enclosures (Porensky and Veblen, 2015; Selemani et al., 2013a; Verdoodt et al., 2010). In Kilosa district some traditional herders engage in bush and grazing control close to their settlements within allocated grazing land, in order to improve rangeland quality (Ruvuga et al., 2020).

This study investigated possible differences in rangeland condition in areas close to and far from settlements in the district since areas closer to settlements and *bomas* are where livestock are kept overnight. The overall aim of the study was to determine seasonal variations in rangeland condition in relation to distance from settlements, using botanical composition, vegetation cover and forage condition as indicators. It was hypothesized that rangeland condition will be better far from settlements than close due to livestock traffic.

2. Methodology

2.1. Study area

The study was conducted in Kilosa district (6–8°S, 36°30′-38°E) in eastern Tanzania. The district has unimodal rain between October and May. Mean annual rainfall in the district is 800–1400 mm, while mean annual temperature is 25 °C as reported by Mtimbanjayo and Sangeda (2018). Miombo woodlands in Kilosa grow on leached sandy loam soil of Ferralsol type and are located in the district's western highlands (2220 m a.s.l). Some of these dry woodlands are state-protected, while general land is managed by village authorities (Backéus et al., 2006; Mtimbanjayo and Sangeda, 2018; Strömquist and Backéus, 2009).

The study centred on three miombo villages, Ulaya Mbuyuni, Kigunga and Ihombwe, all covered by the district land use plan, with allocated grazing area of 120.4 ha, 205.7 ha and 7551.5 ha respectively (see Fig. 1). These villages were selected from a total of 10 villages covered by the plan due to presence of grazing land and permanent presence of traditional herders. According to the village registry, the number of households in the selected villages was 581 in Ulaya Mbuyuni, 347 in Kigunga and 715 in Ihombwe. Of these households, 15 in Ulaya Mbuyuni, 7 in Kigunga and 72 in Ihombwe were located within the allocated grazing land. Grazing practices involved mixed herds of indigenous cattle (*Bos indicus*), sheep and goats foraging together continuously throughout the year. The district livestock records showed that during the study period (May 2018–March 2019), there were 1212 cattle, 312 goats and 418 sheep in Ulaya Mbuyuni, 710 cattle, 155 goats and 229 sheep in Kigunga, and 6211 cattle, 2017 goats and 1418 sheep in Ihombwe. Livestock keepers are not allowed to cut trees or start fires on any of the allocated grazing land. None of the grazing areas had a permanent watering point, so livestock drank from temporary streams that formed on the grazing land during the rainy season and from a permanent river outside the grazing land during dry periods.

2.2. Data collection

A transect line was established across the grazing land of each village (Fig. 1). The length of this line varied with grazed area and was 1300 m for Ulaya Mbuyuni, 2300 m for Kigunga and 12,400 m for Ihombwe. Sampling points were identified and marked at every 10% of the length of transect line, using GPS (Garmin GPSMAP 64s) with 4 m accuracy. Distance to settlements and their distribution within a 1 km radius around sampling points were determined using Google Earth satellite imagery. Secondary rainfall data collected from Tanzania Meteorological Authority (TMA) were used to show rainfall pattern during study period (May 2018–March 2019) and ten years mean rainfall trend (2008–2018).

2.2.1. Botanical composition and vegetation cover

Vegetation cover and forage distribution were measured monthly, using the line intercept method (Godínez-Alvarez et al., 2009). A 50 m tape measure was used as the sampling unit. It was laid starting from the sampling point on the transect line and the linear length of tape measure that intercepted grasses, weeds (unpalatable herbaceous species), tree canopy and bare ground was recorded. Herbaceous plant species found along the tape measure were identified and checked for their desirability as livestock forage, using the Tanzanian forage species identification guide (Kayombo et al., 2016). Tree density was estimated once, at the beginning of the study period, using the point-centred quarter (PCQ) method (Bryant et al., 2004). In this method, a steel cross was thrown randomly from the individual sampling point, the nearest tree was identified and distance from centre of the cross to the identified tree was measured using 50 m tape measures in all four directions of the cross.

2.2.2. Herbaceous forage biomass and grazing management

Herbaceous forage biomass was measured monthly, using a disc pasture meter (Zambatis et al., 2009). Four disc readings (5 m apart) were taken on the herbaceous cover at each sampling point. Disc calibration was done once, at the beginning of the experiment, by relating settling height of the aluminium disc to standing biomass. Herbaceous forage underneath the disc plate at each sampling point was harvested at ground level during calibration. Individual forage samples were oven-dried (60–70 °C) for 48 h and their dry weight was plotted against height, giving a linear equation. Equation (1) was developed and used to estimate herbaceous forage biomass:

$$Biomass\ (kgDMha^{-1}) = 187.9 * Disc\ reading\ (cm) - 84.5\ [R^2 = 0.88] \quad (1)$$

Calculated monthly stocking rate (CMSR) was determined from herbaceous forage biomass measurements. Utilisation efficiency of 30% was used to estimate available forage (Meshesha et al., 2019), since some forages are inaccessible to livestock due to unpalatability and trampling. Tropical livestock unit (TLU, 250 kg) was used as the standard livestock body weight, with daily dry matter (DM) biomass intake estimated to be 2.5% of body weight and assuming 30 days of grazing monthly (Meshesha et al., 2019; Mulindwa et al., 2009). The CMSR value was estimated as the ratio of total useable herbaceous forage biomass to livestock monthly biomass demand (Equation (2)):

$$Calculated\ Monthly\ Stocking\ Rate\ (TLUha^{-1}mo.^{-1}) = \frac{Above\ ground\ biomass*30\%}{250*0.025*30} \quad (2)$$

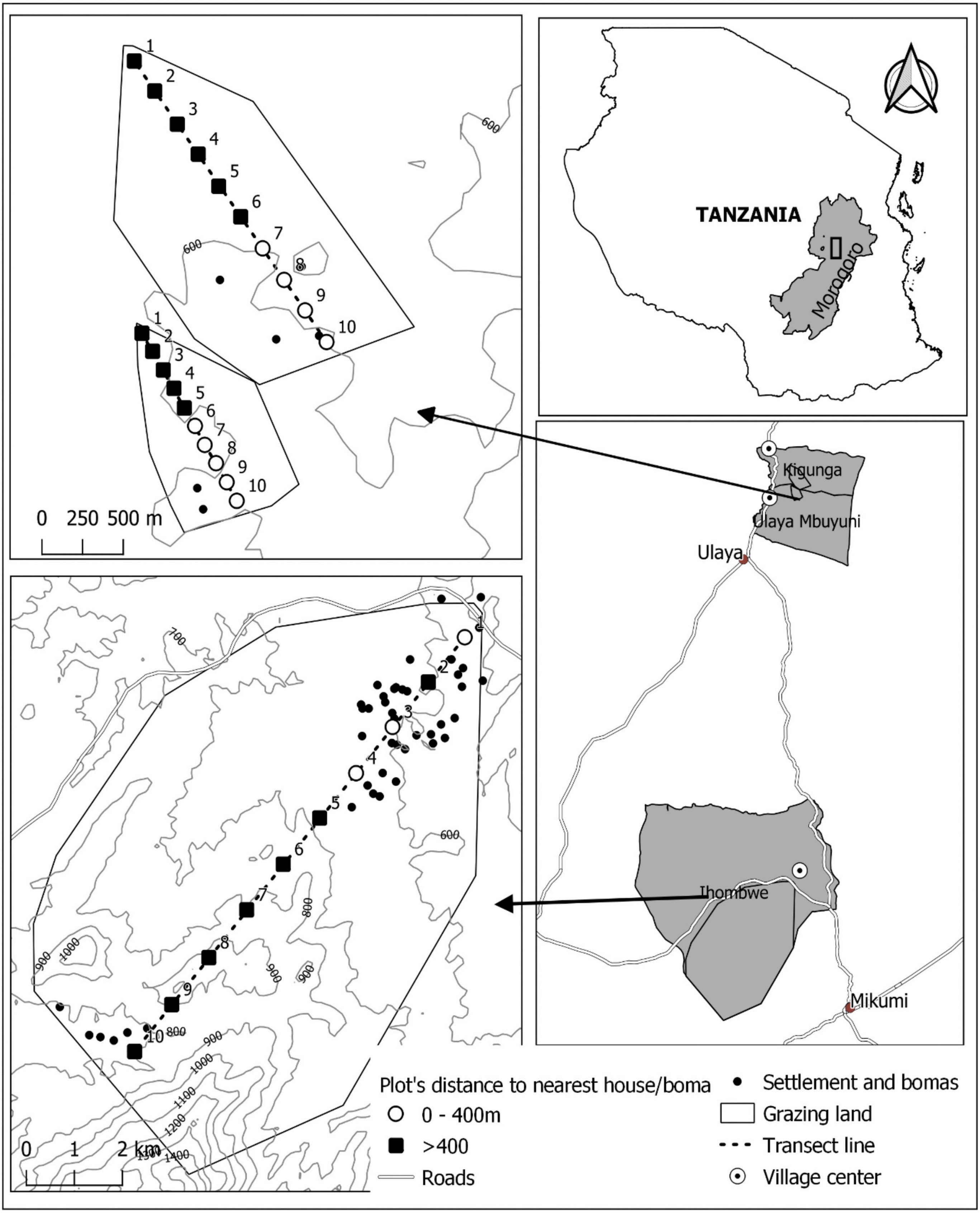

Fig. 1. Map of allocated grazing land in the miombo villages of Ulaya Mbuyuni, Kigunga and Ihombwe in Kilosa district, eastern Tanzania showing, sampling points and settlement distribution along the transect lines.

Reported stocking rate (RSR), i.e. the density of livestock on grazing land based on secondary data (annual number of TLU) obtained from district authority. Number of livestock was converted to TLU, with a conversion factor of 0.7 TLU for cattle and 0.1 TLU for goats or sheep (Wilson, 2003). Thereafter, RSR in the individual village was calculated using Equation (3):

$$\text{Reported Stocking Rate}\ \left(TLUha^{-1}yr^{-1}\right) = \frac{TLU}{\text{Total grazing area}} \tag{3}$$

2.2.3. Forage nutritional analysis

Forage samples for nutritional analysis were collected using a 0.5 m × 0.5 m quadrant, that was randomly thrown from the centre of each sampling point. The herbaceous species within the quadrant were identified and only forage species desired by cattle were sampled. Forages in the quadrant were cut to about 2 cm above the ground and included a mix of young, mature and dry forages, to imitate cattle feeding behaviour (Benvenutti et al., 2009; Dumont and Petit, 1995). Sampled forage species were sent to the animal nutrition laboratory at the Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, for analysis. Individual forage samples were oven-dried at 60–70 °C for 48 h and grinded separately with hammer mill to pass a 1 mm sieve. The individual grinded forage samples from each village transect line in the respective month were pooled pair-wise, i.e. first sampling point with second sampling point, third with fourth and so on, due to the small amount of forage sampled in some months. Association of Official Analytical Chemists (AOAC, 1997) standard methods were used to determine dry matter content (DM; ID 930.15) and ash content (AC; ID 942.05). The Kjeldahl method (ID 954.01) was used in crude protein (CP) analysis, while neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined following the techniques of Van Soest et al. (1991).

2.3. Data analysis

The study period was divided into four distinct seasons based on rainfall amount (Fig. 2). These were late rainy (May and March), early dry (June–August), late dry (September–November) and early rainy (December–February). Sampling points were categorised into different distances from settlements (0–200 m, 201–400 m, 401–600 m, 601–800 m and >1000 m). These categorical distances were grouped into close to settlement (CS, 0–400 m from the nearest settlement) and far from settlement (FS, >400 m from the nearest settlement). The 400 m threshold was selected as representing the area of more intense utilisation, e.g. condensed livestock traffic to night *boma* and to achieve comparable number of sampling points from each village in the two groups. Percentage of herbaceous forage species was calculated as the proportion of the individual forage species in the length of the sampling unit (50 m). Individual herbaceous forage percentage values from the sampling points were grouped according to distance from settlement and season of the year before estimating the average.

The statistical program R version 4.0.1 (R Core Team, 2020) was used to analyse vegetation cover, forage and CMSR data. An ANOVA type III mixed model with interactions was used for analysing grass cover, weed cover, bare ground and herbaceous forage biomass. It took the form: $Y = \text{Season}_{(\text{Fixed})} + \text{Distance}_{(\text{Fixed})} + \text{Season*Distance}_{(\text{Fixed})} + \text{Village}_{(\text{Random})} + \text{Sample point}_{(\text{Random})} + \text{Residual error}$. Mean grass cover was categorised as very poor (0%), poor (1–25%), fair (26–50%), good (51–75%) or excellent (76–100%) according to Sangeda and Maleko (2018). A modified statistical model was used to analyse CMSR, where season was replaced by month, distance was set as random factor

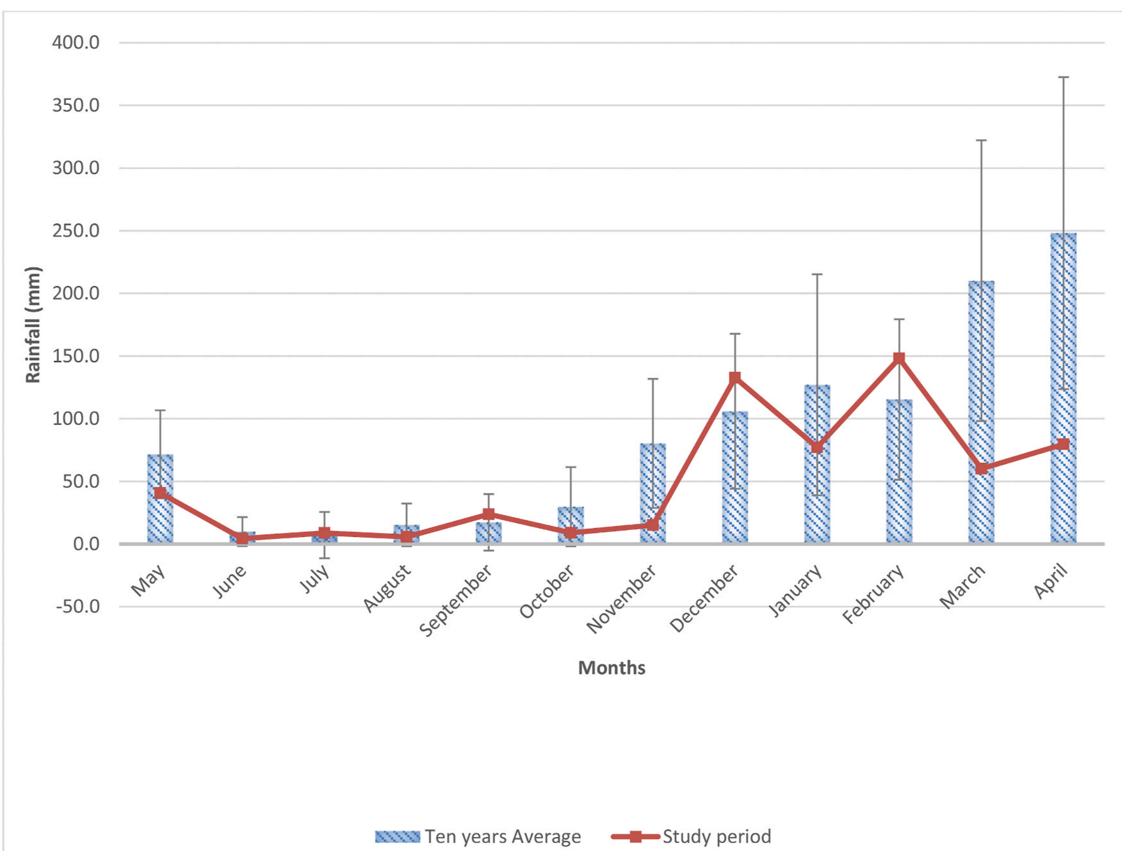

Fig. 2. Annual rainfall distribution in Kilosa district, eastern Tanzania during study period (May 2018–March 2019) and rainfall (mean ± SD) over ten years period (2008–2018).

to generalise grazing land and village was fixed factor. Tree density was analysed using the model: $Y = Distance_{(Fixed)} + Village_{(Random)} + Sample\ point_{(Random)} + Residual\ error$. Canopy cover was analysed using the model: $Y = Distance_{(Fixed)} + Season_{(Random)} + Village_{(Random)} + Sample\ point_{(Random)} + Residual\ error$. Another ANOVA type III model was used to analyse nutritional value of the sampled forages. This model was defined as: $Y\ (DM, CP, Ash, NDF, ADF) = Season_{(Fixed)} + Village_{(Random)} + Sample\ point_{(Random)} + Residual\ error$. Tukey's method was used for mean comparison of independent variables and a difference was declared significant at $p < 0.05$.

3. Results

3.1. Botanical composition

A total of 118 different plant species (see Appendix 1) were found in the three grazed areas, of which 67 plants were categorised as desirable livestock forage. Herbaceous species included a total of 69 different species of grass, legumes and forbs. Grasses comprised 40.6% (n = 28) of all herbaceous species, legumes 23.2% (n = 16) and forbs 7.2% (n = 5), while the remaining 29% (n = 20) were weeds. The key grass species and their growth habit are shown in Table 1 whereby perennials were dominant grass species. *Bothriochloa pertusa* (Ulaya Mbuyuni and Kigunga in all distances and seasons)*, Cynodon plectostachyus* (Ihombwe at CS during dry seasons)*, Hyparrhenia rufa* (Ihombwe at FS in all seasons) and *Urochloa mosambicensis* (Ihombwe at CS during rainy seasons) dominated miombo grazed understory.

3.2. Vegetation cover

Grass cover was, as expected, affected by season ($p < 0.001$, Table 2). It was lowest in late dry compared to other seasons in two distance groups. The two distance groups ($p = 0.751$) and the distance-season interactions ($p = 0.078$) had no effect on grass cover. In the late dry season, FS mean grass cover was categorised as poor (25.1%), the remaining distance-seasons assessments showed fair condition. Weed cover was affected by season, distance and season-distance interaction ($p < 0.05$) and was higher at CS than FS throughout all seasons except the late dry season. Bare ground area ranged between 23.9% and 31.0%, and was not affected by season, distance or distance-season interaction ($p > 0.05$). Tree density was 934 trees ha^{-1} in CS and 1147 trees ha^{-1} in FS, while canopy cover was 36.5% and 41.6% in CS and FS, respectively. These means were not significantly different ($p > 0.05$).

Table 2
Grass cover, weed cover and bare ground (mean ± SE) in miombo grazing land in eastern Tanzania, in relation to distance from settlements (CS = close to settlements (0–400 m); FS = Far from settlements (>400 m)). There was a seasonal effect ($p < 0.05$) in grass and weed cover, while bare ground did not vary seasonally ($p = 0.08$).

Grass cover (%)				
Distance	Late rainy	Early dry	Late dry	Early rainy
CS	$37.7 \pm 5.0^{\delta}$	$34.3 \pm 4.7^{\delta,\dagger}$	$30.4 \pm 4.7^{\dagger}$	$35.9 \pm 4.7^{\delta,\dagger}$
FS	$39.0 \pm 4.7^{\delta}$	$36.2 \pm 4.5^{\ddagger,\delta}$	$25.1 \pm 4.5^{\dagger}$	$32.7 \pm 4.5^{\ddagger}$
Weed cover (%)				
Distance	Late rainy	Early dry	Late dry	Early rainy
CS	$10.4 \pm 1.4^{\ddagger,a}$	$8.0 \pm 1.3^{\delta,\ddagger,a}$	$3.6 \pm 1.3^{\dagger}$	$6.3 \pm 1.3^{\delta,a}$
FS	4.7 ± 1.1^{b}	2.7 ± 1.0^{b}	1.1 ± 1.0	2.8 ± 1.0^{b}
Bare ground (%)				
Distance	Late rainy	Early dry	Late dry	Early rainy
CS	24.8 ± 3.3	24.3 ± 2.9	31.0 ± 2.9	28.2 ± 2.9
FS	23.9 ± 2.7	26.5 ± 2.4	27.8 ± 2.4	24.3 ± 2.4

Means within columns and rows with different symbols or letters are significantly different.

3.3. Forage condition and grazing management

Herbaceous forage biomass was significantly affected by season ($p < 0.001$), while distance and distance-season interaction had no effect ($p > 0.05$, Fig. 3). It was lower during the late dry (298.7 kg DM^{-1} ha for CS and 408.5 kg DM^{-1} ha for FS) compared to late rainy (667.6 kg DM^{-1} ha for CS and 798.3 kg DM^{-1} ha for FS). The nutritional composition of miombo forages also varied among seasons (Table 3). The NDF concentration of miombo forages was lowest during early dry period (531.8 g kg^{-1} DM) compared to the rest of the year, while CP and ADF did not

Table 1
Seasonal distribution and growth habit of some key grass species (mean percentage) in miombo grazing land around three villages in Kilosa district, eastern Tanzania, in relation to distance from settlements.

Forage species	Growth habit	Close to settlements (0–400 m)				Far from settlements (>400 m)			
		Late Rainy	Early Dry	Late Dry	Early Rainy	Late Rainy	Early Dry	Late Dry	Early Rainy
Ulaya Mbuyuni									
Bothriochloa pertusa	Perennial	6.1	10.5	9.5	7.4	17.5	18.0	12.2	12.9
Cynodon dactylon	Perennial	4.6	4.0	3.8	5.6	0.0	0.0	0.0	0.4
Digitaria sanguinalis	Annual	9.2	6.9	7.9	5.3	3.0	3.5	1.6	0.8
Digitaria spp.	Annual/perennial	1.1	3.9	0.2	1.6	0.9	1.6	0.6	0.3
Hetoropogon contortus	Perennial	1.5	1.5	3.3	1.5	5.0	4.7	3.0	2.6
Total grass cover		**28.7**	**28.8**	**29.2**	**29.1**	**30.6**	**30.0**	**20.6**	**21.6**
Kigunga									
Bothriochloa insculpta	Perennial	3.0	0.0	0.0	0.8	2.0	0.0	0.1	0.2
Bothriochloa ischaemum	Perennial	3.0	0.2	2.2	4.1	1.4	0.5	2.6	2.2
Bothriochloa pertusa	Perennial	21.6	27.3	14.6	17.3	21.9	24.5	9.1	15.9
Digitaria sanguinalis	Annual	6.5	4.2	3.4	3.3	2.5	0.8	0.7	2.1
Hetoropogon contortus	Perennial	2.1	1.6	1.1	1.1	2.3	3.5	1.8	1.1
Total grass cover		**41.8**	**37.6**	**27.7**	**38.0**	**38.2**	**32.9**	**19.2**	**30.9**
Ihombwe									
Aristida spp.	Annual/perennial	0.0	0.1	0.6	2.1	1.0	2.2	3.5	1.4
Bothriochloa ischaemum	Perennial	0.3	0.0	0.8	0.7	0.5	0.9	1.8	3.3
Bothriochloa pertusa	Perennial	3.3	5.9	2.4	4.2	9.4	6.0	4.4	5.9
Cynodon dactylon	Perennial	1.2	6.9	8.0	1.5	0.0	0.1	0.6	0.1
Cynodon plectostachyus	Perennial	4.6	7.2	8.8	6.6	0.0	0.0	0.1	0.0
Dactyloctenium aegyptium	Annual	2.0	1.0	0.9	6.1	0.7	1.6	1.0	0.4
Hetoropogon contortus	Perennial	6.8	4.9	2.0	2.8	8.5	10.9	3.0	3.9
Hyparrhenia rufa	Perennial	0.9	0.4	1.3	2.0	11.1	15.3	14.9	20.1
Urochloa mosambicensis	Perennial	10.0	3.7	5.1	12.1	0.7	0.7	0.7	1.3
Total grass cover		**43.8**	**35.5**	**32.6**	**40.8**	**47.3**	**44.9**	**34.9**	**43.6**

*Total grass cover was the sum of all the grass species along the transect line some of which were not reported in the table above due to their low percentage.

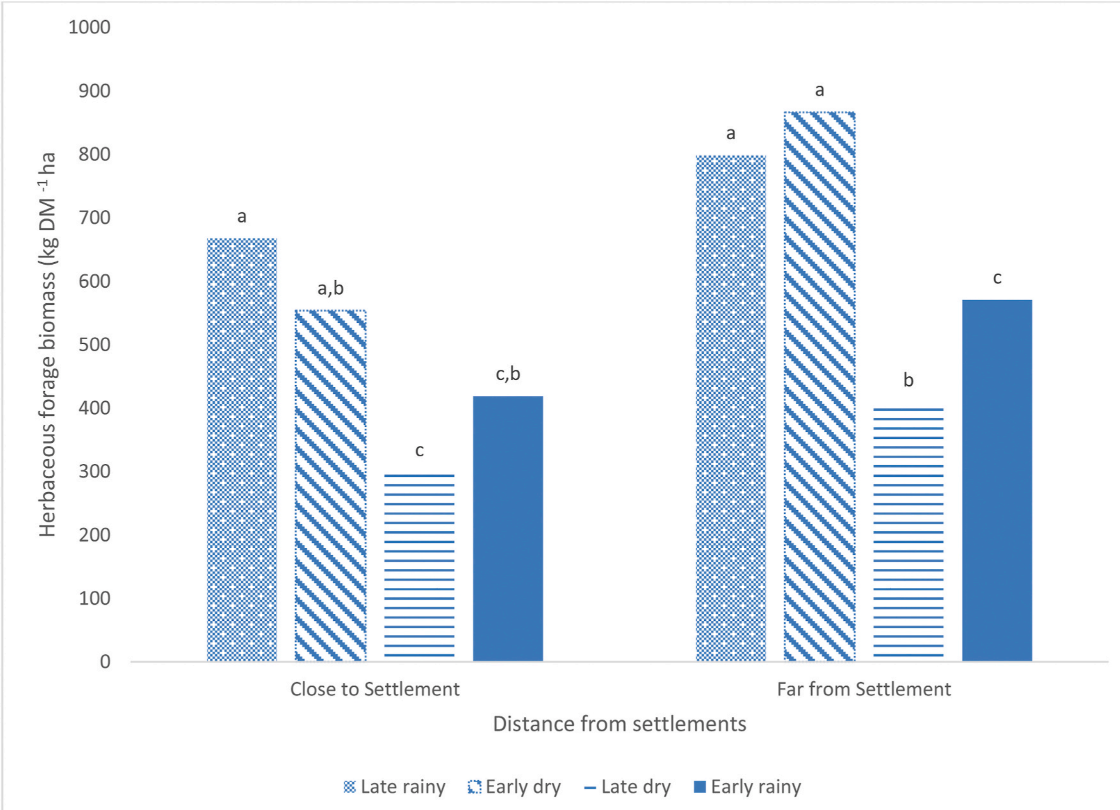

Fig. 3. Seasonal herbaceous forage biomass (kg DM ha^{-1}) in miombo grazing land in eastern Tanzania in relation to distance from settlements. There was a significant seasonal effect ($p < 0.01$) on forage biomass (means within distances with different letters are significantly different), while distance and distance-season interaction did not vary ($p > 0.05$).

Table 3
Seasonal nutritional values (mean ± SE) of forage species in miombo grazing land in eastern Tanzania. DM, Ash and NDF showed seasonal effects ($p < 0.05$), CP and ADF did not vary ($p > 0.05$).

Nutrients	Late rainy	Early dry	Late dry	Early rainy
DM (g kg^{-1})	307.1 ± 31.7[a]	528.5 ± 25.9[b]	558.3 ± 25.9[b]	285.7 ± 25.9[a]
Ash (g kg^{-1} DM)	52.2 ± 3.8[a]	32.9 ± 3.2[b]	27.2 ± 3.2[b]	47.4 ± 3.2[a]
CP (g kg^{-1} DM)	71.4 ± 3.6	73.1 ± 3.0	74.0 ± 3.0	73.3 ± 3.0
NDF (g kg^{-1} DM)	688.9 ± 12.0[a]	531.8 ± 9.7[b]	703.5 ± 9.7[a]	704.5 ± 9.7[a]
ADF (g kg^{-1} DM)	406.3 ± 13.5	402.1 ± 11.1	423.1 ± 11.0	419.0 ± 11.1

DM = dry matter; ash = ash content; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber.
Means within rows with different letters are significantly different.

vary seasonally.

During the study period, RSR was 7.7, 2.6 and 0.6 TLU ha^{-1} $year^{-1}$ in Ulaya Mbuyuni, Kigunga and Ihombwe villages, respectively. Ihombwe grazing land had higher CMSR than Ulaya Mbuyuni and Kigunga grazing land in the rainy and early dry months (Table 4).

4. Discussion

Recorded plant species in the study area (Appendix 1) are typical of miombo and Tanzanian dry rangeland (Backéus et al., 2006; Mtimbanjayo and Sangeda, 2018; Sangeda and Maleko, 2015, 2018; Selemani et al., 2013a; Selemani, 2015). Perennial grass species such as *Bothriochloa* spp., *Cynodon* spp., *Urochloa mosambicensis* and *Hyparrhenia rufa*, which were found close to and far from settlements, tend to dominate moderately grazed rangelands and are known as Increaser 2a ecologically (Egeru et al., 2015; Reda et al., 2020; Tefera et al., 2007; Young et al., 2010). Increaser 2a are usually present in low abundance in under- or overgrazed rangelands, but increase in frequency with selective grazing (Cauldwell et al., 1999), so their presence indicated moderate stocking in the study villages' miombo grazing land. However, annual to perennial grass ratio (Table 1), which is known as a good indicator of open rangeland health (Lohmann et al., 2012; Pfeiffer et al., 2019), was found to have small values, with no seasonal or distance differences. This may indicate that annual to perennial grass ratio is not a very useful indicator for shaded wooded landscapes. Tree density in the study area was slightly above miombo tree density values reported by Lupala et al. (2015) and Shirima et al. (2011). This shows that, in addition to currently fair use of rangeland, tree cover is being well maintained by traditional herders in the area.

The seasonal variations in grass cover and herbaceous forage biomass observed in the present study are expected in dry rangelands (Butt et al., 2009; Treydte et al., 2017). The values obtained were within grass cover and forage biomass values previously reported for Tanzanian rangelands (Sangeda and Maleko, 2018; Selemani et al., 2013a). Grass cover was expected to be poor at CS due to regular livestock traffic and trampling (Dunne et al., 2011; Egeru et al., 2015; Tefera et al., 2007) and relatively good at FS due to selective grazing, however we did not see this trend or differences between the means in two distances. Moreover,

Table 4
Calculated monthly stocking rate (emmeans±SE, TLU ha^{-1} $month^{-1}$) on allocated miombo grazing land in three villages in Kilosa district, eastern Tanzania.

Season	Late rain	Early dry			Late dry			Early rain			Late rain
Month	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb	March
Ulaya Mbuyuni	0.7 ± 0.2^{a}	0.7 ± 0.2^{a}	0.7 ± 0.2^{a}	0.7 ± 0.2^{a}	0.4 ± 0.2	0.4 ± 0.3	0.3 ± 0.3	0.3 ± 0.3	0.3 ± 0.3^{a}	0.6 ± 0.3^{a}	0.6 ± 0.3^{a}
Kigunga	$1.1 \pm 0.2^{\delta,a}$	$0.8 \pm 0.2^{\delta,\dagger,a}$	$0.8 \pm 0.2^{\delta,\dagger,a}$	$0.7 \pm 0.2^{\delta,\dagger,a}$	$0.4 \pm 0.3^{\dagger}$	$0.3 \pm 0.3^{\dagger}$	$0.4 \pm 0.3^{\dagger}$	$0.3 \pm 0.3^{\dagger}$	$0.6 \pm 0.2^{\delta,\dagger,a}$	$0.8 \pm 0.3^{\delta,\dagger,a}$	$0.8 \pm 0.3^{\delta,\dagger,a}$
Ihombwe	$2.4 \pm 0.3^{\delta,*,b}$	$2.7 \pm 0.3^{*,b}$	$1.9 \pm 0.3^{\delta,b}$	$1.7 \pm 0.3^{\delta,b}$	$1.0 \pm 0.3^{\dagger}$	$1.1 \pm 0.3^{\ddagger,\dagger}$	$1.0 \pm 0.3^{\dagger}$	$1.0 \pm 0.3^{\dagger}$	$1.6 \pm 0.3^{\delta,\ddagger,b}$	$1.8 \pm 0.3^{\delta,b}$	$1.8 \pm 0.3^{\delta,b}$

Means within rows and columns with different symbols or letters are significantly different

FS had poor grass cover during late dry period after categorisation, this could have been caused by herders immigration (Butt et al., 2009; Ruvuga et al., 2020). In Kilosa study villages, seasonal immigration of traditional herders from other areas was common due to permanent presence of allocated grazing land. Rainfall during the study period (Fig. 2) was lower than the ten years average and previous amount reported in earlier studies for Kilosa district (Backéus et al., 2006; Mtimbanjayo and Sangeda, 2018).

Weed cover (Table 2) was not high enough to categorise grazed area as degraded, although the risk of undesirable development is there. In order to maintain current rangeland condition and ensure sustainability in miombo grazing land, adaptive grazing management with adjusting stocking rate following monthly changes in forage biomass is advised (Steffens et al., 2013; Teague and Barnes, 2017).

Reported stocking rate (RSR) calculated from official livestock data for Ulaya Mbuyuni and Kigunga villages was higher than previous values reported for communally grazed open rangeland (Meshesha et al., 2019; Mulindwa et al., 2009; Sangeda and Maleko, 2018). Monthly stocking rate calculated from forage biomass (CMSR; Table 4) was within the rangeland grazing capacity reported by Mulindwa et al. (2009) and Sangeda and Maleko (2018). The higher RSR than CMSR found for Ulaya Mbuyuni and Kigunga villages might have been because of their small areas and high grazing pressure. Since CMSR was estimated from herbaceous forage biomass measured in continuously grazed areas, the measured biomass was what remained after livestock grazing. Also, actual stocking rate in the study village was higher than reported values (RSR) which could be due to herders immigration from other villages, and hence threatening rangeland condition (Pfeiffer et al., 2019; Tessema et al., 2011) and causing increased weed cover. Without efficient regulatory agreements, traditional or official, it may be difficult to adjust stocking rate monthly in the communal rangelands such as miombo grazing land where livestock are grazed continuously (Glowacki, 2020; Solomon et al., 2007). Lowest monthly forage biomass value measured in the respective grazing area could be used in estimating annual stocking rate in similar continuously grazed drylands to ensure that grazing land sustainability is maintained.

Forage nutritional values followed normal seasonal variations reported for DM and NDF (Safari et al., 2011; Selemani et al., 2013b), but not for CP, which was not affected by season (Table 3). This indifference of CP to normal variations associated with grass growth is most likely attributable to the forage sampling technique used in the present study. The intention was to sample a mix of forage species in the quadrat, to imitate cattle as bulk feeders (Benvenutti et al., 2009; Dumont and Petit, 1995). This means that each sample consisted of both fresh grass and matured standing hay. Accumulation of standing hay in miombo grazing land at the beginning of growing season might have been caused by low frequencies of fires at the end of the dry period, which limited nutrient recycling (McGranahan et al., 2014; Yoshihara et al., 2015). Nonetheless, the CP values obtained were lower than those previously reported for the same matured forage species in open rangeland and miombo grazed areas (Ruvuga et al., 2020; Safari et al., 2011; Selemani et al., 2013b).

5. Conclusion

Rangeland condition was generally fair in allocated miombo grazing area in Kilosa district, eastern Tanzania. Botanical composition indicated moderate grazing, while tree density did not indicate degradation in the allocated grazing land. Grass cover was fair without significant mean differences between areas close to and far from settlements hence we reject the stated hypothesis. This study showed that moderate livestock grazing in wooded landscapes is important to avoid serious degradation of herbaceous plants or tree cover. However, observed weed cover may lead to decline in rangeland condition due to possible replacement of desirable forage species in the grazing land. Stocking rate should be adjusted following monthly forage biomass changes in drylands, if this is impossible under continuous grazing system it should be set at the lowest monthly forage biomass in order to ensure grazing land sustainability.

Author statement

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Anthony Zozimus Sangeda worked as the consultant for Tanzania Forest Conservation Group (TFCG), one of the stakeholders in the Kilosa district land use plan.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2021.112635.

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