Published by SET Publisher

Journal of Basic & Applied Sciences

ISSN (online): 1927-5129

Vegetation Composition, Forage Biomass and Soil Seed Bank of a Continuously Grazed Rangeland Site in Tropical Sub-Humid Environment, Tanzania

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Article Info:

Keywords:
Rangeland,
vegetation cover,
bush encroachment,
communal grazing.

Timeline:
Received: May 25, 2022
Accepted: June 05, 2022
Published: June 20, 2022

Citation: Mdegela TE, Maleko DD, Msalya GM, Mtengeti EJ. Vegetation composition, forage biomass and soil seed bank of a continuously grazed rangeland site in tropical sub-humid environment, tanzania. J Basic Appl Sci 2022; 18.

Abstract:

Most rangelands along the agro-pastoral villages of Tanzania are yearlong grazed and at various states of degradation. These rangelands contribute to over 60% of the meat and milk production in the country. An inventory was conducted to assess the status of grazing resources in a typical agro-pastoral village of Tanzania having communal rangelands. Systematic random sampling techniques were employed whereby line transects and quadrat frame were used following standard procedures to collect samples and undertake field measurements for both vegetation and soil parameters. The vegetation cover for desirable pasture species, undesirable pasture species and litter were 67.7%, 10.5% and 9.4%, respectively. The soil bare patches covered 12.3 % of the surveyed rangeland site. The most dominant grass species were *Enteropogon macrostachyus*, *Bothriochloa insculpta* and *Heteropogon contortus*. Forage dry matter (DM) yield was 806.8 kg DM/ha. Tree density was 1500 trees/ha and the total canopy cover was 63.49%. *Combretum collinum* was the most dominant tree species. Soil bulk density, pH, organic carbon, nitrogen, phosphorus and potassium were 1.4 g/cm^3, 6.3%, 1.14%, 0.09%, 0.89 mg/kg and 0.33 g/kg, respectively. A total of 11 dicotyledonous species mainly forbs and 9 monocotyledonous species including two perennial grasses were revealed from the incubated soil samples. The findings of this study demonstrate that the communal grazing areas have low pasture productivity, poor soil seed-bank and high cover of woody plants mainly bushes. In order, to improve forage biomass at the study site and elsewhere with similar environments selective bush clearing and re-seeding should be considered.

DOI: https://doi.org/10.29169/1927-5129.2022.18.07

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INTRODUCTION

Rangelands are areas where grasses, forbs and shrubs is a dominant vegetation type i.e. unforested areas were both domesticated and wild ungulates wonder for search of pasture and water [1]. Rangelands cover about 30 - 40% of the earth's land and support the livelihood of about 1-2 billion people mostly in marginalized rural areas [2]. Intensive land management practices including tillage, application of synthetic fertilizers, herbicides or pesticides are uncommon in rangelands; while fire and extensive livestock grazing are the main management tools [3].

In Tanzania, most of the rangelands lack proper grazing systems, inventory and monitoring of both biotic and abiotic resources including vegetation, soil and water characteristics [4]. Also, most communal rangelands in Tanzania are continuously (yearlong) grazed and encroached with bushes and alien invasive species such as *Parthenium hysterophorus* and *Prosopis juliflora* [5,6] Moreover, climate change has shown to have negative consequences to Tanzania rangelands including prolonged droughts leading to forage scarcity with eventual loss of animal condition and even mortality of livestock species [7,8]. However, information with regard to vegetation composition both herbs and wood as well as associated soil seed-banks is still scarce for most rangelands in Tanzania that are under continuous grazing. Therefore, there is a need to conduct grazing land resources inventory in rangelands in order to ascertain the current pasture productivity for informed rangeland improvement initiatives.

This study was therefore conducted in a semi-arid rangeland site in Tanzania so as to assess pasture species composition, ground cover and dry mater yield, tree density and canopy cover as well as soil physical, chemical and seed bank characteristics. It is envisaged that the findings of this study will help a number of stakeholders including livestock keepers, planners and policy makers at the study site and elsewhere with similar environment to make informed decision for rangeland improvement initiatives. Rangeland improvement activities such as bush and invasive species control, range reseeding, stock control and pasture management if they have to be effective and sustainable, undertaking range inventory and monitoring is imperative [9].

MATERIAL AND METHODS

Study area Description

The study was conducted at Lubungo village in Mvomero district which is located at north east of Morogoro region at latitude 6° 49' S and longitude 37° 30' E in Tanzania (Figure **1**). The altitude of the study area ranges between 300 and 400 m above the sea level. The study site receives a mean annual rainfall of about 885 mm per annum. Lubungo village have a communal grazing land of about 1200 ha and ruminant livestock population of 3319 cattle, 766 goats and 159 sheep. Lubungo pastoral village was ideal for this study because about 76.4% of its land (Figure **1**) is categorized as rangeland and is mainly used for livestock grazing including cattle, goats, sheep and donkey.

Vegetation and Soil Sampling Design

Line interception method was used to assess pasture species composition and percentage vegetation cover [10]. In which, three parallel transect lines of 700 m long and 400 m apart were established at the grazing areas (rangelands) of Lubungo village. Eleven line interception sampling units of 10 m using a tape measure long were fitted in each transect line of 700 m at an interval of 70 m. In each line interception sampling unit two quadrat frames each 0.25 m^2 were thrown at random in left at the 5^{th} meter and right side in 10^{th} meter of the sampling unit to sample desirable pastures and soil for determination of the pasture dry matter yield and soil physical and chemical properties determinations. The soil samples were collected at a depth of 0 – 20 cm and then bulked to get 2 soil samples per transect and therefore a total of 6 samples for the three transects. The soil samples were sent to the Soil Laboratory of Sokoine University of Agriculture for selected physical and chemical properties determination. Forage samples were collected through cutting the grass and forbs at a stub height of 5 cm followed by weighing to get total fresh weight. Thereafter, a sub-sample of about 250 g was taken and oven dried to constant weight at a temperature of 80 °C for forage dry matter determination.

Point Centered Quarter (PCQ) method was used to determine tree density and their canopy cover according to the procedures described by [11]. In every line interception sampling unit a 1m long cross made of two sticks was placed at the 5 m mark of the tape measure (center of the line) on the ground and the distance of the four nearest trees falling within each quarter of the cross were measured to the center of the cross (quarter distance). Also, the canopy cover of each tree was measured for estimating the canopy cover of the rangeland while the quarter distance was used for estimating tree density [11].

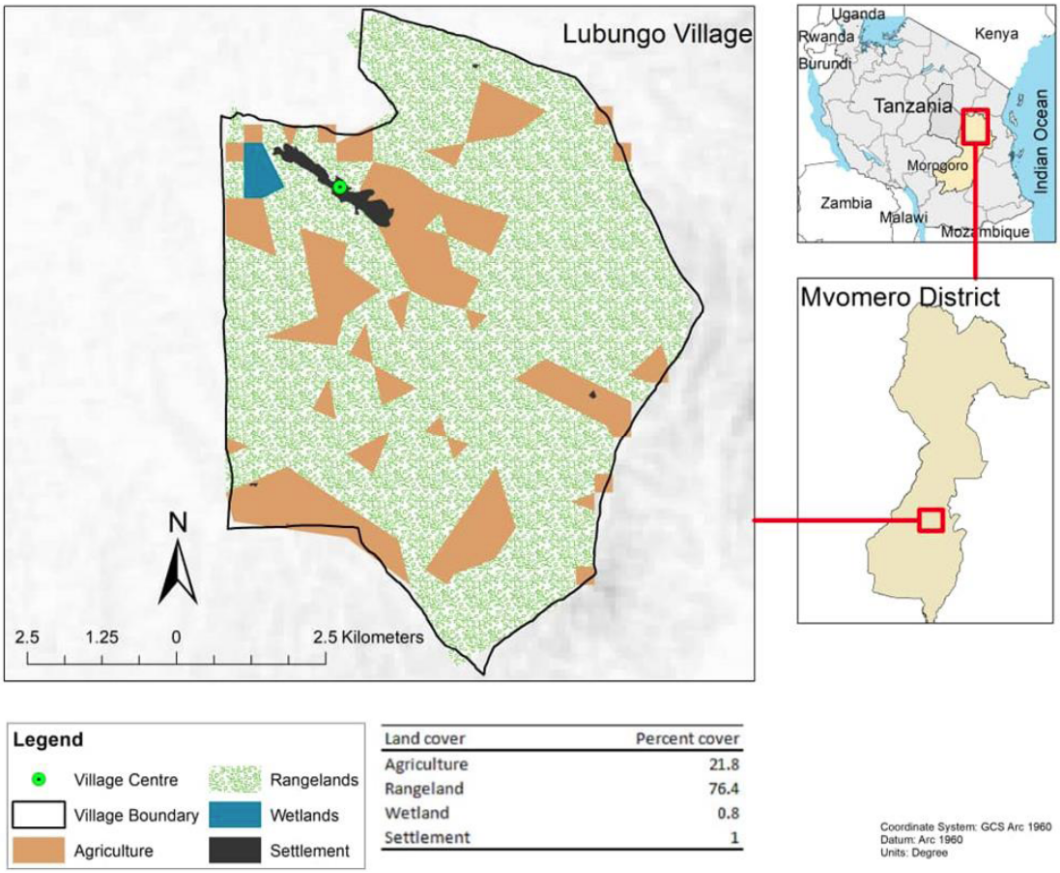

Figure 1: A map showing land cover types and location of the study site (Lubungo village), Movomero district, Morogoro region, Tanzania.

Soil Seed-Bank Seedling Density Determination

Soil samples at a depth of 5 cm, 30 cm long and 30 cm wide was collected for soil seed-bank determination whereby live vegetation samples including leaves and stem, as well as visible litter was sorted out. The soil samples were collected adjacent quadrant frames making a total of 33 samples. The soil sample for soil seed bank determination was packed into the labeled paper bag, put into plastic bucket and immediately sent to Sokoine University of Agriculture where it was incubated for analysis of soil seed bank density and plant species composition.

Whereby, each soil sample was filled at plastic pot with a diameter of 22 cm and depth of 3.5 cm. The pots were then placed in transparent nylon greenhouse structure measuring 2 m x 2 m x 2 m to prevent incoming seeds from the surroundings. The pots were covered by perforated nylon to minimize moisture loss and the cover was removed after seven days to allow the germinated seeds access more light and remove impedance for growth. Moisture content of the soil was maintained all the time by regular watering with industrial bottled drinking water so as to prevent any foreign seed from untreated water.

Data on seedlings emergence was recorded every 7 days for 8 weeks starting from seventh day since incubating date. Each emerged seedling per pot was counted and the number of seedlings per hectare was calculated so as to obtain soil seed-bank density. With the aid of an experienced botanist, identification of germinating plants for botanical composition of the soil seed bank of the area started in 8th week. However, some of the seedlings died before reaching the stage of being identified.

Data Analysis

The data for assessment of vegetation characteristics, productivity and soil seed bank which included vegetation ground cover, dry matter yield, soil seed bank characteristics, soil characteristics, tree density and canopy cover of the communal grazing area were analyzed by means of Microsoft Excel Spreadsheet computer program to generate descriptive statistics including mean, percentage and standard error.

RESULTS

The communally grazing land had ground cover of desirable plants, undesirable plants species, litter and bare soil patches of 67.7±2.71%, 10.5±1.45%, 9.4±0.61% and 12.3±1.54% respectively (Table **1**).

The dominant desirable forage grass species were *Bothriochloa intermedia, Enteropogon macrostachyus, Heteropogon contortus* while doimnant undesirable grass species was *Aristida stipoides.* Undesirable forb species included *Indigofera arrecta* and *Sida acuta* (Table **2**). The dry matter yield of desirable forage species was estimated to be 806.77±29.9 kg DM per hectare.

The tree density was 1500 trees per hectare with the total canopy cover of 63.49%. The most dominant tree species were *Combretum collinum, Comiphora africana* and *Piliostigma thonningii* with densities of 864, 163 and 97trees/ha and canopy cover of 22.6%, 6.2% and 5.4%, respectively (Table **3**).

The soil of the reserved grazing area was sand clay loam with 33.22% clay, 2.82%silt and 62.96%sand. It was slightly acidic with pH ranging from 6.1 – 6.5, moderate bulk density, low organic carbon and low Nitrogen(N), Phosphorus(P) and Potassium(K) (Table **4**).

A total of 9 monocotyledon seedlings species were recorded with a total seed density of 476851 seeds/ha on the other hand 11 dicotyledonous seedlings species with seed density of 138888 per hectare were recorded (Table **5**). The dominant seedlings in monocotyledon were *Aristida stipoides, Dactyloctenium aegyptium and Enteropogon spp* with seed density of 180555, 97222 and 60185/ha respectively. On the other hand the dominant seed species in dicotyledonous were *Mollugo nudicaulis* and *Indigofera arrecta* with seed density of 27777 and 32407/ha, respectively as shown in Table **5**. The seedlings emergence started on 5th day of the soil incubation and some seedlings started dying on 45th day onward before being identified due to shallow soil depth of 3.5 cm.

DISCUSSION

The results of the assessment of vegetation characteristics, pasture biomass and soil seed bank on a continuously grazed land during the dry season

Table 1: Percentage Herbaceous Vegetation Covers in the Continuously Grazed Rangelands at the Study Site in October 2018

Transect lines	Desirable (%)	Undesirable (%)	Litter (%)	Bare soil (%)
1	61.70	13.56	7.58	17.16
2	64.49	12.48	11.20	11.84
3	76.98	5.53	9.56	7.94
Mean	67.72	10.52	9.45	12.31
Standard error	±2.71	±1.45	±0.60	±1.54

Table 2: Frequency of Occurrence and Ground Cover of Different Plant Species in the Continuously Grazed Rangelands at the Study Site in October 2018

Plant species	Plant type	Frequency of occurrence (%)	Ground cover (%)	Grazing Preference
Enteropogon macrostachyus	Grass	33.33	30.17	Desirable
Heteropogon contortus	Grass	25.00	14.50	Desirable
Themeda triandra	Grass	12.50	4.17	Desirable
Bothriochloa pertusa	Grass	12.50	1.39	Desirable
Brachiaria sp	Grass	6.25	0.65	Desirable
Pogonarthria squarrosa	Grass	8.33	1.43	Desirable
Aristida stipoides	Grass	18.75	3.57	Undesirable
Indigofera arrecta	Forb	22.92	4.63	Undesirable
Sida acuta	Forb	16.67	2.32	Undesirable

Table 3: Frequency of Occurrence of Different Tree Species, Tree Density, Crown Cover and Canopy Cover in the Continuously Grazed Rangelands at the Study Site in October 2018

Tree name	Frequency of occurrence (%)	Tree density (tree/ha)	Mean crown cover(m^2)	Tree canopy cover by each species/ha(m^2/ha)	Canopy cover of each specie/ha (%)
Euclea divinorum	4.2	16.3	5.16	84.20	0.84
Combretum hereroense	4.2	16.3	3.78	61.66	0.61
Piliostigma thonningii	12.5	97.8	5.53	541.40	5.41
Dalbegia sp	4.2	48.9	0.95	46.49	0.46
Combretum collinum	87.5	864.1	2.62	2267.44	22.67
Commiphora africana	29.2	163	3.82	624.18	6.24
Acacia nilotica	16.7	81.5	8.69	708.62	7.08
Terminalia seriacea	4.2	32.6	4.43	144.75	1.44
Terminalia brownie	12.5	65.2	1.21	79.51	0.79
Brachystegia bussei	4.2	16.3	5.40	88.18	0.88
Sclerocarya birrea	4.2	32.6	44.17	1440.36	14.40
Combretum schumanii	4.2	16.3	5.95	97.13	0.97
Dicrostachys cinerea	4.2	16.3	4.61	75.26	0.75
Grewia bicolor	8.3	16.3	4.41	72.02	0.72
Rhus natalensis	4.2	16.3	1.11	18.12	0.18
Total		1499.9			63.49

Table 4: Physical and Chemical Characteristics of Soils of the Continuously Grazed Rangelands at the Study Site in October 2018

Parameters	BD(g/cc)	OC (%)	PH	N (%)	P(mg/kg)	K($Cmolkg^{-1}$)
Mean Values	1.40	1.14	6.33	0.09	0.89	0.33
SE±	±0.003	±0.026	±0.035	±0.004	±0.273	±0.02

BD = Bulk density, OC = organic carbon, N = Nitrogen, P = Phosphorus, K = Potassium.

showed that there were high percentage ground cover with desirable pasture species as compared to undesirable pasture species, litter material and bare soil patches. The dominant desirable pasture species components were *Enteropogon macrostachyus, Bothriochloa intermedia* and *Heteropogon contortus* with frequency of occurrence of 33.33%, 29.17 % and 25% and percentage ground cover of 30.17 %, 15.42, and 14.50% respectively. The higher dominance of desirable species such as *Enteropogon macrostachyus* which produces higher forage biomass though less leafy implies that if the rangelands at the study site are properly managed its pasture productivity can be easily increased [12]. In particular, re-seeding with leafy and high nutritious drought resistant forage grasses such as *Cenchrus ciliaris* (buffel grass) and *Eragrostis superba* (maasai love grass) are deemed suitable for improving both rangeland productivity and forage nutritive value [13]. The forage dry matter yield of about 807 kg of dry matter (DM) /ha observed in this study is relatively low compared to 1260 kg DM/ha which was reported in communal rangelands of northern Tanzania [5]. The forage biomass was found to be low in in contrast to the soil fertility indices of the study site that was observed to be relative within the desirable ranges and with pH of 6.3 that is suitable for good performance for most forage plants. On the other hand, informal discussion with the local pastoralists indicated that drought recurrences, bush encroachments and overgrazing have been a growing challenge at the study site. This was attributed to lack of proper grazing management plans including rotational and deferred-rotational grazing practices at the study site.

Also, most likely the pasture dry matter yield per unity area was found to be low due to high tree density of

Table 5: Monocotyledon and Dicotyledonous Soil Seed-Bank Density Characteristics

Monocotyledon	Family name	No. Seedlings/ha	Pasture type	Life form
Brachiaria spp	Poacea	13888.9	Desirable	Perennial
Dactyloctenium aegyptium	Poacea	97222.2	Desirable	Annual
Echinochloa colona	Poacea	41666.7	Desirable	Annual
Aristida stipoides	Poacea	180555.6	Undesirable	Perennial
Bothriocloa pertusa	Poacea	32407.4	Desirable	Perennial
Enteropogon macrostachyus	Poacea	60185.2	Desirable	Perennial
Panicum spp	Poacea	27777.8	Desirable	Perennial
Leptocarydion vulpiatrum	Poacea	18518.5	Undesirable	Annual
Digitaria velutina	Poacea	4629.6	Desirable	Annual
Total		**476851.9**		
Dicotyledon				
Commelina spp	Commelinaceae	9259.3	Desirable	Perennial
Mollugo nudicaulis	Commelinaceae	32407.4	Unedible	Annual
Tridax procumbens	Asteraceae	9259.3	Unedible	Annual
Indigofera arrecta	Fabacea	27777.8	Unedible	Annual
Portulaca oleracea	Portulacaceae	13888.9	Unedible	Annual
Abutilon indicum	Malvaceae	4629.6	Unedible	Annual
Borreria pusilla	Rubiaceae	9259.3	Unedible	Annual
Vernonia cinerea	Asteraceae	4629.6	Unedible	Annual
Solanum incunum	Solanaceae	4629.6	Unedible	Annual
Senna tora	Fabaceae	13888.9	Unedible	Annual
Malvastrum coromandelianum	Malvaceae	9259.3	Unedible	Perennial
Total		**138888.9**		

1500 trees per hectare and canopy cover of 63.49% under continuously grazing practice. This is thought to have affected pasture species composition and dry matter productivity in various ways. The dominant tree species were *Combretum collinum, Comiphora africana* and *Piliostigma thornningii* with tree density of 864, 163 and 97 trees/ha, respectively. High woody plant cover in the grazing land is known to reduce grass cover and dry matter yield production [14].

Regardless of high tree density, canopy cover and bare soil patches in some areas, the soil sample taken from the bare soil patches showed relatively high germinable soil seed bank with seed density of 476,851 monocotyledon and 138,888 dicotyledonous seeds per hectare and comprised of 9 and 11 plant species, respectively. Most seeds in the soil seed bank were of annual grasses, undesirable and un-edible annual forbs with very few perennial forage grasses. This may have been attributed by anthropogenic activities such as overgrazing and shifting cultivation. Continuous grazing system which is practiced at the study site's communal rangelands seems do not allow the desirable perennial grasses to reach seeding stage of growth. In addition, shifting cultivation and heavy grazing have been reported to cause disturbances to grassland ecosystems which affect negatively the size and composition of grasses in the soil seed bank [15]. Heavy grazing causes removal of immature reproductive plant parts leading to low soil seed bank and thus low recovery of the palatable vegetation and change in pasture species composition of the grazing land [16].

The seedlings compositions from the current soil seed bank indicated low grazing potential of the site because of prevalence of many annual grasses, undesirable and inedible annual forbs. Rangeland improvement practices including re-seeding, over-sowing and planned rotational grazing can improve soil seed-bank

and eventually the condition of degraded rangelands [17].

CONCLUSIONS

The results of this study shows that the tropical sub-humid rangeland site under continuous grazing had high percentage ground cover of desirable pasture species compared to undesirables and bare ground patches. The bare ground patches had high soil seed bank densities which was mainly composed of annual grasses and forbs. Seeds of few perennial grasses and several undesirable and un-edible annual forbs were recorded in the grazing land soil seed bank taken in the dry season. The dry matter yield during the dry season was rather low due to high tree density and high tree canopy cover which could have affected the photosynthesis process, growth and dry matter production of the understory herbaceous vegetation during the previous wet season.

From these results it can be recommended that rangeland sites under continuous grazing system should have a regular biotic and abiotic resources inventory. This is deemed essential so as to direct its improvement programmes such as selective bush clearing to reduce the tree density and canopy cover to about 20% in order to allow pasture to access adequate light for growth and increase pasture biomass production. Nonetheless, further research on a large scale involving rangelands under different ecological zones and management regimes such as cattle ranch areas and wildlife protected areas is recommended.

ACKNOWLEDGEMENT

We thank Sustainable Agriculture Tanzania (SAT) for funding this study and pastoralists at the study site for providing enormous support during field surveys. This paper is part of the first author's Master of Sciences research work at the Sokoine University of Agriculture, Tanzania.

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