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Research Paper

Ecological implications of bush encroachment on foraging behavior of dairy cows and goats at SUA farm, Morogoro, Tanzania

Implicaciones ecológicas de la colonización de especies leñosas en el comportamiento del pastoreo de vacas y cabras lecheras en SUA Farm, Morogoro, Tanzania

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Abstract

The study was carried out at SUA Magadu Farm to investigate the influence of bush encroachment in a native rangeland on foraging behavior and grazing distribution of dairy cows and goats. Characterization of bush in terms of woody density was done using the PCQ method. A mixture of animals (150 cows and 60 goats) were rotationally grazed on areas with 3 different levels of bush encroachment (dense - 60%; moderate - 35%; and open grassland - ≤5%) and grazing behavior of 3 cows and 3 goats was monitored. Six trained observers recorded behavior of these animals for 2 hours in the morning and 2 hours in the afternoon for 9 days on a rotational basis. There were significant interactions between animal species in terms of grazing behavior and level of bush encroachment. Both species spent similar amounts of time grazing on open grassland (>75% of total feeding time) but on treatments with moderate and dense bush encroachment levels goats spent at least 70% of their time browsing, while grazing time of cows did not change. Goats took many more bites than cows on all treatments and as a result spent more time walking than cows. The implications of these findings for management of bush encroachment are discussed. Further studies on nutritive values and chemical composition of key forage species in the study area are recommended as well as the changes in behavior with different seasons and the impacts on animal production.

Keywords: *Acacia* spp., bite rate, feeding, focal observation, spatial distribution.

Resumen

En el SUA Magadu Farm, Morogoro (37°39' E, 06°05' S; 500–600 msnm), Tanzania, se evaluó el efecto de la colonización de especies leñosas (sobre todo *Acacia* spp.) en el comportamiento del pastoreo de vacas y cabras lecheras en un pastizal nativo compuesto por una diversidad de gramíneas de variable utilidad forrajera. Las lecturas de la densidad de especies leñosas (matorrales) se hizo utilizando el método PCQ. Para el efecto, se empleó un grupo de animales compuesto por una mezcla de 150 vacas y 60 cabras que pastaron en forma rotacional en áreas con 3 niveles diferentes de densidad de vegetación leñosa (denso - 60%, moderado - 35% y campo abierto - ≤5%). Se escogieron al azar 3 vacas y 3 cabras para la toma de datos por 6 observadores entrenados, quienes registraron el comportamiento de estos animales durante 2 horas en la mañana y 2 horas en la tarde por un período de 9 días en forma rotatoria. Los resultados mostraron interacciones (P<0.05) entre las especies animal en términos de comportamiento del pastoreo, y la densidad de las especies leñosas. En campo abierto tanto las vacas como las cabras permanecieron períodos similares de tiempo pastando (>75% del total de tiempo usado para pastoreo más ramoneo); por otra parte, en los niveles moderados y densos de vegetación leñosa las cabras permanecieron al menos 70% de su tiempo ramoneando, mientras que el tiempo

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de pastoreo de las vacas no cambió. Las cabras tomaron un número muy mayor de bocados que las vacas en todos los tratamientos y consecuentemente pasaron más tiempo caminando que las vacas. Se discuten las implicaciones de estos resultados para el manejo de las especies leñosas en pastizales. Se recomiendan estudios sobre el valor nutritivo y la composición química de las especies forrajeras más importantes en el área de estudio, así como sobre los cambios en el comportamiento de pastoreo en función de la época de año y su impacto en la producción animal.

Palabras clave: *Acacia* spp., distribución espacial, observación focal, pastoreo, tasa de bocado, vegetación leñosa.

Introduction

Over the past 50 years the semi-arid savanna ecosystems throughout the world have suffered severe bush encroachment (Britz and Ward 2007; Kambatuku et al. 2011), which is associated with the reciprocal competitive interaction between trees and grasses (Kambatuku et al. 2011). Although bush encroachment is associated with heavy grazing pressure by livestock (Tefera et al. 2007), wildfire and effects of climate change (O'Connor and Chamane 2012), the ecological implications are poorly understood. Many studies, e.g. Ward (2005) and Tefera et al. (2007), suggested that bush encroachment reduces grazing capacity through suppression and replacement of palatable grasses and herbs by encroaching woody species, which often are unpalatable to domestic livestock, resulting in reduced carrying capacity. The decrease in grazing capacity has significant ecological and sociological implications because semi-arid savanna ecosystems in Africa are home to a large proportion of the world's human population, including many pastoralists, whose livelihoods are threatened by this process (Gowing and Palmer 2008).

Interestingly, woody plants are normally not considered when estimating carrying capacity of grazing land, despite their importance as a cheap source of fodder for ruminants (Moleele 1998). Knowledge of the ruminant-woody plant interaction is most important for appropriate management of livestock and vegetation, particularly in semi-arid savanna ecosystems (Thomas and Twyman 2004). Moleele (1998) hypothesized that animals normally respond to harsh conditions by modifying their grazing behavior to meet their nutritional requirements. Therefore, understanding the consequences of increasing bush encroachment on foraging behavior of dairy cows and goats is imperative for determining effective management strategies. To understand the ecological implications of woody encroachment on livestock performance and carrying capacity of rangeland, quantitative data on woody plant density and distribution in relation to how grazing animals respond to bush encroachment are required. Currently, there is limited information on foraging behavior of both dairy cows and goats in these situations, particularly how they respond to spatial heterogeneity following bush encroachment.

Animal distribution on rangeland has ecological implications in terms of nutrient extraction and ecosystem impact. For example, uneven distribution of grazing animals can threaten ecosystem health by exacerbating processes of deterioration such as soil erosion (Bailey et al. 1996). Most rangeland resources are heterogeneous due to a combination of biotic and abiotic factors and therefore rangeland utilization is rarely uniform (Vermeire et al. 2004). Encroachment of bush or weeds, poor distribution of water resources and frequency of burning normally result in a patchy distribution of forage resources, which strongly influences animal grazing behavior.

Increases in livestock populations in Tanzania have been associated with changes in composition of vegetation from grassland to woodland (Wiskerke et al. 2010). Currently, Tanzania is ranked second in terms of livestock population in Africa with 25 M cattle, 16.7 M goats and 8 M sheep (MLFD 2015). Over-utilization of rangeland resources in parts of the country has resulted in transformation of previous grassland ecosystems to dense woodland, accompanied by poor production of the herbaceous layer (Selemani et al. 2013a). The predominant woody plants in most rangelands in Tanzania are *Acacia* spp., which may reflect overgrazed land, as *Acacia* trees have the ability to tolerate heavy grazing pressure and thrive well in degraded rangelands (Tefera et al. 2007). The shift from grassland to woodland ecosystems should have ecological implications, particularly for grazing animals, in terms of behavioral responses, grazing distribution and utilization of available resources. Information regarding the impacts of vegetation change on behavioral responses of different classes of livestock is crucial for sustainable livestock production and rangeland management.

The current study was undertaken to: 1) assess the influence of different levels of bush cover on foraging behavior of dairy cows and goats; and 2) determine the effects of bush encroachment on grazing distribution of dairy cows and goats. The study hypothesized that accessibility of fodder on areas with heavy bush encroachment is restricted for foraging animals and thus affects stock distribution, method of foraging and choice of type of forage.

Methodology

Description of study area

The study was conducted at SUA Magadu Dairy Farm about 5 km from Morogoro Municipal (37°39' E, 06°05' S; 500–600 masl). Average annual temperature in the region is 18 °C but sometimes reaches 30 °C in the lowland river valleys. Rainfall is bi-modal, averaging 600–900 mm per annum (Paavola 2004). Short rains often occur in November–December, followed by a short dry period in January–February, with heavy rain normally falling in March–May and a long dry season in June–November. The agro-ecological zone of Magadu Farm is low mountainous country below the slopes of Uluguru Mountain and the common vegetation is a mixture of grassland and woodland. The study area has increasingly become populated by woody plants, largely dominated by *Acacia nilotica*, *A. seyal* and *A. tortilis*. The dominant desirable native grass species are *Urochloa mosambicensis*, *Bothriochloa pertusa*, *Cynodon nlemfuensis*, *C. dactylon* and *Hyparrhenia* spp., while the common undesirable grasses are *Sporobolus* spp. However, useful originally planted grass species such as Napier grass (*Pennisetum purpureum*), Rhodes grass (*Chloris gayana)* and buffel grass (*Cenchrus ciliaris)* are also present. The farm is heavily infested with notorious invasive species, noted species being *Lantana camara* and *Solanum incanum*, which are quite prevalent in bushland. Soils of the study area are primarily sandy (12% clay, 4% silt and 84% sand) with pH of 6.6, 0.12% total N, 46.2 mg available P/kg and 0.61 mg K/g (Kizima et al. 2014). The common livestock on the farm are cattle, goats, sheep and horses.

Research design and sampling procedures

Prior to behavioral observations, a vegetation survey was conducted to characterize the status of woody en-+croachment in SUA Magadu Farm. The Point Centered Quarter (PCQ) method of Cottam and Curtis (1956) was used to estimate woody density and percentage crown cover. The farm was stratified into 3 subplots (approx.-imately 40 ha dense bush, 45 ha moderate bush and 50 ha open grassland) based on the extent of woody encroachment from visual observation. In each subplot 2 diagonal transect lines were established. Along transect lines, the cross-points (with 4 quarters) were marked at 50 m intervals, the nearest woody species were identified from each quarter and their distances from the center were measured. In addition, crown diameter of each identified woody species was recorded. Finally, absolute woody density and percentage crown cover of each subplot were estimated. Absolute density (λ) is defined as the number of trees per unit area and is calculated as: $\lambda = 1/r^2$, where r = mean quarter distance obtained by dividing sums of all quarter distances by number of trees sampled. The λ is easily estimated per square meter so λ is multiplied by 10,000 to express as number of trees per ha (Mitchell 2007; Volpato et al. 2010). Areas of individual trees were calculated and percentage cover was computed by comparing total areas of subplots and total areas covered by trees as described by Mitchell (2007).

The behavioral observation study was carried out between the end of the short dry season and the onset of the heavy rainy season in March 2017. Despite spatial variation in production of the herbaceous layer following bush encroachment, growth rates of grasses and herbs during the rainy season are generally superior to those in the dry season (Kizima et al. 2014). For the behavioral study we used focal observation procedures as described by Martin and Bateson (2007). Six focal animals, 3 Friesian dairy cows and 3 Toggenburg dairy goats, were randomly selected from the groups of 150 cows and 60 goats for behavioral observation. Friesian dairy cows and Toggen-burg goats were studied because of their significant economic contribution to Tanzania's dairy industry (Njombe et al. 2011). All selected focal animals were ear-tagged for ease of identification in the field during observations. All animals (150 cows and 60 goats) were rotationally grazed as a group (dense bush, moderate bush and open grassland) with a full grazing cycle occupying 9 days (3 days per subplot). All animals were housed at night and in the middle of the day and allowed to graze only during 08:00–12:00 h and 14:00–17:00 h. Six trained observers were responsible for recording the behavioral activities exhibited by the focal animals. Observations were continued for 2 hours in the morning and 2 hours in the afternoon each day for 3 days consecutively for each subplot. To reduce the influence of bias by individual observers, observers were allocated a different focal animal each day. The parameters recorded included time spent (in seconds) in different behavioral activities, e.g. grazing, browsing, walking, ruminating, idling and other. Observa-tions were carried out for 5 minutes followed by a 5 minute break, giving 50% of actual observation and another 50% for recording parameters. An animal was considered to be idling when standing or lying without feeding or ruminating. Other parameters recorded were: number of bites, number of patches visited and number of feeding stations. A patch was defined by aggregation of forage species, where an animal initiates grazing before reorienting (moving) to another location, and a feeding station was distinguished by a given head position without moving the feet (Adler et al. 2001).

Statistical analysis of data

The Proc Mixed Model of SAS (2004) was used to analyze the fixed main effects of bush cover (thick bush, moderate bush and open grassland), livestock species (cows and goats) and the two-way interaction effect of bush cover x animal species. Observers, days and residual were treated as random effects in this model while individual animal's measurements (ID) were tested as repeated measures within different bush levels. Treatment differences were separated using the Least Squares Difference (LSD) as described by Montgomery (2001). For spatial distribution of animals the General Linear Model of SAS (2004) was used to analyze the main effects of bush cover and animal species and interaction effects of bush cover x animal species. The contrasts of the least square means (lsmeans) of the interactions were calculated and tested with the F test at 5% probability. Prior to statistical analysis, the distribution of data for dependent variables was checked using the Anderson-Darling test under proc in SAS (2004) and data were normally distributed.

Results

Range inventory using the PCQ method established that the absolute densities of woody plants (trees/ha) in thick bush, moderate bush and open grassland were: 608 ± 60.4; 355 ± 60.4; and 50.6 ± 60.4 trees/ha, respectively. The corresponding values for percentage crown cover for thick bush, moderate bush and open grassland were: 60; 35; and 5%, respectively. More than 70% of woody species in the study area were *Acacia* spp. dominated by, in descending order, *Acacia nilotica*, *Acacia tortilis* and *Acacia seyal*. Other woody species were: *Harrisonia abyssinica, Kigelia africana, Dichrostachys cinerea, Senna siamea, Leucaena leucocephala* and *Combretum* spp.

There were significant interactions between bush level and livestock species in terms of foraging behavior as shown in Table 1, although there was obviously some degree of dietary overlap between grazers (cows) and browsers (goats). Grazing was the major activity for cows in all situations and for goats in open grassland, while browsing was the main activity for goats in moderate bush and less so in thick bush. While goats spent the same amount of time grazing as cows in open grassland, they spent much less time grazing than cows in moderate bush with thick bush intermediate, spending significantly more time browsing in areas with significant bush encroachment than dairy cows. In contrast, cows spent slightly more time browsing in open grassland than in bush treatments. Total time devoted to grazing plus browsing by dairy cows was 15% longer on open grassland than on bush treatments, while goats spent 18% more time in these activities when on the bush treatments.

The study recorded a significantly higher number of patches and feeding stations in thick bush and open grassland than in moderate bush, while the number of bites was inversely proportional to bush density (Table 2). Goats visited more patches, had more feeding stations and took twice as many bites as cows (Table 3).

Goats spent little time browsing within a single patch, tending to move quickly to the next patch, especially in open grassland and thick bush (Figure 1A), and maximized bite rate in moderate bush (Figure 1B).

Table 1. The interaction between bush level and livestock species for foraging behavior.

Bush-Livestock		Mean time (seconds) spent per activity for each 5 minute observation period					
		Grazing	Browsing	Walking	Ruminating	Idling	Other
Open grassland	Cows	179.1a[1]	59.7c	18.0d	26.5a	10.9b	6.16b
	Goats	176.4a	38.8e	79.3a	2.23d	0.56c	2.27c
Moderate bush	Cows	157.9b	52.6d	28.9c	20.9b	21.1a	19.8a
	Goats	81.2d	182.5a	32.9c	0.26d	0.00c	1.23c
Thick bush	Cows	154.0b	51.3d	58.2b	15.2c	12.5	8.16b
	Goats	119.2c	146.2b	33.2c	0.00d	0.00c	1.36c
s.e.		2.98	1.88	2.11	1.74	1.46	1.08

[1]Values followed by different letters within columns are significantly different at P<0.05.

Table 2. The effect of bush cover on numbers of patches, feeding stations and bites per 5-minutes interval.

Treatment	No. of patches	No. of feeding stations	No. of bites
Open grassland	13.7a[1]	31.6a	98.2a
Moderate bush	11.3b	27.8b	94.4b
Thick bush	13.6a	30.9a	87.5c
s.e.	0.26	0.72	0.91
P value	0.001	0.004	0.001

[1]Values followed by different letters within columns are significantly different at P<0.05.

Table 3. Number of patches, feeding stations and bites for cows and goats per 5-minutes interval.

Animal species	Number of patches	Number of feeding stations	Number of bites
Cows	6.0	18.6	63.8
Goats	19.8	41.6	122.9
s.e.	0.21	0.59	0.74
P value	0.001	0.001	0.001

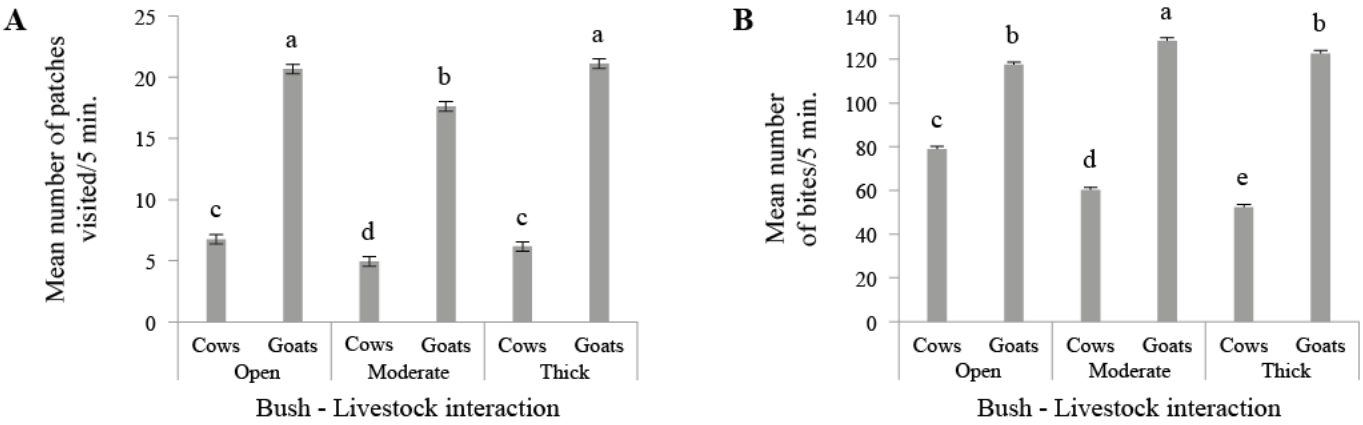

Figure 1. Effect of bush-livestock interaction on: **A)** number of patches; **B)** number of bites.

Discussion

The pattern of declining grazing time as bush density increased is probably associated with changes in herbaceous vegetation because woody encroachment is normally accompanied by decrease in herbaceous production and undesirable shifts in vegetation composition (Tefera et al. 2007). Transformation of grassland to woodland creates sub-habitats which differ from open grassland and hence exert different influences on grazing behavior. Cattle normally prefer grazing on open grassland because of their inherited grazing abilities, morphological and physiological adaptation and security against predation (Coughenour 1991; Bailey et al. 1996; Selemani et al. 2013b). It was interesting that, on open grassland with minimal browse available, time spent grazing by cows and goats was similar, but where there was adequate browse available, goats displayed their preferred habit of spending much more time browsing and actually spent as much time browsing on the moderate bush treatment as they did grazing on open grassland. While cows compensated for the reduced herbage available in bush treatments by limited browsing, their overall feeding time (grazing plus browsing) was reduced, while goats actually increased their overall feeding time where there was adequate browse available.

It was of interest that the highest browsing time by goats was in moderate bush cover. The significant differences in browsing time between moderate and thick bush could be due to differences in growth stage and maturity of woody plants as well as accessibility of browsable materials in these treatments. Thick bush consisted of largely mature, taller trees such as *Acacia nilotica*, and goats had difficulty accessing the foliage as it was often beyond their reach, while moderate bush contained accessible young sprouting leaves following recent bush clearance. According to Illius et al. (1999), selection of plant species and plant parts normally relates to nutritional value and digestibility of the

material, taking into account the growth and maturity stage of particular plants. Cows and goats are highly adapted to grazing and browsing, respectively, due to their body morphological structure and digestive ability. However, the notable dietary overlap between goats (browsers) and cows (grazers) in the open grassland was associated with an acute shortage of browsing materials with both species spending more than 75% of the time grazing. The type of vegetation, forage availability and season normally affect foraging behavior of ruminants (Selemani et al. 2013b) as was displayed on the moderate bush plots where cows continued to spend 75% of the time grazing, while goats spent 70% of the time browsing. Free-ranging animals tend to trade-off between quality and quantity, taking into account the balance between energy gain and energy expenditure. Although the Optimal Foraging Model (OFM) predicts that animals tend to select the best forage species of highest nutritional value (Merritt Emlen 1966), constraints other than forage quality can limit animal selectivity (Feasta-Beanchet 1988). Forage availability can also affect foraging behavior independent of quality and therefore dietary overlap is more pronounced during acute shortage of forage (Selemani et al. 2013b).

Animal foraging behavior or perceptions of a resource pattern is largely determined by the relative consistency in assemblage of the plant populations (patchiness) that are clustered in response to soil type or pattern of disturbance (Senft et al. 1987). A patch is defined as spatial aggregation of bites over which instantaneous intake rate remains constant (Baumont et al. 2000). Variations in patch structure, nutritive value and species composition influence selectivity and amount of time animals spend within a particular patch. The significantly higher number of patches in thick bush and open grassland compared with moderate bush possibly reflects differences in nutritive value and vegetation structure. Both open grassland and thick bush most likely provided inadequate forage resources that forced foraging animals to select many patches to satisfy their nutritional requirements. For example, open grassland was dominated by grasses such as *Urochloa mosambicensis*, *Bothriochloa pertusa*, *Cynodon nlemfuensis* and *Hyparrhenia* spp., which naturally tend to have low digestibility and low crude protein at the end of the short dry season. Mwilawa et al. (2008) pointed out that in semi-arid regions natural pastures are characterized by low nutritional value when mature, which native species normally achieve very rapidly. On the other hand, higher numbers of patches in thick bush could be attributed to poor accessibility and tree maturity. There is growing evidence that diet selection is largely regulated by physical structure rather than nutritive value of particular tree species (Bryant et al. 1991). The thick bush was colonized mainly by *Acacia* spp. with defensive thorns and spines. According to Rooke (2003), more closely spaced thorns and spines restrict movement of animals and hence reduce accessibility of forage. Therefore the lower number of bites in thick bush as established in the current study might be associated with plant physical attributes rather than chemical defense mechanisms because higher concentrations of secondary compounds are more pronounced in younger shoots than in mature ones (Rooke 2003), which would be the case in moderate bush.

The higher preference for woody vegetation shown by dairy goats over dairy cows has also been observed in other studies (Celaya et al. 2007; Selemani et al. 2013b). In addition, goats spent little time browsing within a single patch and tended to move quickly to the next patch, especially on open grassland and thick bush. According to the OFM, differences in foraging abilities among animals are a result of natural selection (MacArthur and Pianka 1966; Merritt Emlen 1966; Pyke 1984). Goats have significantly higher inherited foraging ability than cattle and are more efficient at selecting a high quality diet and maximizing energy intake within a high quality patch or landscape (Gordon 2003; Goetsch et al. 2010). Goats probably maximized bite rate in moderate bush in preference to other subplots due to availability of high quality browse as discussed earlier. Goats are able to survive harsh conditions due to their unique dietary selection (Pfister and Malechek 1986), as there is a close relationship between foraging behavior and survival fitness (Pyke 1984). Survivability of goats is a function of their high ability to select from within available forage and to utilize a wide range of ecological habitats.

Conclusions and Recommendations

The study has shown that the degree of bush encroachment had a significant influence on foraging behavior of dairy cows and goats. Transformation of grassland to woodland created sub-habitats which differ from open grassland, and total time spent grazing plus browsing by dairy cows was reduced by about 12% on areas with significant bush encroachment. Interestingly, time devoted to browsing in each case remained constant at about 25% of total time devoted to browsing plus grazing. Unless the quality and quantity of forage available on the different treatments varied markedly, production levels might be expected to decline slightly on bush areas for cows. On the other hand foraging behavior of goats changed dramatically as amount of bush encroachment increased. Depending on the quality and quantity of

browse available, production could be affected considerably by level of bush encroachment. In the absence of information on effects of different bush encroachment levels on performance of the two species, it is not possible to state whether or not cows should preferentially be run on grassland and goats on areas invaded by shrubs. Studies are needed not only to determine what impacts there might be on production levels from the various treatments but also to measure availability of herbage and browse on the different treatments as both quantity and quality affect performance. As both goats and dairy cows lactate, it would be easy to measure milk yields since are highly sensitive to feed intake. Further studies are needed to provide information on these particular aspects and also how patterns might change with the various seasons and availability and quality of grass/herbage versus browse differs. Further studies on nutritional composition and phytochemical analysis of key forage species in the study area are recommended.

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