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The effects of cattle-goat mixed grazing on steer performance and rangeland condition in semi-arid north eastern Botswana

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MNF, collected data & analysis, statistical analysis, preparation of manuscript; MSW, Conceived idea, designed study, collected data, preparation of manuscript; MK, designed study, collected data, preparation of manuscript

ABSTRACT

Cattle and goats mixed grazing trial was carried out at Impala Research Station from January 2007 to October 2010, to determine the influence of different combinations of cattle and goats ratio on the performance of cattle as well as herbaceous basal cover in a mixed Mopane bushveld in north-eastern, Botswana. Treatments of cattle to goat ratios used were 0:0 (control), 0:1, 1:0, 1:1, 2:1, and 3:1 at a stocking rate of 12Ha/LSU in respective paddocks. A total of 51 Tswana male cattle weaners and 75 male and female Tswana goats were used and allowed to graze continuously for 18 months covering both wet and dry seasons after which steers were replaced by other set of weaners. Only steers were weighed every 4 weeks after feed and water had been withheld overnight. Overall there was no significant difference ($P>0.05$) in growth between the steers in different paddocks for the two batches of animals used. However, there was a significant difference in steer growth between grazing ratios 1:0, 1:1, 2:1 and 3:1 during the dry season ($P<0.05$) for both batches. There was a significant increase ($T = -8.71$, $P < 0.00$) in poor grass species in all the paddocks, a significant decrease ($T = 2.48$, $P < 0.05$), in litter for ratios 1:0, 1:1 and 2:1 as well as significant decrease ($T = 3.60$, $P < 0.05$), in bare ground for grazing ratios 0:1, 1:1 and 3:1 between 2007 and 2009. There was also a significant increase ($T= -7.56$, $P <0.05$) of total covers from 2007 to 2009. Cattle to goat grazing ratios 2:1 and 3:1 showed high weight gains in steers compared to steers in grazing ratios 1:0 and 1:1. The study shows that mixed grazing gives an advantage on complementary use of pasture resource by different livestock species especially during resource limited periods.

Keywords: Herbaceous basal cover, mixed grazing, steer performance, Tswana steer, Tswana goat

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INTRODUCTION

Livestock farming contributes significantly to the economy of Botswana and the people as a whole (Mphinyane 2002). Since grazing forms the basic and cheap feed resources for livestock farmers, most farmers, especially of beef cattle, are tempted to increase their herds. As such rangelands have very high numbers of livestock. Overstocking coupled with frequent droughts results in substantial degradation of vegetation cover, soil erosion and subsequent loss of biodiversity, as well as reduced carrying capacity. Mixed grazing of animals that are ecologically dissimilar is one option to reverse degradation, improve range condition and productivity as well as carrying capacity and animal performance. Since herbivore species sharing a rangeland may directly or indirectly interfere with the food resources for each other and could alter each others' foraging behaviour, mixed grazing has some ecological influences (McNaughton 1976, De Boer and Prins 1990, Prins and Olff 1998, Makhabu, *et al*., 2006). Interspecific competition and facilitation may take place between herbivore species sharing a rangeland but on the other hand they might not affect each other's performance (McNaughton 1976, Hulbert and Andersen 2001, Makhabu 2005, Makhabu *et al*.,2006). The use of rangelands by two species, one predominantly being a grazer and the other predominantly being a browser, might result in a balanced use of feed resources, resulting in reduced habitat degradation, density and architecture of unwanted plants (Sweet and Mphinyane 1986, Olson *et al*., 1999, Du Plessis *et al*., 2004). Economically, the advantage of this system is that the producer can improve the cash flow and reduce risks due to diversified production (Holechek *et al*., 1989, Du Plessis *et al.,* 2004). One of the biological ways that may control bush encroachment is the use of browsing animals, and the use of goats have been promoted in southern Africa (Sweet and Mphinyane 1986, Du Plessis

et al., 2004). The use of goats as a biological control of bush regrowth following other treatments has also shown good results in reducing Gambel oak sprouts in Colorado (Davis *et al*., 1975), by suppressing woody species. The use of pasture resources by two species, however, does not necessarily lead to the improved animal output on both species as observed by Kitessa and Nicol (2001), who attributed this to vegetation species diversity, stocking rate, animal ratio and choice of substitute animals.

In some parts of Botswana *Acacia* species are invading once-open areas and are reducing the space available for grasses. Also, some farmers practice cattle and goat mixed grazing system but it is not known what cattle to goats ratio gives the best results in terms of animal performance and vegetation condition.The objective of this study was therefore to determine the influence of different combinations of stocking ratios of steers and goats on steer performance in a mixed Mopane bushveld, as indexed by weight changes. The effect of different stocking ratios on basal cover of the herbaceous layer was also investigated.

MATERIALS AND METHODS

Study site

The study was conducted at Impala Ranch (21°08′ – 21°11′ S, 21°35′ -27°37′ E) about 7 km east of Francistown, Botswana. The area is generally flat with an altitude of about 1020 m above sea level. The rainfall is seasonal falling mainly between November and April. The mean annual rainfall is about 630 mm. A sketch map of the ranch is shown in Figure 1. The area is classified as mixed Mopane bushveld. The main grass species include *Panicum maximum*, *Urochloa mosambicensis Aristida congesta, Bothriochloa insulpta, Eragrostis rigidior, Enneapogon scoparius, Schmidtia pappophoroides and Brachiaria nigropedata.* Woody plant species include; *Colospermum mopane Dichrostachys cineria*, *Acacia* species, *Grewia flava* as well as *Combretum apicalatum*. A number of forbs are also present. The soils are classified as haplic lixisol, a typical sodic type and characterized by clay (FAO 1991).

Rainfall and temperature

Rainfall at Impala was relatively high in 2006 and 2007 compared to 2008 (Figure 2). No rainfall was recorded from July to September 2006, April to August in 2007, and from June to September 2008. The long term rainfall pattern for Francistown shows that there is usually no rainfall in July with little amounts received in May, June and August. The area only experience good rains in the months of November, December, January and February. The long term temperatures ranged between 23 and 35 degrees Celsius (Figure 2).

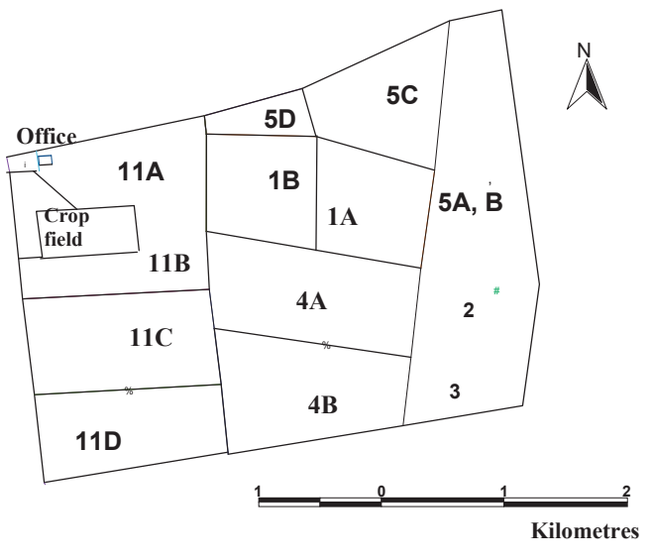

Figure 1: Map of Impala Research Station showing paddocks used and their sizes.

Experimental design

Six paddocks were used, for the trial involving 6 treatments of cattle to goat ratios of 0:0 (control), 0:1(goats only, 1:0 (cattle only), 1:1, 2:1, and 3:1 respectively (Figure 1, Table 1) at a stocking rate of 12Ha/LSU (1.667 steers taken to be equal to 1 LSU because at 18 months they are expected to be around 270 kg while 6 goats were taken to be equal to 1 LSU). LSU assumed to be an animal that weighs 450 kg. The treatment ratios are number of LSU contributed by cattle to number of LSU contributed by goats. Tswana weaner steers 7 – 12 months old and 18 months old Tswana goats (male and female) were selected. Fifty one weaners and 75 goats were used and distributed as shown in Table 1 and were allowed to graze continuously all year round. All animals were supplemented with Di-calcium Phosphate (DCP) and salt at 2:1 ratio, while water was supplied *ad libitum*. Husbandry practices included control of common diseases and parasites by vaccinations, deworming as required in routine management of livestock in Botswana.

Data collection

Steer performance

Steers were weighed every 4 weeks after withholding feed and water overnight. Steers remained in paddocks for 18 months and were then replaced with other set of weaner steers. Goats were used continuously for the duration of the study. Animals which remained in paddocks between January 2007 and July 2008 are referred in the study as batch 1, and those that remained in paddocks between September 2009 and October 2010 are referred in the

study as batch 2. The study was carried out from 2007 to 2010.

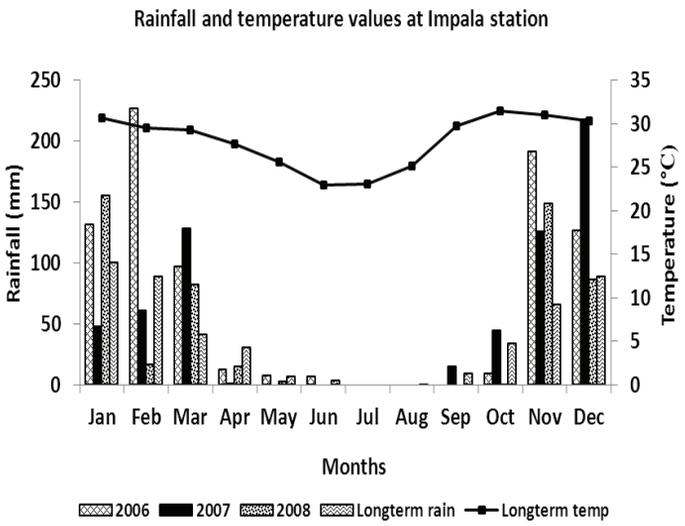

Figure 2: Rainfall and temperature for Impala Research Station from 2006 to 2008 and long-term for Francistown

Table 1. Treatment ratios and number of animals stocked at 12 ha/LSU

Treatment (LSU)		Animal No		Land available	
Cattle	Goats	Cattle	Goats	Paddock	Area (ha)
1	0	23	0	4A	168
1	1	8	30	5C	121
0	1	0	15	5D	30
2	1	9	17	1B	103
3	1	11	13	1A	107
0	0	0	0	5A, 5B	283

Vegetation

In each paddock, three randomly placed 30 m x 10 m plots were used. The wheel-point method (Tidmarsh and Havenga 1955) was used to determine the botanical composition and basal cover of the sward during the months of February and September for wet and dry season data collection. The clipping method was used to collect herbaceous layer samples in randomly placed 1m^2 quadrats just outside the plots, to avoid interference with steer activities (Cook and Stubbendieck, 1986). Clipping was done at 2 cm above ground level to simulate cattle grazing level, separated by species and then analysed at the Soil and Plant Analytical Laboratory, Sebele, Botswana. The samples were oven dried at 60°C for 96 hrs to determine Dry Matter (DM), ground and analyzed for Phosphorus (P) by measuring absorption at 670.0 nm wavelength of UV visible recording spectrophotometer, Calcium (Ca) using Atomic Absorption Spectrophotometer Method, Crude Protein (CP) by macro-Kjeldahl technique, neutral detergent fibre (NDF) and acid detergent fibre (ADF) following Van Soest, (1982) and *in vitro* true digestibility (IVTD) following Tilley and Terry (1963).

Statistical Analysis

Data were subjected to MINITAB statistical software version 14. A one way analysis of variance (ANOVA) was used to determine influence of different stocking ratios on steer performance and basal cover. Where significant differences existed, means were separated using Tukeys comparison Test. Spearman's rank correlation coefficient (r_s) was applied to determine the correlation between rainfall and weight change. Regression analysis was used to determine influence of rainfall on herbaceous cover and nutrient quality which affects steer weight gain. The student *t*-test was used to test if there was significant differences in species cover between 2007 and 2009 in different grazing ratios. All tests were considered significant at $P<0.05$ level.

RESULTS

Steer performance

There was no significant difference ($P > 0.05$) in weight of steers between the grazing ratios in the first batch. When the data were separated into dry (May to October) and wet seasons (November to April), the mean weights (401.8 kg and 404.6 kg) for grazing ratios 1:0 and 1:1 respectively were significantly lower than the mean weights (431.7 kg and 445.0 kg) for grazing ratios of 2:1 and 3:1 respectively ($F= 13.76$, $R^2= 83.76$, $P < 0.05$) for the first batch of animals. There was also no significant difference ($P > 0.05$) in weight of steers between the grazing ratios in the second batch. The dry season mean weights (516.4 kg and 521.2 kg) for grazing ratios of 1:0, and 1:1 respectively, were significantly lower than the mean weights (557.4 kg and 560.2 kg) for grazing ratios 2:1 and 3:1 respectively ($F= 19.58$, $R^2= 74.60$, $P < 0.05$). The average daily weight gains (ADG) of the steers in the first batch were 0.38kg/d for ratio 1:0, 0.41kg/d for ratio 1:1, 0.43kg/d for ratio 2:1 and 0.51kg/d for ratio 3:1. The average daily weight gains (ADG) of the steers in the second batch were 0.43kg/d for ratio 1:0, 0.43kg/d for ratio 1:1, 0.48kg/d for ratio 2:1 and 0.46kg/d for ratio 3:1. During the dry season grazing cattle from ratio of 1:0 was affected more and lost more weight compared to the other ratios (Figure 3 and 4).

Herbaceous composition

There was no significant difference in basal cover between different grazing ratios. There was however, a significant increase (T = -8.71, P < 0.05) in poor grass species (especially *Aristida congesta*) for all ratios, but a significant decrease (T = 2.48, P < 0. 05) in litter for ratios 1:0, 1:1 and 2:1 as well as significant decrease (T = 3.60, P < 0.05) in bare ground for ratios 0:1, 1:1 and 3:1 between 2007 and 2009 (Table 2.). There was also a significant difference (T= -7.56, P < 0.05) between total herbaceous covers for 2007 and 2009. Good grass species coverage increased for grazing ratios of 2:1 and 1:0.

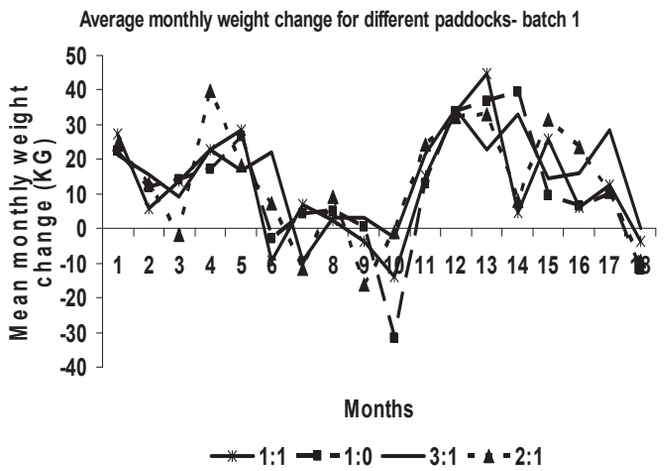

Figure 3: Average monthly weight change for batch 1 (start month is January 2007).

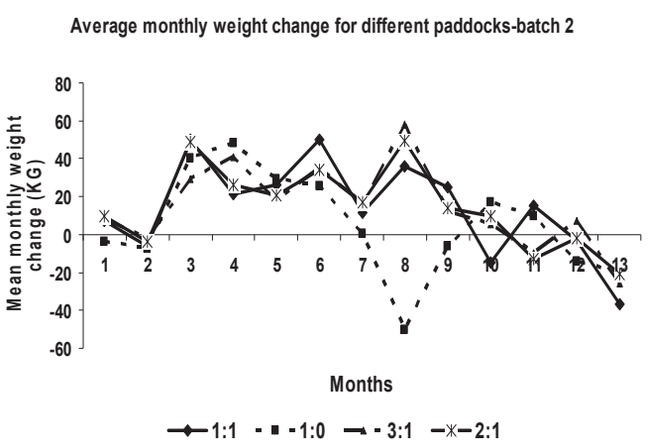

Figure 4: Average monthly weight change for batch 2 (start month is October 2009).

During comparison of grass species between grazing ratios for 2007, P was found to be significantly high in grazing ratio of 2:1 for *Bothriochloa insculpta*, *Eragrostis rigidior*, *Enneapogon scoparius*, *Panicum maximum* and *Schmidtia pappophoroides*. P was significantly low in grazing ratio 1:1. DM was significantly high in grazing ratio of 2:1 for *S. pappophoroides* and ratio 3:1 for *Panicum maximum*, but significantly low in ratio 1:1.

ADF and Ca were significantly high in grazing ratio of 2:1and 1:1, respectively, for *B. insculpta,* whereas Ca was significantly low in ratio 2:1 (Table 3)
There were significant differences in CP, NDF, IVTD, ASH and ADF (P < 0.05) between grasses in March 2007 (Table 3), whereas DM was not different. For the macro-minerals, Ca was significantly different among grasses although P was not different. *P. maximum* had the highest Ca at 37% while *A. congesta* had 16%. The Ca: P ratios in the results were ranging from 2:1 to 4:1 for 2007.

Comparing grass species between grazing ratios for 2008, revealed significantly high NDF in grazing ratio of 0:1 for grass species *S. pappophoroides*, but significantly low in ratio 2:1. The nutrition values for other grass species were not significantly different between grazing ratios.

There was a significant difference in CP between species (Table 4) while there were no differences for DM, ADF, NDF, and IVTD between grasses in 2008. For the macro-minerals, Ca was significantly different between grasses while P was not different. *P. maximum* had highest Ca (34%) while *Melinis repens* had the lowest at 18%. The Ca: P ratios in the results were ranging from 3:1 to 4:1 for 2008.

There was positive a correlation between the weight change in the first batch for 3:1 grazing ratio and the longterm rainfall pattern for Francistown. Weight change increased with increasing rainfall. There was also negative correlation between the grazing ratios of 2:1 and 3:1 for the second batch and long-term rainfall for Francistown. Weight change decreased with increasing rainfall.

Weight change in grazing ratio 3:1 for the second batch, was affected by IVTD and NDF combined (Table 5). Weight change for grazing ratio 2:1 was affected by ASH and IVTD combined

DISCUSSION

Animal performance

The overall weight gain was not significantly different between different grazing ratios, maybe, because a conservative stocking rate of 12ha/ LSU was used. However during the dry season when there was limited forage, cattle grazing together with goats gained more weight compared to those grazing alone.

Table 2: Botanical analysis of different grazing ratios expressed as percentage basal cover for years 2007 (1) and 2009 (2)

Total basal cover, basal cover of forbs, litter, good and poor grasses by grazing ratio

Year	Variable	0:1	1:0	1:1	2:1	3:1
1	Total cover	37.23[a]	19.66a	26.56a	36.47a	34.23a
2	Total cover	67.04[b]	51.04b	42.71b	73.08b	55.15b
1	Good	14.36[a]	8.43a	15.63a	6.47a	10.33a
2	Good	17.32a	22.4b	15.63a	15.38b	11.34a
1	Poor	20.21a	8.43a	5.21a	22.35a	17.39a
2	Poor	46.93b	22.4b	21.88b	49.45b	35.05b
1	Forb	2.66a	2.81a	5.73a	7.65a	6.52a
2	Forb	2.79a	6.25b	5.2a	8.24a	8.76a
1	Litter	22.34a	41.57a	41.15a	38.24a	29.89a
2	Litter	15.08a	13.02b	23.44b	7.69b	29.38a
1	Bareground	38.29a	25.84a	27.08a	17.06a	30.43a
2	Bareground	18.99b	33.85a	30.21a	19.23a	11.34b

NB: Different letters between pairs in the same column denotes means that are significantly different (P<0.05).

Table 3: Nutritional and mineral composition (%) of some dominant grasses 2007

Species	P	Ca	CP	NDF	ADF	ASH	ADL	DM	IVTD
A. con	0.1200[a]	0.16556a	6.424b	72.896c	42.398b	8.176a	4.919a	95.017a	45.848b
B. ins	0.10286[a]	0.20714a	4.863a	73.616d	41.013a	10.396b	4.999a	94.979a	41.176a
E. rig	0.09333a	0.19778a	4.849a	76.304d	44.783c	8.158a	5.482a	94.132a	39.203a
E. sco	0.06857a	0.25429b	5.217a	75.201d	46.257c	10.053b	6.361a	95.579a	39.459a
P. max	0.12000a	0.37250c	6.619b	72.058c	42.405b	11.249b	4.945a	95.038a	47.657b
M. rep	0.10500a	0.27833b	5.678a	71.908c	42.170b	9.033a	4.963a	95.008a	50.643b
S. pap	0.11125a	0.28875b	5.515a	72.664c	42.876b	9.055a	4.780a	95.475a	46.139b

[abc] denotes column means that are significantly different (P<0.05).*Aristida congesta* (A. con)*, Bothriochloa insculpta* (B. ins)*, Eragrostis lehmanniana* (E. leh), *Eragrostis rigidior (*E. rig)*, Enneapogon scoparius (*E.sco)*, Panicum maximum (*P. max), *Melinis repens (*M. rep)*, Schmidtia pappophoroides (*S. pap),and *Urochloa mosambicensis (*U. mos)*,*

Table 4: Nutritional and mineral composition (%) of some dominant grasses 2008.

Species	P	Ca	CP	NDF	ADF	DM	IVTD
A. con	0.07172[a]	0.22027b	5.0185ab	82.71a	51.793a	89.80a	52.920a
B. ins	0.06829[a]	0.22514b	4.1710b	72.99a	43.127a	92.81a	50.266a
E. rig	0.06890a	0.19800b	3.8304c	69.05a	43.367a	93.79a	44.298a
E. sco	0.05475a	0.22500ab	4.8368ab	75.78a	47.345a	93.88a	45.215a
M. rep	0.06233a	0.18233b	4.3623ab	77.79a	48.810a	93.37a	49.723a
P. max	0.08600a	0.34200a	5.7053a	73.82a	43.805a	93.01a	51.185a
S. pap	0.07371a	0.23214ab	4.5279ab	72.98a	44.489a	93.67a	50.869a

[abc] denotes column means that are significantly different (P<0.05). *Aristida congesta* (A. con)*, Aristida stipitata (A. stip), Bothriochloa insculpta* (B. ins)*, Eragrostis rigidior (*E. rig)*, Enneapogon scoparius (*E.sco)*, Melinis repens (*R. rep)*, Panicum maximum (*P. max) and *Schmidtia pappophoroides (*S. pap)

Table 5: Regression analysis on one or two independent variables on mean weight and coefficient of determination for the whole year

Grazing ratio	independent variable	b^1	b^2	r^2	P-VALUE
3:1	IVTD+ NDF*	-0.787	0.29	67.6	0.002
3:1	IVTD	-1.03	-	48.0	0.004
2:1	IVTD	-2.03	-	71.5	0.038
2:1	IVTD+ ASH	-2.02	1.79	71.6	0.034

*IVTD = in vitro true digestibility, NDF = neutral detergent fibre

This might be because cattle are predominantly grazers, thus during the wet season more of the grass biomass is utilised and there are low pasture reserves left for the dry season. In contrast when there are less numbers of cattle, there will be more reserves for dry season. Abaye *et al.* (1994) reported that there was no difference in weight between cattle grazing alone and those grazing with sheep. Abaye *et al.* (1994) also observed that at the start of the growing season, pastures with cattle only had excess forage but at the end of the growing season forage mass was at the lowest. This agrees with the present results and this, coupled with low nutrition in grasses, is likely to be the reason why cattle at 1:0 and 1:1 ratios lost weight during the dry season. During the following wet season, the malnourished cattle then had compensatory growth when the forage availability and quality improved. This shows that cattle performance is adversely affected by low nutrition. Animut *et al.,* (2005) and Silanikove (2000) established that compared to goats and sheep, cattle are affected by nutrient deficit due to lower capacity in nitrogen recycling.

The average daily weight gain for the first batch was highest in grazing ratio of 3:1 followed by ratios 2:1 and 1:1 in that order, which could be attributed to available grass in mixed grazing compared to mono grazing. The average daily weight gain was highest in 3:1 grazing ratio suggesting that not only is mixed species grazing important, but the number *per* species used should also be equal or not very different, which was also reported by Kitessa and Nicol (2001) and Gonzales–Montagna *et al. (*2005). Gonzales–Montagna *et al.* (2005) reported a balance between efficiency and grazing pressure in mixed grazing of heifers and ewe lambs, with 53% being lambs. In the second batch the highest average daily gain was in grazing ratio of 2:1 followed by 3:1 and 1:1 respectively. Factors affecting average daily gain observed during the wet and dry seasons were mainly the decrease in forage nutrition and/or biomass. In the present results, cattle in

grazing ratio of 2:1, with 65% goats, had performance similar to 3:1 or better.

Animals with a diet of 10% CP and 45% dry matter digestibility can gain 0.5 – 0.6 kg *per* day (McDowell 1972). Cattle in grazing ratio of 3:1 for the first batch were able to gain in the above mentioned range, despite CP values of all the grasses being lower. Even though cattle can browse during times when grass biomass is low (Moleele 1998), the area being predominantly *Mopane* woodland does not provide a lot of nutrients (Moleele 1998). Dry *Mopane* leaves contain less than 9% CP which is not enough to maintain live weight in dry season. Aganga and Mesho (2008) also pointed out that browse can only provide 2.95 – 5.31 MJ ME kg^{-1}DM while the maintenance of cattle is 6.02 MJ ME kg^{-1}DM.

Herbaceous composition

There was a significant increase in poor species in all grazing ratios but a significant increase in good grasses in grazing ratios of 2:1 and 1:0. This may be because cattle grazed mature sward and encouraged tillering of those good species.

Rainfall amounts can bring out different responses on different grass species. Fynn and O'connor (2001) found that heavily tufted perennial grasses like *B. insculpta* and *Panicum* species increased under moderate rainfall and grazing, which was the same case with the present study. There was an increase in forbs in the paddock where cattle grazed alone because there were no goats which normally consume more forbs compared to cattle. The present results are similar to that of Hayes and Holl (2003) who compared cattle in grazed and ungrazed areas. Cattle may open up areas where they graze thereby increasing sunlight availability to ungrazed forbs improving their growth vigour (Damhouureyeh and Harnett 1997). An increase in forbs could also mean that the paddock had high disturbance and was in a poor condition. In 2008 phosphorus ranged from 0.06 to 0.1% which is below cattle maintenance requirement of 0.12%. Phosphorus and calcium are important in animal growth and weight gain with a critical ratio Ca: P of 2:1 (Kallah *et al.,* 2000). The present results fall within the recommended tolerance range ratio of 1:1 to 7:1 (Kallah *et al.,* 2000), as well as the critical ratio. However, Di-calcium phosphate was used as supplement. Calcium requirements for ruminant diets in the tropics are in the range of 0.17 to 0.77%, and the current results fall within the range except for *A. Congesta* which is considered a poor grass.

Steer weight increased with increasing rainfall in grazing ratio of 3:1 for the first batch. This has been reported by Fynn and O'connor (2001) that rainfall affects nutrition which in turn affects weight.

In the second batch, grazing ratios of 3:1 and 2:1 steer weights reduced with an increase in long term rainfall patterns. The reduction in animal weight during high rainfall found in this study, have also been reported by Fynn and O'connor (2001), who observed a quadratic relationship between rainfall and weight gain *per* hectare. Increased grass growth changes leaf to stem ratio which reduces forage intake, hence the negative impact on weight gain (Fynn and O'connor 2001). Warm temperatures are good for plant growth; high rainfall could affect the grazing of animals, hence resulting in low weight gains (Pitt and Heady (1978).

NDF consists of cellulose, hemicelluloses and lignin. Lignin affects the digestibility of grasses especially at mature stage, which means the higher the lignin the lower the digestibility. When there is more rainfall, NDF is lower (Pitt and Heardy 1978, Kallah *et al.* 2000) as in the present study; NDF for 2007 was lower than 2008. The average daily gain for grazing ratio 3:1 in the second batch might have been affected by lignin and digestibility, which would suggest that the animals could have gained more weight. The grazing ratio of 2:1 might have been affected by ASH and IVTD. Digestibility played a role, while the gain also was affected by amount of organic matter consumed, however dry matter intake estimation was not done. Due to lower rain in 2007 and 2008 in the area as well as high temperatures in 2008, forage was stressed and maybe reached maturity quickly, or dried quickly, and had high NDF value and lower digestibility (Kallah *et al.* 2000).

CONCLUSION

The grazing ratio of 3:1 and 2:1 has shown better performance than other ratios in the mixed grazing trial. There was higher average daily gain (ADG) recorded in the grazing ratios for both batches. There was also an increase in good species in grazing ratio of 2:1. The study shows that mixed grazing gives an advantage on complementary use of pasture resource by different livestock especially during resource limited periods.

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Conflict of interest: None

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