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Full Length Research Paper

Investigating the effects of different grazing ratios and stocking rate of cattle and goats under mixed-species grazing on different plant species

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The study focused on investigating the effects of different grazing ratios and stocking rate of cattle and goats under mixed species grazing on different species of plant. The experimental site was Matopos Research Station farm in Zimbabwe. This study was confined to the commonest grass species and forbs at the experimental site. Treatments spanned a period of eight years; from 1999 to 2007. Generally, heavy goats stocking rate resulted in low productivity of browse biomass while heavy cattle stocking rate resulted in low herbaceous biomass productivity. The present results do not support existence of a linear relationship between herbaceous biomass productivity and annual rainfall. Rather, a quadratic relationship existed, suggesting that there might be other factors in addition to rainfall that accounted for biomass productivity. Grazing ratios and stocking rate of cattle and goats, year and their interactions affected the productivity of plant species in the rangeland. Finally, farmers are encouraged to practice mixed-species grazing at an optimal grazing ratio of 4 cattle and 36 goats per 20 ha of rangeland.

Key words: Mixed-species grazing, stocking rate, grazing ratio, cattle, goats, biomass.

INTRODUCTION

The greatest opportunity of sustainable agriculture in the semi-arid areas of Zimbabwe and the world exists through mixed farming systems (Lebbie et al., 1993; Jones, 2002; Walker, 2002). Over the past century, rangelands have been progressively stressed by over use, the infringement of cultivation, urbanization and infrastructure development, in addition to the recent unfavourable land redistribution policies in Zimbabwe. The world's rangeland can be a valuable, low cost and sustainable source of high quality animal proteins and micronutrient and, as such, an important resource in the fight against hunger and malnutrition if properly managed and utilised (Anderies et al., 2002). Rangeland can be fully utilised through multi-species grazing hence the need for a viable grazing ratio that cannot lead to its under-utilisation and over-utilisation (Donaldson, 1979; Aucamp et al., 1984; Prosser, 1995). Mixed species grazing has received little research attention, despite the fact that most communal and small-scale commercial farmers in Zimbabwe graze cattle and goats together. Goats and cattle have different targets regarding dietary preferences and grazing behaviour when exposed to rangeland. Besides both being herbivores, cattle prefer grass and goats prefer shrubs, forbs and tree leaves. Multi-species grazing exploits the complementary aspects

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of these dietary differences (Vallentine, 1990; Prosser et al., 1997; Schauer et al., 2006). The main and fundamental objective of multi-species grazing is to improve grazing efficiency or the utilisation of available resources while maintaining and improving animal production (Gambiza and Sikosana, 1989; Dahl et al., 1999; Pratt and Rasmussen, 2001).

The production of goats has been rarely practiced and it is declining despite the importance of goats when it comes to adapting to seasonal changes and meat for small ceremonies. Many farmers have bias towards cattle production neglecting the production of goats. Cattle do not survive well in winter and diseases can easily attack them. Co-production of both animals means they will complement each other. Although literature exists for stocking and grazing ratio models in the United States of America and Europe, very little research in this area has been done in Africa. Model building approach as a tool to support practical decision making at local level relies heavily on indigenous knowledge and flexibility, as required by variable and contingent conditions (Mearns, 1997a, b). According to Coughenour (1991), the general assumptions for model building of stocking rate and grazing ratio are that:

i) The current status of the rangeland vegetation is considered in the context that conservation of each vegetation component can be secured through the application of suitable grazing intensities which will maintain a steady rate of the vegetation dynamics.
ii) The intake of the animal species does not vary for the different vegetation components with grazing pressure.

Cattle prefer grass in all seasons regardless of availability. Based on research conducted on a variety of range types by researchers at North Dakota State University, season long cattle diet averages about 75% grass, 15% forbs and 10% shrubs or browse. Cattle will consume some forbs early in the season, but generally avoid most shrubs regardless of season. Goats are more opportunistic, and will graze a greater variety of plants in all seasons. Most studies show a preference for forbs early in the season and shrubs late in the season, while grass consumption can vary significantly depending on the availability of other preferred species (Prosser, 1995; Prosser et al., 1997; Pratt and Rasmussen, 2001; Owen et al., 2005; Schauer et al., 2006). The key to effectively using multi-species grazing lies in understanding the dietary and behavioural differences between cattle and goats, recognizing seasonal variation, and properly monitoring and managing the range to balance the grazing pressure and prevent potential problems like carrying capacity deficiencies and inefficient stocking rates. A number of methods have been suggested in the literature for assessing the carrying capacity in grazing systems. These include comparative analysis of different areas, production consumption predictions and simple population dynamic models (Pratt and Rasmussen, 2001).

Other factors such as rainfall and soil fertility reportedly determine peak biomass for grazing opportunity (Rutherford, 1978; Penning de Vries and Djiteye, 1982; Wagenaar and de Ridder, 1985; Prince and Astle, 1986; de Leeuw and Nyambaka, 1988). It is generally accepted that multi-species grazing is a very important aspect of sustainable livestock production. However, with respect to goats and cattle, the precise interactions for optimal grazing ratios and stocking rates, as well as impacts of these factors on different species of plants in a rangeland are yet to be studied. The principal aim of this study therefore was to assess the effects of different grazing ratios and stocking rates on different species of plant in order to develop a model for mixed grazing of cattle and goats in relation to the available biomass, in the semi-arid areas of Zimbabwe. The outcome of this study is anticipated would help optimise mixed grazing regimes for cattle and goats, and provide understanding regarding the complexity of factors that affect biomass productivity in rangeland simultaneously grazed by these two groups of livestock.

MATERIALS AND METHODS

Experimental site

The experimental trial was conducted at Matopos Research Station farm located in the semi-arid areas of Zimbabwe. The semi-arid areas of Zimbabwe usually receive low to medium rainfall and high maximum temperatures ranging from 27 to 32°C thus rendering the place suitable for ranging. The site is at an altitude of 1416 m with a mean annual rainfall of 600 mm which usually falls between October and April. Marked fluctuation in rainfall brings about corresponding fluctuations in herbage production from year to year. The land is characterised by clay soil (red and black), thorn acacia species and other shrubs in the browse layer, while the field layer is composed of perennial grasses with occasional annuals. A brief description of the area and its dominant vegetation has been documented (Ward et al., 1979; Maposa et al., 2010). The commonest grasses are *Themeda triandra*, *Heteropogon contortus*, *Cymobopogon plurinodis*, *Eraglostis* species and *Digitaria ternata*. Only these common species and forbs were considered for analysis in this study.

Experimental design

The experiment was conducted using five different treatments namely five different cattle and goat combinations (Table 1). The study was run uninterrupted for eight consecutive years, that is, from 1999 to 2007. A total of 360 indigenous breeding does (*Matabele* goats) of stratified age groups were used. All goats were mated in May and June to kid once a year. Indigenous cattle, either *Tuli* or *Nkone* breeds were used. Steers were used in this experiment. This is because steers are easy to control, rarely change their behaviour and are not aggressive. In each treatment group there were two age groups, young weaners and old weaners in equal proportions. The old weaners were slaughtered each year and replaced by young weaners. The farm was divided into 10 paddocks of 20 ha each. Due to the variability in the paddocks, a Randomised Block Design (RBD) was chosen with five treatments and two replicates. Three stocking rates (which is the number of animals per unit area per unit of time) namely, 2.4, 2.8 and 3.3 ha/livestock unit (LU) of five steer:goat ratios (8:12, 8:36, 4:36, 4:60

Table 1. Cattle and goats' combinations and stocking density.

Treatment no.	Treatment (description of animal stock)	Cattle	Goats	Ha/LU	LU/20 ha
1	Heavy cattle / light goats	8	12	3.3	6.0
2	Heavy cattle / medium goats	8	36	2.4	8.4
3	Light cattle / medium goats	4	36	3.3	6.0
4	Light cattle / heavy goats	4	60	2.4	8.4
5	Medium cattle / medium goats	6	36	2.8	7.2

LU = 500 kg live weight.

and 6:36) were used (Table 1). Livestock unit (LU) is usually 500 kg live weight. Each paddock had 24 plots of 20 by 10 m and each plot had 6 randomly selected quadrates which were 1 m by 50 cm. All the dominating species of plant in every quadrate were clipped at ground level or 5 cm above ground and then dried and weighed. This was done in late wet season where the effects of treatments could be realized.

Rainfall data was also collected at the experimental site to give the annual average rainfall over the period of the experiment.

Statistical techniques

Three statistical techniques were used in the analysis namely:

i) Simple linear and multiple regression models.
ii) Analysis of covariance: A technique that combines ANOVA with the principle of regression analysis.
iii) Repeated measures (within- subject analysis).

All the three techniques have widely been used and are well documented in many textbooks and articles (Mead, 1989; Chaterjee and Price, 1991; Neter et al., 1996; Montgomery, 2004). Regression models were developed for herbaceous biomass (dependent variable) and mean annual rainfall (explanatory or independent variable). In the repeated measures analysis time (year) was regarded as a split unit factor. This aspect of the experiment helped in addressing how the effects of treatments on different species of plants vary with time. Repeated measures are a class of mixed models where fixed effects are the treatments and random effects are time (year) effects. In repeated measures analysis of variance, the effects of interest were:

i) Between-subject effects (year)
ii) Within-subject effects (treatment)
iii) Interactions between the two types of effects (treatment*year).

Data analysis for this experiment was done using statistical packages namely GENSTAT and MINITAB as well as Microsoft Excel.

RESULTS

The results from GENSTAT and MINITAB as well as Microsoft Excel spreadsheet output are presented here. Figure 1 presents results for the average biomass productivity per treatment. Generally, the browse biomass per hectare was always lower than the herbaceous biomass due to the fact that the area under investigation is mainly suitable for cattle ranching. Results show that light cattle stocking rate (4:36), treatment 3, resulted in a higher production of herbaceous biomass. On the other hand, light goat stocking rate (8:12), treatment 1 resulted in the highest browse biomass production. The lowest herbaceous and browse biomass productivity was experienced in paddocks where heavy goat (4:60), treatment 4 was used. Table 2 presents results of simple linear regression models for herbaceous biomass and annual rainfall. The results showed insufficient evidence to support the existence of a linear relationship between herbaceous biomass and annual rainfall for all the treatments at the 5% level of significance (p-value > 0.05). Table 3 presents results of quadratic regression models for herbaceous biomass and annual rainfall. The results in Table 3 showed overwhelming evidence of highly significant quadratic relationship between herbaceous biomass and annual rainfall for all the treatments (p-value < 0.001) over the period of the experiment. The R-square values for all the treatments for the quadratic models are greater than 95% implying that more than 95% of the variability in herbaceous biomass is accounted for by annual rainfall in the quadratic models. A summary of results on the effect of treatments on different plant species is given in Table 4. The results in Table 4 indicated that both the treatment factor and the split unit factor (time) have significant effects on the productivity of *Themeda triandra*, *Heteropogon contortus*, *Cymobopogon plurinodis* and *Eraglostis* species. Time factor has significant effect on 'forbs' while treatment factor has no significant influence on the production of 'forbs'. However, both treatment and time factors have no significant effect on the productivity of *Digitaria ternata*.

The interaction of treatment and time has significant effect on *H. contortus*, *C. plurinodis* and forbs. However, the interaction of treatment and time has no significant effect on the production of *T. triandra*, *Eraglostis* species and *D. ternata*. It is clear from Table 4 that the productivity of *D. ternata* species is independent of treatment factor, time and their interaction.

DISCUSSION

The lack of a simple linear relationship between herbaceous biomass and annual rainfall is opposed to the results found in Kenya and Northern Tanzania (de Leeuw and Nyambaka, 1988) and West Africa (Penning de Vries and Djiteye, 1982; Wagenaar and de Ridder, 1985). The disparity may be attributed to the bimodal

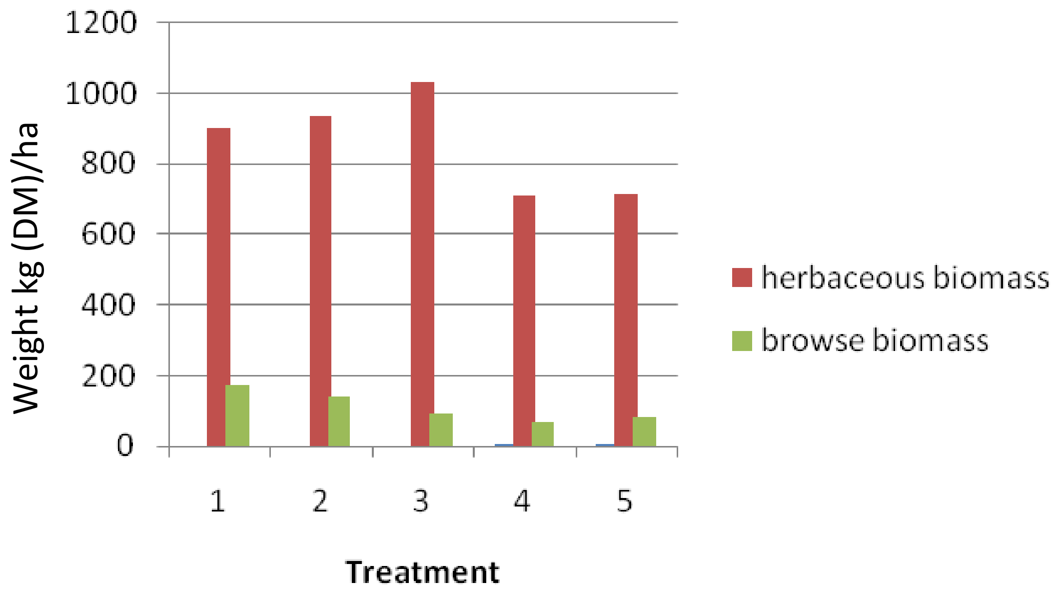

Figure 1. Average biomass productivity per treatment.

Table 2. Simple linear regression models for herbaceous biomass and annual rainfall.

Treatment no.	Beta coefficient (β_1)	Coefficient of determination (R^2)	P-Value
1	2.028	0.527	0.065
2	4.780	0.544	0.058
3	1.548	0.370	0.147
4	4.848	0.534	0.062
5	3.671	0.531	0.063

Table 3. Quadratic regression models for herbaceous biomass and rainfall.

Treatment no.	Beta coefficient (β_1)	Beta coefficient (β_2)	Coefficient of determination (R^2)	P-Value
1	122.0	-23.27	0.981	< 0.001
2	281.1	-53.61	0.992	< 0.001
3	125.1	-23.97	0.951	< 0.001
4	287.9	-59.92	0.983	< 0.001
5	217.5	-41.50	0.975	< 0.001

Table 4. Summary of results for analysis of variance from the repeated measures technique.

Plant specie	Treatment (p-value)	Time (p-value)	Time*Treatment (p-value)
Themeda triandra (TT)	0.032**	0.011**	0.303^{ns}
Heteropogon contortus (HC)	0.003***	< 0.001***	< 0.001***
Cymobopogon plurinodis (CP)	0.002***	< 0.001***	0.048**
Eraglostis species (ESP)	0.021**	< 0.001***	0.339^{ns}
Digitaria ternata (DT)	0.332^{ns}	0.052^{ns}	0.533^{ns}
Forbs (FB)	0.081^{ns}	0.041**	0.046**

Key: **, *** and ns indicate significant at 5%, highly significant at 1% and non-significant respectively.

annual rainfall and higher soil fertility in Eastern Africa. The explanation for this disparity in West Africa is still unclear. However, the significant quadratic relationship between herbaceous biomass and annual rainfall is similar to findings from Northern Tanzania, Kenya and West Africa. The reason for a non-linear relationship between biomass productivity and annual rainfall in Zimbabwe can be attributed to the existence of different plant species in the range which react differently to the amount of rainfall. Some plants perform better with little rainfall while some yield less with excess rainfall. This is evidenced by a quadratic relationship between the two variables. Those plants which do not yield much under more rainfall usually perform better with little rainfall. The other possible reason for a non-linear relationship between the two variables under all treatments is that, animal consumption does not depend only on its weight but also on the availability of food. When there is excess feeding material, animals also tend to consume more. The productivity of the common grasses *T. triandra*, *H. contortus*, *C. plurinodis*, *Eraglostis* species and forbs were found to be heavily influenced by treatment and time factors and/or their interaction. This could be due to the fact that these plant species are much preferred feeding materials for cattle and goats. The independence on the productivity of *D. ternata* could suggest, though without verification, that it is not a favourite feeding material for both animal species. It was found that light cattle stocking rate (4:36) led to a higher production of herbaceous biomass whereas light goat stocking rate (8:12) resulted in the highest browse biomass production.

The lowest herbaceous and browse biomass productivity was experienced in paddocks where heavy goat stocking rate was used. Similar results of relatively low herbaceous and browse biomass were found for medium cattle and goat stocking rate (treatment 5). This could be attributed to the competition for food in both treatments 4 and 5 resulting from increased number of goats and also to the fact that goats are opportunistic and will graze a greater variety of plants in all seasons (Prosser, 1995; Prosser et al., 1997).

Conclusion

We conclude by encouraging farmers to practice mixed species grazing of cattle and goats with either 4 cattle and 36 goats or 8 cattle and 36 goats on 20 ha of land. The optimal grazing ratio found in this study was 4 cattle and 36 goats per 20 ha of land. Further research should include, but not limited to similar experimental trials in sites with homogeneous conditions in order to solidify the conclusions in Zimbabwe.

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