CHAPTER 1
INFLUENCE OF LIVESTOCK GRAZING WITHIN PIOSPHERES UNDER FREE RANGE AND CONTROLLED CONDITIONS IN BOTSWANA

Introduction and Review of Techniques

1.1 Introduction

Livestock production is extremely important in Botswana's national economy (contributes 4% of the total exports) and remains a priority enterprise in most of the rural economy where 55% of the population derive their income mainly from agriculture because of climatic, soil and vegetation limitations. The climate of Botswana is predominantly semi – arid to arid (Pike 1971), with rainfall confined to the months of October through March. The amount ranges from 250mm in the south – west to over 700mm in the extreme north – west. The high frequency of prolonged dry spells during critical growth periods and extreme localization of storms all combine in various ways to make dry land agriculture and range management a hazardous undertaking.

The soils are predominantly sandy soils of the Kalahari in the central and western zone, and the heavier textured soils of the Molopo catchments in the eastern part of the country. The sub – desert soils form the most extensive group (84%) and includes most of the soils of the Aeolian origin (Bawden & Stobbs 1963). These soils have been described as unproductive, but respond very well to phosphorus, nitrogen and manure (Bawden & Stobbs 1963; Van der Merwe 1949).

The vegetation of the Kalahari area are mainly occupied by T. sericea woodland and low shrubs of G. flava, D. cinerea and B. petersiana. In some areas Acacia erioloba is the dominant woodland. The vegetation of the alluvial and basic complex of the Molopo catchments consist of mainly Acacia mixed woodland. These include a number of local dominants associated with specific conditions. These soils have by far the highest production potential. However, overgrazing in these areas results in bush encroachment. Mopane woodland is associated with high clay soils with a high sodium content and occur extensively on calcrete soils or sand underlain by calcrete (FAO 1990).

There are two types of livestock production system, namely the communal and the commercial production systems. Eighty two percent of the national herd is under communal management systems (unfenced grazing land) and 18% is under commercial management systems (fenced grazing land) (Central Statistics Office 1986). The communal grazing rangeland is thus of major importance in the livestock industry as a whole.

Livestock production in the communal grazing areas is characterized by the integration of grazers (cattle and sheep) and browsers (goats). This has generally been reported to promote more effective utilization of both browse and herbaceous plants (Stuart – Hill & Tainton 1988). It has been assumed that the relative grazing or browsing pressure exerted by livestock affect the competitive balance between the herbaceous and woody plants, and that balance in turn affects the most profitable stocking rate for both browsing and grazing animals (Teague *et al.* 1981; Stuart – Hill & Tainton 1988). Communal grazing systems in Botswana are often based around a central water source (borehole, wells or temporal water pans) around which livestock graze. As livestock numbers have increased over time, a zone of degradation developed around the water source and livestock were forced to travel further searching for better grazing. The concentration of livestock around the water point is a norm and knowledge of soil nutrient distribution, through dung or urine is very important if not essential.

Because of the paucity of information on these facets it is necessary to investigate under both communal and commercial systems the seasonal diets of livestock and the influence of animal concentration around the water points, on range condition and soil nutrient distribution. Knowledge of livestock feeding habits and preferences is also essential for designing effective grazing systems and formulating economical supplementation programs.

Information from such a study would benefit the range users with respect to the competition for different plant species between animals. Such information would also provide a scientific basis for allocating different animal species to specific vegetation types to achieve better and more efficient range utilization or to use the animal to manipulate the vegetation structure and composition. With the development of the new agricultural policy in the livestock sector, this information would also aid in the fencing and water distribution decisions at the existing cattle posts in the communal grazing areas.

1.2 Hypotheses

The main thrust of the investigation is based on the hypotheses that:

- increased concentration of excreta near water points improves the fertility status of the soil and hence potential productivity and nutritive value of forage plants in those areas and hence their relative acceptability.

- frequency or intensity of grazing (correlated with distance from water point) may make species more acceptable because of vegetative and leafy growth with few stems.

- animal species differ in their plant species preference spectrum and that these spectrums may overlap to a greater or lesser extent at different times of the year.

- preference does vary with distance from the water point and that these preferences may be affected by; a) composition of material on offer; b) physiological maturity of material; c) grazing pressure and stocking density.

1.3 Objectives

The objectives of this research are:

1. To compare forage preferences (for different plant species) of cattle, sheep and goats in different seasons and relate this to forage availability and density.
2. To determine the influence of livestock concentration on both vegetation and soil fertility status in the vicinity of the water point.
3. To determine the forage quality through the seasons and to relate this to forage preference.

1.4 A review of techniques used in the study of grazing behaviour of ungulates

The composition of diets selected by domestic ruminants has long been of interest to range and wildlife ecologists (Storr 1961; Van Dyne & Torell 1964). The influence of species selected by ruminants on the dynamics of grassland communities has long been observed and is implicit in the increaser - decreaser classification of species (Weaver & Clements 1935; Dyksterhuis 1949). Information on the preferences of large free roaming herbivores is an important tool in resource management (Hansen & Martin 1973; Scotcher 1979; Holechek *et al.* 1982; McInnis *et al.*1983). Such information can be used in the assessment of nutrient intake of animals and evaluation of forage competition between herbivores.

The most commonly used techniques for estimating diet composition of large ruminants include:, forage utilization, direct observation and microhistological identification of plant material in oesophageal,gut or dung samples. The latter examines plant residues recovered from oesophageal fistulas, stomach or rumen contents and the feaces. Each of these techniques has its own advantages and disadvantages. This has heated the controversy as to which is the most useful in determining the diet of large herbivores (Storr 1961; Stewart 1967; Holechek *et al.*1982; McInnis *et al.*1983).

1.4.1 Forage utilization technique

The forage utilization method is reported to be one of the oldest approaches used to evaluate the diet of grazing animals (Holechek *et al.* 1982). The advantages of this approach include speed and the fact it provides information on where and to what extent the range is being used. When a forage species was used and how often a species was used are, however, questions this method will not answer, unless surveys are repeated at frequent intervals (Daines 1976). The greatest disadvantage with any utilization method is that large losses of plant parts from trampling, weathering, and animals other than those of interest can occur and these can confound the results. Smith & Shandruk (1979) observed that utilization is difficult to detect when grazing is light and when more than one herbivore is present it may not be possible to separate their effects. There are also limited opportunities of observing wild ungulates. However, the use of tamed animals (Cooper & Owen - Smith 1985) can minimize these difficulties but they provide limited and possible unrepresentative samples (Krueger *et al.* 1974; Smith & Shandruk 1979). Studies comparing utilization data with fistula samples were observed to lack agreement (Laycock *et al.* 1972; McInnis 1977). Roos *et al.* (1973) however, demonstrated agreement of data obtained from the wheel point method, as a measure of species utilization, and that of oesophageal fistula samples.

1.4.2 Direct observation technique

This method is known for its simplicity. Minor equipment requirement and ease of use are its major advantages. Difficulties in plant species identification and quantification of how much of a plant was consumed are, however, important problems with the procedure (Pieper 1978). Quantitative information has, however, been obtained from bite - counts and grazing time approaches (Ahmed & Bonham 1982). The time spent grazing each species is quantified and assumed to be proportional to the preference for that species. Wild animals are, however, often difficult to locate and approach closely for accurate observation with the direct observation method. These problems may be reduced by using tame animals (Cooper 1982; Cooper & Owen - Smith 1985), but only one animal can be observed at a time. Krueger *et al.* (1974) mentioned that diet selection is a complex behavioral act that is influenced by several factors such as physiological condition, degree of hunger, topography, other animals present and past grazing experience, all of which influence which, and how much of, plant species is consumed.

1.4.3 Oesophageal fistula technique

The use of oesophageal fistula has been restricted to domestic animals because an easily manageable animal, amenable to frequent handling is essential (Vavra *et al.* 1978). The technique is reported to be the most accurate (Cook 1964; Van Dyne & Torell 1964). However, the following disadvantages associated with the use of the technique have been identified: a) associated surgery; b) fistulated animals are grazed for short time and c) incomplete collection. Other disadvantages associated with the technique, as outlined by Holechek *et al.* (1982), include contamination by rumen contents, high cost and low sampling precision for individual species in the diet.

1.4.4 Faecal technique

The faecal technique is increasingly advocated, to avoid the disadvantages of other methods, for determining the diet of free - ranging ruminants. This method depends on the identification of indigestible cutinized fragments of leaves persisting in the faeces (Hercus 1960; Storr 1961; Stewart 1967; Sparks & Malecheck 1968; Liversidge 1970; Scotcher 1979). Faecal samples can be obtained without intensive animal observation, disturbance of the animal, dense vegetation or topographical hindrances. It allows sampling under natural conditions of any number of animals; the faeces themselves are representative of food selected at different times and over different parts of the animal range (Hansen & Martin 1973; Scotcher 1979; Holecheck *et al.* 1982).

The greatest limitations of the technique are that overall accuracy is a problem (Stewart 1967; Stewart & Stewart 1970; Scotcher 1979; Holechek *et al.*1982); the time required to train technicians and variation in accuracy between technicians (Holechek & Gross 1982). Hansen & Martin (1973) indicated that even if the discerniability of plant fragments is changed by digestion, the magnitude is not generally great enough to destroy the identifying characteristics. Studies by Storr (1961) and Williams (1969) have shown that only a few plant species could not be found in the faeces after they have gone through the digestive tract of a herbivore. The epidermal tissues of forbs were not as easily found in cattle and sheep faeces (Free *et al.* 1970) or in that of the grey rhebuck (Ferreira & Bigalke 1987). During the growing season the faecal analysis method tends to under - estimate the forbs and overestimate the grasses (Vavra *et al.* 1978) in the diet when compared to fistula technique. However, in winter the two methods were found to be comparable. Samples from oesophageas, rumen and faeces of sheep were compared to the actual diet in a study by McInnis (1977). Faecal samples were lower in the composition of forbs (with respect to the contribution) than the actual diet as well as the oesophageal and rumen samples. Not all studies have shown the under estimation of forbs in the actual diet. Hansen & Martin (1973) reported good agreement between composition of ingested and faecal material. Johnson & Pearson (1981) reported high similarity between oesophageal fistula and faecal samples from cattle though there was a tendency for forbs to be under estimated. Most scientists mention that differential digestion of plant species has little or no influence on the proportion of identifiable plant fragments (Free *et al.* 1970; Todd & Hansen 1973; Anthony & Smith 1974;

Dearden *et al.* 1975; Alipayo *et al.*1992). Sanders *et al.* (1980) cautioned that a method for determining grazing animal diet should: a) allow free animal movement and completely natural selection of all available plants regardless of the size of the area, b) allow for diet selection regardless of the terrain c) be equally useful for both domestic and wild animal d) should require minimum animal care and be relatively objective and e) allow identification of each individual plant species consumed. Omphile (1997) indicated that these requirements, laid down by Sanders *et al.* (1980), rule out the use of conventional approaches to diet selection, such as direct observation, forage utilization or oesophageal techniques. Hence, the advocated faecal procedure, which meets the conditions outlined by Sanders *et al.* (1980).

1.5 Forage Availability

Diet composition data alone are not sufficient to explaining the reason for observed diet differences between animal species, or switching of diet through the seasons. A knowledge of the reason why herbivores select the species that they eat is necessary for an understanding of the forage needs of range animals and the underlying basis of composition interaction among them (Hanley 1982). Information on herbage availability and quality is therefore, also essential.

Vegetation analysis is necessary for determining stocking rates; determining changes in range condition and determining the responses to many other treatments (Pieper 1978; Stuart - Hill 1985). There are many techniques available for measuring vegetation condition. Some of these include measuring production, cover, density, abundance and composition of herbage. Each has its advantages and disadvantages and the correct choice depends on the individual situation. The most widely used methods for estimating herbage availability include: a) clipping method, b) indirect method and c) weight estimate methods.

In most parts of Southern Africa primary production is limited to one growing season per year and herbage availability changes throughout the year, mostly through herbivory after its peak production.

1.5.1 Clipping Method

This is the most extensively used method in experimental work where forage production and /or availability is the dependable variable. Although the method is considered the most accurate, it has many drawbacks for administrators, researchers or ranchers, is time consuming and costly. Quadrats or plots of various sizes and shapes have been used for clipping studies depending on the nature of the vegetation being sampled. One important consideration in choosing quadrat size and shape is the perimeter - area ratio (Mueller-Dombis & Ellenberg 1974). A major source is the boundary error, deciding what is inside the quadrate and what is outside; this error increases as the perimeter increases.

1.5.2 Indirect Methods

Since direct clipping of vegetation has many drawback, many indirect methods have been suggested. If some easily measured variable were closely related to production, then once the relationship was established, only the easy measurement needs to be made. Jordaan *et al.* (1991) observed that tuft volumes were highly related to herbage yield and woody plants canopy volumes (Smit 1989) were found to be related to browse yield. The height - weight method seems to be a reliable indirect method for determining utilization of perennial grasses (Cook & Stubbendieck 1986). The problem with the procedure is the construction of height - weight tables which is a tedious work and should be done with consideration of the growth forms of plant species resulting from different sites and climate.

The disc meter has been used as a rapid, and non – destructive method for making accurate estimates of herbage yield (Bransby *et al.* 1977; Bransby & Tainton 1977). The problem associated with this technique is the change in phenological growth stage in pure stands of sward and changes in species composition in mixed swards, which might affect the regression relationship (Bransby *et al.* 1977). The meter should be calibrated frequently to ensure reliable estimates throughout the season. Many indirect methods, when compared with the clipping technique, may be relatively inaccurate owing to operator or environmental factors (Bransby *et al.* 1977; Pieper 1978). Probably the most used indirect method is that of relating rainfall to vegetation production because of high correlation between herbage yield and rainfall (Barnes & McNeill 1978; Field 1978; Pieper *et al.* 1971; Pumphrey 1980). The disadvantage of this method is that several years of data are needed with a wide spread in rainfall data, and data from one site may not be applicable to another site (Pieper *et al.* 1971).

1.5.3 Estimation Methods

Nearly all estimation methods use clipping for comparisons with the estimates. Such estimates may range from an ocular estimate of a whole paddock to an estimate on a small quadrat by species. The double sample method was devised by Pechanec & Pickford (1937) to provide an easy, rapid method for determining range production (Tadmor *et al.* 1975; Ahmed & Bonham 1982). During the use of the method frequent checks (clippings) are made to serve as an adjustment for the estimator. This approach increases accuracy of the estimates (Cook & Stebbendieck 1986; Pieper 1978). The method has been used extensively (Tadmor *et al.* 1975; Barnes *et al.* 1982). The regressions obtained locally range between 0.87 to 0.97. The major advantage of the double sampling procedure is the increased size of sample that may be realized.

1.6 Herbage quality

In the semi - arid environments of Southern Africa the herbivore community often consists of several species of grazers and browsers utilizing a large diversity of plant species. Bouttom *et al.* (1988) mentioned that the abundance of plant species might create a false impression that food sources for animals are plentiful. In some conservation areas, McNaughton (1988) suggested that limited supplies of food, and /or mineral deficiencies in food items, regulate the herbivore population. Food quality is influenced by the concentration of nutrients and by the balance between nutrients required for nutritional sufficiency (O'Reagain & Mentis 1988; Georgiadis & McNaughton 1990) and inhibitory chemicals (Cooper & Owen - Smith 1985). It is known that variations in nutrient content occur between, and within, plant species and that herbivores select their food to obtain a nutritionally balanced diet (Owen - Smith & Novellie 1982; Hardy & Mentis 1986; O'Reagain & Mentis 1988; McNaughton 1988). Some grass species are characterized by high levels of a particular element (APRU 1977), and no single species can accumulate high levels of all nutrients (Georgiadis & McNaughton 1990). The variation in individual mineral concentrations, found among plant species may explain the observation that herbivores tend to diversify their diets (Bouttom *et al.* 1988). Each plant species shows a highly distinctive element profile, distinctions that are maintained between sites and over time. McNaughton (1988) noted that species composition at a given site is of fundamental importance in determining the availability of element to herbivores. He also mentioned that as herbivore activity can radically change species composition, it affect the nutritional content of their diet.

Many studies have reported a high concentration of nitrogen, phosphorus and other nutrients and low concentration of fibre soon after growth resumes at the on set of the rainy season (APRU 1977; Hardy & Mentis 1986; O'Reagain & Mentis 1988). Plant species selection by animals has been shown to be positively associated with the content of protein, potassium and phosphorus but negatively correlated to fibre content (Heady 1964). However, attempts to predict dietary selection on these bases in sheep (Westoby 1974), kudu (Owen - Smith & Novellie 1982), goats and impala (Cooper & Owen - Smith 1985) have been unsuccessful. The latter proponents demonstrated that plant secondary metabolites (tannins) are important determinants of dietary selection among browsers. However, Stebbins (1981) and Coughenour (1985) suggested that plant secondary chemicals in grasses play a relatively insignificant role in the diet selected by grazers. Plant structure, percentage leaf, tuft diameter, leaf canopy and tensile strength of leaves has been found to influence diet selection (Theron & Booysen 1966; Gammon & Roberts 1978; O'Reagain & Mentis 1988).

The mineral content of forages is generally a reliable index of the ability of forages to meet the mineral requirements of animals. In wildlife studies it was observed that the spatial distribution of wild animals was a result of mineral content of forages; particularly phosphorus, sodium and magnesium(McNaughton 1988). Pienaar *et al.*(1993) mentioned that it is possible to predict the performance of grazing animals given a certain level of available forage of particular quality in any livestock management enterprise.

1.7 Structure of the Thesis

The goal and specific purposes of this thesis have been stated in the subsequent sections. It is hoped this thesis will prove useful not only as a thesis but also as a reference for livestock graziers, range technicians / or scientists and land administrators responsible for livestock water point (boreholes) allocation. This thesis is divided into four parts. The first part (chapter 1) serves as an introduction to give the reader the background information on livestock production systems in Botswana and those factors limiting production. The chapter also overviews the most frequently applied techniques when sampling vegetation and livestock diets. Part two (chapter 2) presents the characteristics (climatic, soils, and livestock units) and experimental design of the study area. Part three (chapter 3) focuses on the soil texture and nutrition and has been written to reflect the changes in the concepts of animal as agents in redistributing soil nutrients through their dung and urine. The final part (chapters 4 –8) deals with vegetation available biomass, its quality and utilization by livestock. The interrelationships between soil – plant – animal are indicated to facilitate an understanding of what plants do, how this influences animals, how animals can utilize and manipulate plants.

The order of chapters reflect my own bias about the sequence of topics in general range management. In developing what I have found to be an effective topic sequence, I have also attempted to make chapters sufficiently independent so that their order of presentation can be easily modified.