CHAPTER 3

Influence of livestock concentration at water points on the distribution of soil nutrients along the distance from water point

3.1 Introduction

Soils, along with climate, are indicated as the primary agents in plant selection through evolutionary change (Brady 1974; Barbour *et al.* 1980). In general, finer textured soils are reported to have greater porosity than sandy soils (Brady 1974; Siderius 1972). Water moves into and drains out of sandy soils with much greater ease than finer textured soils, which means that sandy soils are more permeable than fine textured soils.

A sandy soil carries less organic matter than finer textured soil. This is probably because of the lower moisture content and greater oxidation occurring in lighter soil (Brady 1974). On the other hand the clay fraction acts as soil nutrient storage and improves the water holding capacity. Clay particles and colloidal organic matter within the soil are negatively charged on their surfaces. Brady (1974) reported that the capacity of these particles to provide the primary soil nutrient storage results from a) the negative charge on the particles and b) their very large surface to volume ratio. Cation exchange capacity is a measure of the number of negatively charged sites on soil particles that attract exchangeable cations, that is, positively charge ions that can be replaced by other such ions in the soil. The factors that strongly influence the cation exchange capacity of a soil are the type of clay content and the humus content.

Typically soils exhibit pH values that range from 4 - 8, although certain soils may have higher or lower values. A pH of less than 6.6 is considered an acid soil. Nutrients are both brought from subsoil by plants and then deposited with litter on the surface. Grasses tend to use more bases, and grasslands often prevent the soil pH dropping (Barbour *et al.* 1980). The effect of soil pH on nutrient availability is of particular importance. The availability of nutrients such as nitrogen and phosphorus and the leacheability, or solubility, of nutrients such as potassium or phosphorus is strongly influenced by soil pH. A pH of 6.5 to 7.5 is best for phosphorus availability, and to most nutrients needed for plant growth.

Plant tissue is the primary source not only of food for the various soil organisms but of organic matter, which is essential for soil formation. Organic matter has been indicated

(Brady 1974) to have a great influence on soil properties such as;

a) soil colour,

b) structure, plasticity and water holding capacity,

c) cation adsorption capacity and

d) the availability of nutrients.

Kalahari sands generally form poorly structured and infertile soils with poor moisture retaining capacity (McKay 1968). The few reconnaissance studies undertaken in Western Kalahari (Bergstrom & Skarpe 1985; DHV 1980), Southern Kalahari (Buckley *et al*. 1967; Leistener 1967; Blair Rain & Yalala 1972) and Eastern Kalahari (Perkins 1991; Siderius 1972), all indicate slight to moderate acidic soils, deficient in all essential plant nutrients, especially phosphorus. These soils have a lower organic carbon content than those in the North (DHV 1980). In general these results match with the environmental history which was dominated by aelion process (Leistener 1967), and a negligible rate of soil formation due to the removal of organic matter by wind and termite activity. Significant silt – clay fractions are generally confined to inter – dune depressions, dry river valleys and pans.

Grazing animals may, however, change the distribution pattern of nutrients. Many of the plant nutrients consumed by grazing animals return to the soil through dung or urine, but not necessarily at the same place where they were eaten. There are areas of concentration around which faecal deposits and urination spots are found. For livestock these areas are around water points, bedding grounds and areas of level topography or where preferred plants are growing (Lange 1969; Hyder 1969). Hilder (1966) found that about one third of sheep faeces were deposited on only five to seven percent of the pasture. This material contains large amounts of nitrogen, phosphorus, etc. Estimates vary, but it has been estimated that 80 – 95% of nutrients eaten by range animals are excreted and returned in soil.

Knowledge of soil characteristics is essential to the range manager. This is because soil is the primary factor determining the potential for forage production of an area within a given climate (Barbour *et al*. 1980). The objective of this research was to determine the influence of livestock concentration at water points on the distribution of soil nutrients through dung and urine deposits along the transect from the water point.

3.2 Methods and material

Nutrient content of the soil was determined from soil samples taken from both the traditional cattle posts of the free range grazing area and from the livestock controlled condition (ranch). In the communal grazing area, two cattle posts were chosen for investigation. Soil samples were taken at nine locations along a transect radiating from the water point. Samples were taken at distances of 0, 150, 300, 500, 700, 1000, 1500, 2500 and 4000 metres away from the borehole. These locations were replicated three times at each cattle post. The zero (0) location is near the water trough where animals concentrate or rest after drinking water. On the traditional cattle posts conditions, livestock kraals or abandoned old kraals are found within the vicinity of the cattle post, which makes the area look more like a sacrifice area.

In the livestock controlled condition (ranch), soil samples were also taken along three transects for each grazing system (see treatment design). The treatments were replicated twice. Samples were taken at distances of 0, 150, 300, 600, 950, 1500, and 2450 metres away from the water point.

Samples were taken from the upper 10cm. Three individual samples from each location were collected and bulked together. Each soil was analysed for pH, phosphorus, calcium, magnesium, sodium, cation exchange capacity, organic carbon and some samples were also analysed for particle size.

This investigation was conducted to provide base information for further research. As such, analyses using the general linear model was used for all variables (pH, phosphorus, calcium, magnesium, potassium, sodium and organic carbon). The protected Fisher's Least Significant Difference was used to separate the means of the main effects (Steel & Torrie 1980)

3.3 RESULTS

3.3.1 Soil particle size

Average particle size in soils for both the Makhi ranch and adjacent free range grazing area revealed that fine sand or very fine sand composed of 51.59 and 15.18% respectively (Table 1). Medium sand was 24.45% while coarse sand was 5.45% and silt counted for only 3.11%. The soil did not contain any clay.

Table 3.1. Particle size in soil in the Makhi area

Very fine sand	15.18%
Fine sand	51.59%
Medium sand	24.45%
Coarse sand	5.45%
Very coarse sand	0.03%
Fine silt	3.11%
Silt	0.13%
Clay	0

3.3.2 Variation in soil nutrients along the transect from water in controlled grazing conditions – Makhi Ranch

Table 3.2 illustrates the variation of soil nutrient status measured along transects at increasing distance away from the water point at Makhi ranch. The results reveal the general infertility and acidic nature of the Kalahari sands. Even in tabulated form, the results illustrate impact of livestock around the water point on soil nutrient status. This is, however, localised and generally confined to the first 0 - 150m zone. Concentration of soil nutrients was higher ($P < 0.05$) at the first location (0m) than subsequent locations. Strikingly, values from the table illustrate how large impacts occur mainly at the first location and to a lesser extent out to 150m zone. Beyond 300m soil nutrients decrease to an almost constant level up to the furthest location of what may be considered the background nutrient status to be found in the Kalahari sandveld. All the variables measured appeared to be responsive to the variation at the 0 - 150m from the water point. All soil nutrients appeared to be consistently low at all but the 0 and 150m distance, where the input of dung and urine typically resulted in high values.

Dung, with a large number of cations or phosphates locked up in the organic matter, clearly had a profound influence on soil nutrients.

Table 3.2. Variation in soil nutrient status along transects away from the water point in controlled grazing conditions.

					Exchangeable Cations (c mo+/kg)			
Dist. (m)	pH ($CaCl_2$)	P (ppm)	OC (%)	:CEC (c mo+/kg)	Mg	K	Ca	Na
0	6.34^{a}	41.59^{a}	0.68^{a}	6.09^{a}	1.23^{a}	1.41^{a}	2.80^{a}	0.38^{a}
150	4.59^{b}	20.21^{a}	0.20^{bc}	5.15^{a}	0.84^{ab}	0.35^{b}	1.55^{b}	0.14^{a}
300	4.51^{b}	13.42^{b}	0.24^{b}	3.33^{b}	0.70^{b}	0.29^{b}	1.31^{b}	0.09^{a}
600	4.34^{b}	11.29^{b}	0.18^{c}	2.75^{b}	0.57^{b}	0.17^{c}	1.06^{b}	0.11^{a}
950	4.24^{bc}	11.08^{b}	0.17^{c}	2.46^{b}	0.44^{b}	0.17^{c}	1.04^{b}	0.11^{a}
1500	4.34^{b}	9.01^{c}	0.21^{bc}	2.80^{b}	0.54^{b}	0.18^{c}	1.01^{b}	0.11^{a}
2450	4.07^{bc}	8.50^{c}	0.20^{bc}	2.63^{b}	0.43^{b}	0.15^{c}	0.66^{c}	0.09^{a}

Means in each column followed by the same superscript are not significantly (P> 0.05) different between distances

Key to soil nutrients: pH = Acidity, P = phosphate, OC = organic carbon, Ca = calcium, Mg = magnesium, K = potassium, Na = sodium and CEC = cation exchange capacity and Dist = distance.

3.3.3 Variation of soil nutrients between the grazing systems at Makhi ranch

Mean variation in soil nutrient status between the grazing treatments at Makhi ranch is illustrated in Table 3.3. The continuous grazing system tended to be higher ($P < 0.05$) in pH, phosphorus, calcium and cation exchange capacity than the other grazing systems while sodium, magnesium, potassium and organic carbon showed no differences between the treatments. The 3 – paddock, 9 – paddock and non - grazing systems showed no difference in soil nutrient status. However, the magnitude of difference for all minerals between the treatments was very small.

Table 3.3. Mean variation in soil nutrients at each grazing system in controlled conditions - Makhi ranch

Treatment	pH ($CaCl_2$)	P (ppm)	OC (%)	CEC (c mo+/kg)	Exchangeable Cations (c mo+/kg) Mg	K	Ca	Na
1- Pd grazing	4.69[a]	17.25[a]	0.28[a]	3.81[a]	0.69[a]	0.33[a]	1.48[a]	0.13[a]
3 - Pd grazing	4.44[b]	11.61[a]	0.24[a]	3.08[a]	0.56[a]	0.31[a]	1.01[c]	0.15[a]
9 - Pd grazing	4.54[ab]	14.91[a]	0.28[a]	2.96[b]	0.65[a]	0.33[a]	1.27[b]	0.11[a]
Non - grazing	4.52[ab]	13.66[a]	0.24[a]	3.70[a]	0.63[a]	0.29[a]	1.18[b]	0.12[a]
Mean	4.52	14.59	0.27	3.28	0.66	0.32	1.24	0.13

Means in each column followed by the same superscript are not significantly (P>0.05) different between distances

3.3.4 Variation in soil nutrients in free – range grazing

Variations in the soil nutrient status along the transect away from the water point at Masaane and Motshwagole cattle posts on the free – range grazing are illustrated in Tables 3.4 and 3.5. The trend of soil nutrient along the transect away from the water point is the same for the two cattle posts and also follow that found on the Makhi grazing trial, namely that of decreasing nutrient status with increasing distance from the water point. The two cattle posts appeared to have the same level of all soil nutrients except for phosphorus and pH despite the borehole age or the stocking rate practiced at the borehole (Chapter 2). Phosphorus levels were marginally higher at the Masaane cattle post than at the Motshwagole cattle post while pH was higher at the Motshwagole cattle post. Phosphorus and cation exchange capacity were the most variable attributes along the transect from water points for both cattle posts.

Table 3.4. Mean soil nutrient status along the transect from the water point at Motshwagole cattle post.

Dist. (m)	pH (CaCl$_2$)	P (ppm)	OC (%)	CEC (c mo+/kg)	Exchangeable Cations (c mo+/kg) Mg	K	Ca	Na
0	6.63^{a}	21.89^{a}	0.36^{a}	5.20^{a}	1.16^{a}	0.60^{a}	2.58^{a}	0.21^{a}
150	5.91^{a}	15.01^{b}	0.33^{a}	3.89^{b}	0.84^{b}	0.31^{b}	2.30^{a}	0.08^{a}
300	5.74^{ab}	13.69^{bc}	0.22^{b}	3.24^{bc}	0.62^{bc}	0.16^{b}	1.70^{b}	0.08^{a}
500	5.08^{bc}	12.38^{bc}	0.28^{ab}	3.43^{bc}	0.77^{b}	0.22^{b}	1.22^{b}	0.12^{a}
700	5.13^{bc}	9.05^{c}	0 .30^{ab}	3.05^{c}	0.87^{b}	0.20^{b}	0.94^{bc}	0.11^{a}
1000	5.21^{bc}	9.51^{c}	0.27^{ab}	2.64^{c}	0.68^{bc}	0.20^{b}	0.60^{bc}	0.08^{a}
1500	5.16^{bc}	10.32^{bc}	0.22^{b}	3.13^{c}	0.62^{bc}	0.20^{b}	0.57^{c}	0.09^{a}
2500	4.42^{c}	8.14^{cd}	0.24^{b}	2.85^{c}	0.46^{c}	0.17^{b}	0.64^{bc}	0.08^{a}
4000	4.24^{c}	7.31^{d}	0.23^{b}	2.44^{c}	0.38^{c}	0.13^{b}	0.48^{c}	0.11^{a}
Mean	.5.28	14.29	0.20	2.05	0.71	0.23	1.17	0.16

Means in each column followed by the same superscript are not significantly (P> 0.05) different between distances

Table 3.5. Mean soil nutrient status along the transect away from the water point at Masaane cattle post.

Dist. (m)	pH (CaCl$_2$)	P (ppm)	OC (%)	CEC (c mo+/kg)	Exchangeable Cations (c mo+/kg) Mg	K	Ca	Na
0	5.84^{a}	21.64^{a}	0.28^{a}	3.76^{a}	0.73^{a}	0.42^{a}	2.36^{a}	0.28^{a}
150	5.78^{a}	15.99^{ab}	0.28^{a}	3.25^{a}	0.59^{a}	0.30^{ab}	1.35^{ab}	0.21^{a}
300	5.26^{ab}	14.41^{b}	0.21^{b}	3.17^{a}	0.60^{a}	0.20^{b}	1.30^{b}	0.13^{a}
500	4.47^{b}	12.74^{abc}	0.26^{ab}	2.13^{b}	0.55^{ab}	0.18^{b}	0.96^{b}	0.13^{a}
700	4.21^{b}	12.25^{c}	0.16^{b}	2.07^{b}	0.51^{b}	0.18^{b}	0.89^{b}	0.14^{a}
1000	5.02^{ab}	12.34^{c}	0.16^{b}	1.36^{b}	0.54^{b}	0.20^{b}	0.68^{b}	0.15^{a}
1500	4.69^{b}	12.17^{c}	0.18^{b}	1.54^{b}	0.59^{ab}	0.19^{b}	0.96^{b}	0.15^{a}
2500	4.44^{b}	12.22^{c}	0.17^{b}	1.57^{b}	0.39^{b}	0.16^{b}	0.67^{b}	0.15^{a}
4000	4.47^{b}	12.32^{c}	0.17^{b}	1.44^{b}	0.48^{b}	0.18^{b}	0.67^{b}	0.15^{a}
Mean	4.95	16.03	0.27	3.20	0.67	0.33	1.54	0.16

Means in each column followed by the same superscript are not significantly (P> 0.05) different between distances

Table 3.6 presents a comparison of soil nutrient status measured at two cattle posts in the free range grazing studied. Results between the cattle posts reveal a higher ($P < 0.05$) content of organic carbon, cation exchange capacity and phosphorus at Masaane cattle post. The high livestock units carried at the latter cattle post (Chapter 2) might probably account for the higher soil nutrient measured. The other soil nutrients were similar at both sites. Phosphorus and cation exchange capacity were the most variable soil nutrients observed between the cattle posts. However, the values at the Motshwagole cattle post tended to be lower than the mean of the two sites.

Table 3.6 Mean variation in soil nutrients at two cattle posts in the free -range grazing conditions.

Cattlle post	pH	P	OC	CEC	Exhangeable Cations (c mo+/kg)			
	(CaCl2)	(ppm)	(%)	(c mo+/kg)	Mg	K	Ca	Na
Motshwagole	5.28[a]	14.29[b]	0.20[b]	2.05[b]	0.71[a]	0.23[a]	1.17[a]	0.16[a]
Masaane	4.95[a]	16.03[a]	0.27[a]	3.20[a]	0.67[a]	0.33[a]	1.54[a]	0.16[a]
Mean	4.94	14.04	0.24	3.07	0.66	0.27	1.28	0.16

Means in each column followed by the same superscript are no significantly (P> 0.05) different between distances

3.4 DISCUSSION

Over large areas of the Kalahari soils are deficient in soil nutrients making those localities that are rich in nutrients important to grazing animals. The enrichment of soil, occurring within the immediate vicinity of the water points is due, theoretically to the input of dung and urine coincident with the daily animal concentration around the water point and is the result of the centripetal movement of nutrients from the area over which animal graze. These data are concurrent with those found elsewhere (Tolsma *et al.* 1987a; Ernst & Tolsma 1989; Perkins 1991). However, Perkins (1991) reported a zone of 25 – 50m having more concentrated nutrients compared to the 0 – 150m zones reported in this study. The variation might have been attributed by the borehole age or stocking rate fluctuation experienced on each borehole. However, reduction in livestock units at a particular borehole is likely to weaken the link between herbivore impact and length of exploitation. A large amount of cations or phosphates remain locked up in the organic matter, and clearly has a profound influence on soil nutrients. As a result, phosphorus and to a lesser extent cation exchange capacity showed the higher variation with distance from water point and between cattle posts.

There were no differences in soil nutrient status between the two cattle posts of the free – range grazing except for organic carbon, cation exchange capacity and phosphorus. However, the Masaane cattle post tended to have higher values in nutrient content than the Motshwagole. These differences can be interpreted in terms of animal population at each cattle post or the time the borehole had existed (Chapter 2). Livestock units were higher at Masaane cattle post and might have influenced high soil nutrient status despite the late date of drilling the borehole. Makhi and Motshwagole boreholes were drilled at an earlier date but tended to be lower in soil nutrient status probably due to lower stocking rates. High soil nutrient status observed at the continuous grazing system might have been contributed by the landform within the ranch as one replication of the continuous system had more bottomland grey soil colour and was characterized by bigger trees of Acacia gerradii.

3.5 CONCLUSION

The generally homogeneous nature of the Kalahari soils is notable in terms of the silt - clay content and a mean sand grain size in the fine sand fraction along all the transects from water points and confirms the extensive literature on characteristic of the Kalahari sandveld.

Chemical analyses revealed the low background fertility of the Kalahari sand with significant variation only being registered around the water points. The impact of dung and urine on soil chemistry is localised to the area immediately around the water point (0 –150m). Phosphorus and to a lesser extent cation exchange capacity were the most responsive attributes to variation along the transect from the water point.

However, phosphorus and cations in particular, give a clear proof to the general infertility of the Kalahari sands with low values at and beyond 300m from the water point.

High stocking rates applied at any particular borehole had an influence on the level of the soil nutrient status. Thus an early step in any management plans directed at conserving the soil resource should aim to ensure a more even spread of nutrient recycling. In this respect it is also important to ensure that access to water should not be a limiting factor.