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Full Length Research Paper

Analysis on the effects of kraal manure accretion on soil nutrient status through time

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This study investigated the influence of the accumulation of animal wastes on the soils of active kraal sites through time. This investigation involved the sampling and analysis of the soils of kraals that had been in use for periods ranging from 2 to over 45 years. Soil sampling and analysis were done both in the dry and wet seasons for comparative purposes. The properties of the kraal soils were compared with those of control sites. Samples were taken from 25 kraals categorized into 5 age (length of use) groups: < 5years; 6 - 10; 11 - 20; 21 - 40; > 40 years. The soils were sampled at two depths, 0 – 15 and 15 – 35 cm. Soil parameters analyzed included particle size distribution (%), bulk density (g/cm^3), pore space (%), moisture content (%), pH in water and in potassium chloride solution, EC (µS/cm), organic matter (%), CEC (meq/100g), exchangeable bases: Ca^{++}(cmol$_c$/kg), Mg $^{++}$(cmol$_c$/kg), K^+(cmol$_c$/kg), Na^+(cmol$_c$/kg); nitrogen: NH_4-N (mg/kg), NO_3-N (mg/kg), TKN (%), and Olsen P (mg/kg). Results showed a direct correlation between length of active kraal utilization and impact of animal waste concentration on the soil with correlation coefficients as high as r = 0.99 and r = 0.95 for pH and OM respectively. Nutrient levels in kraal soils of all ages were significantly higher (P = 0.05) than those of the control site soils. Most nutrient elements showed increases ranging from about 2 - 30 times greater than in the control site soils. Soil nutrient levels were higher in the dry season than in the wet season. The nutrient enrichment in the kraals extended deep into the soil, at least, to the 35 cm depth. The organic and nutrient enrichments of the soils also had very positive effects on soil moisture and structural characteristics. However, this highly localized nutrient enrichment of kraal soils is detrimental to the long term sustainability of arid ecosystems and soil productivity. The nutrients concentrated in kraals have been harvested from the surrounding areas by grazing animals and transferred to the kraal sites. In a situation of sedentary kraaling that exists in semi arid lands of Botswana where rotation of kraal sites or the harvesting of animal manure from kraals for use as soil manure is not commonly practiced, the concentration of soil nutrients at scattered kraal spots causes an imbalance in the spatial pattern of soil and plant productivity in the arid land ecosystem. The entire ecosystem is made poorer by this phenomenon.

Key words: Active kraal, sedentary kraaling, soil nutrients, semi arid.

INTRODUCTION

The use of kraals in traditional livestock management systems has been widely investigated, with most studies tending to focus on their importance as nutrient reserves that can be exploited to support crop production (Kangalawe et al., 2008) and as highly productive niches in marginal ecosystems (Stelfox, 1986; Muchiru et al., 2008). The large quantities of dung and urine accumulated in cattle kraals consist of plant nutrients harvested and transferred by livestock from the surrounding landscape (Russelle, 1992). This resource cycle leads to persistent removal of nutrients from source areas (La Rovere et al., 2005) and sustained impairment of their productivity (Gandah et al., 2003). Although, nutrient translocation is crucial in sustaining the dynamics

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Abbreviation: OM, Organic matter; CEC, cation exchange capacity.

Table 1. Active kraals investigated and duration of kraal utilization.

Length of time of active utilisation of kraals	Number of sites for each kraal category
< 5years	5
6 -10 years	5
11 – 20 years	5
21 – 40years	5
> 45years	5

of semi-arid ecosystems (Powel et al., 2004), facilitated concentration of nutrients at scattered spots such as kraals, can induce imbalances potentially capable of undermining the sustainability of the ecosystems themselves. The kraals disrupt the natural nutrient cycle by locking up nutrients at confined localities in pastoral systems where manure is not harvested to improve soil fertility (Turner 1998a; Augustine, 2003).

In semi-arid Botswana, contemporary livestock management is heavily based on the traditional kraaling culture where rotation of kraal areas is not a common practice. Traditional kraal owners actively utilize the same locations for kraal areas for decades especially within the vicinity of water sources such as boreholes, wells or shallow depressions (water pans). This is in contrast with similar pastoral economies in other areas such as in Kenya (Muchiru et al., 2008); Niger and Mali (Harris, 2002); Ethiopia and Sudan (Elias et al., 1998) where mobile kraals or deliberate rotation of kraal areas is a common practice. In addition, even though the benefits of kraal manure are traditionally known and strongly promoted by modern agricultural practices (Harris, 1996; Mmopelwa, 1998*)*, active collection and utilization of the manure for soil amendment in arable farming is still reported to be limited in Botswana (Seleka, 1999; MoA, 2007). Thus, traditional kraals in Botswana are characterized by thick accumulations of young and old manure which constitute nutrient over-enrichment and a major point source of environmental pollution. This prompted this study to analyze soil nutrient levels in actively utilised cattle kraals of various ages from less than 5 to over 45 years around the Tlokweng Village of Botswana where traditional livestock management is dependent on overnight confinement of livestock in kraals for security against theft and for ease of access to lactating cows for milking.

Guided by knowledge of prolonged use of kraals in this environment, the objectives of this investigation were to analyze and compare 1) soil nutrient levels in active kraals of different ages with a view to investigating the influence of active use of the kraals on soil characteristics over time; 2) soil nutrient levels between dry and wet seasons with the view of assessing variations in nutrient concentrations between the seasons and 3) soil nutrient concentrations at surface (0-15 cm) and subsurface (15–35 cm) soil depths.

STUDY AREA

Tlokweng Village is located East of Gaborone in the South East District of Botswana (Figure 1). The area has a semi-arid climate characterized by marginal (525 mm mean annual rainfall) and erratic (23% CV) rainfall most of which falls during the summer period between November and March. Mean temperatures range between 25 and 35°C in summer and between 3 and 11°C in winter. The soils are dominated by Arenosols and weakly developed Luvisols that are interrupted by Vertisols in riparian corridors (SMASP, 2006). Vegetation has been described as tree and shrub savanna (Skarpe, 1991).

METHODS

Selection of Kraals for study

The choice of kraals was limited to those that are traditionally constructed. They are characteristically open (unroofed) with no concrete floors or bedding material such that the livestock dung and urine are deposited directly on the soil surface. The kraal fences are constructed of poles cut from different kinds of trees and/or shrubs, many of which are thorny.

The kraal selection process began with a community meeting (Kgotla) attended by community elders and members as well as the agricultural (veterinary) extension staff. The purpose of the meeting was to establish a rapport with the kraal owners and seek their cooperation in facilitating the study. The active kraal samples were thus selected based on interviews with the extension workers and herders followed by field reconnaissance by the researcher. The selected kraals were geo-referenced using a GPS and finally included in the study only after a site visit by the facilitating veterinary/extension staff and extensive discussions with the kraal owners. To analyze and compare soil nutrient levels within and between kraal areas, the kraal samples were stratified into five groups according to duration of utilization, that is, the number of years since establishment (Table 1).

Soil sampling

Soils were sampled at five randomly located points within each kraal. Sampling was done at two depths, 0 – 5 and 5 – 35 cm. Thus, ten soil samples were collected from each kraal, giving a total of 50 soil samples for each group of kraals and 250 samples for all the 25 kraals studied. Soil sampling was done both in the dry and wet seasons for reasons indicated above. This meant that this study involved the laboratory analysis of 500 soil samples

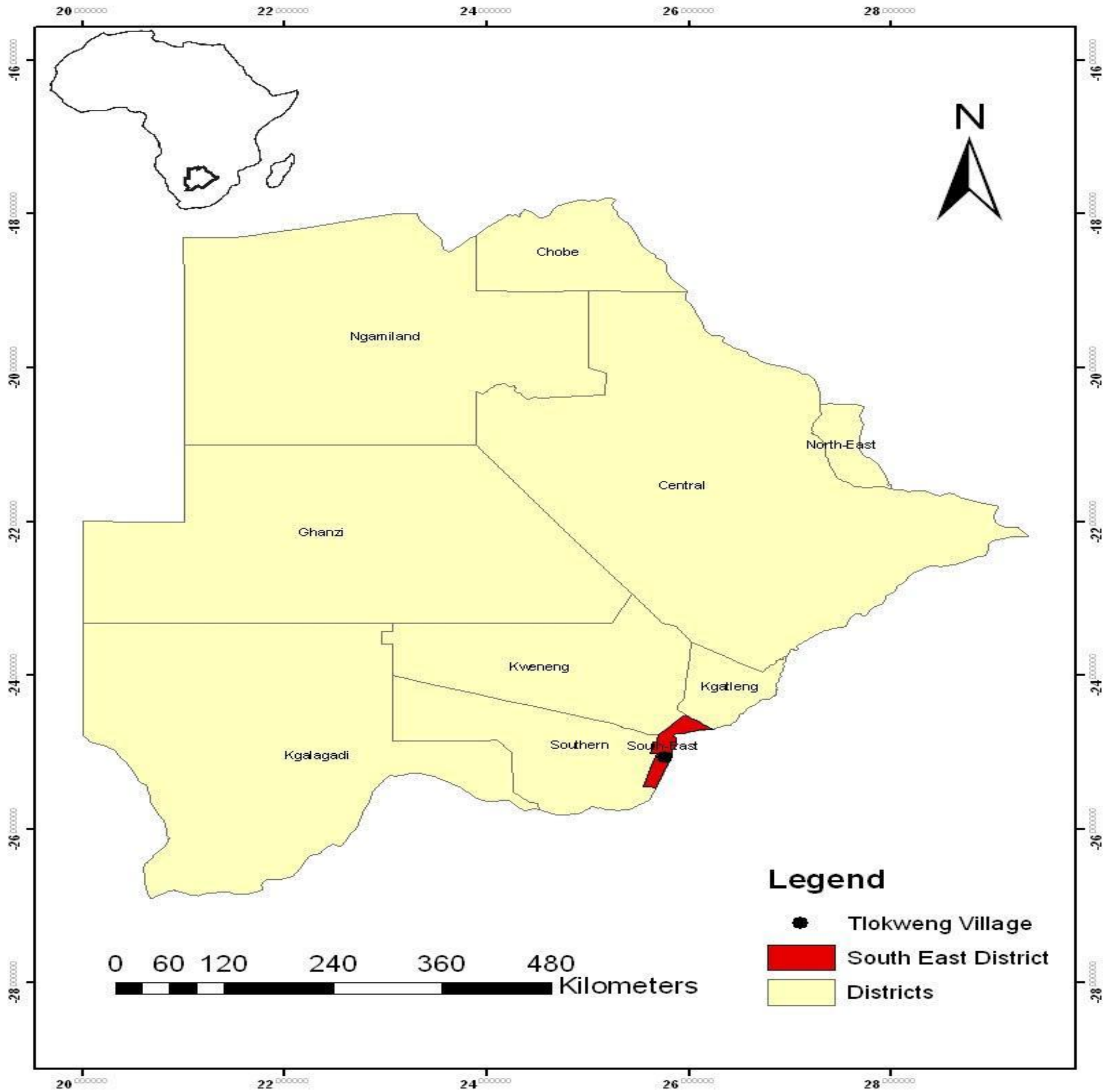


Figure 1. Location of Tlokweng Village in the South East district of Botswana.

altogether.

Soil analysis

Soil samples from control sites and active kraals were analysed to determine temporal variations in the physical and chemical properties. The parameters that were investigated are as shown in Table 2. Particle size distribution was analyzed by (1) wet sieving to screen sand particles from silt and clay after dispersing cemented aggregates in sodium hexametaphosphate (Na_6PO_4), and (2) fractionation (the hydrometer method was used) to separate silt from clay. Soil textural classes were objectively determined based on the data from the particle size analysis and using the Textural Auto lookup software (TAL Version 4.2). Soil moisture content, D_b and percentage (%) pore space were determined according methods described in USDA, (1996) and van Reeuwijk (1993).

Soil pH was determined by using the HANNA 210 Microprocessor with end values being obtained by averaging three readings for each sample. Electrical conductivity (EC (µS/cm)) was determined by using a programmable Vacuum Extractor (SampleTek-Smetter Design, Lincoln, Nebraska) to prepare saturated samples that were subsequently analyzed using a thermo orion conductivity cell. Plant available nitrogen (PAN) was considered to be the equivalent of mineral N which was estimated from observed values of NH_4-N and NO_3-N that were determined

Table 2. Active cattle kraals and control sites properties of soil samples extracts during the dry season.

	Control	Sample average values by duration of Active kraals				
Soil parameter	**Site values**	**< 5 years**	**10 years**	**20 years**	**30 years**	**> 45years**
$pH\text{-}H_2O^{a}$	5.5	7.9*	8.0**	8.6	8.9*	9.0*
$pH\text{-}KCl^{a}$	5.4	7.3	7.6	8.4	8.4	8.6
CEC (meq/100 g)^{c}	2.5	8.2*	6.3**	4.5*	4.3*	4.5*
OM (%)^{a}	0.7	2.0	2.3	2.4	2.4*	2.6*
Pore space (%)^{b}	42.3	42.5	41.0	40.0	40.0	40.0
Moisture content (%)^{c}	1.2	31.3	31.2	32.5	34.4	35.3
Bulk density (g/cm^{3})^{e}	1.5	0.9	1.5	0.9	1.5	1.0
EC (µS/cm)^{c}	19.4	58.0*	90.0*	100.0*	100.0*	100.0*
Olsen P (mg/kg)^{d}	0.7	18.0*	17.0*	19.0*	19.5*	19.8*
Exch. K ($cmol_c$/kg)^{a}	1.3	22.2*	24.4*	25.5*	27.1*	27.2*
Exch. Na ($cmol_c$/kg)^{a}	0.4	1.5*	2.0*	2.6*	3.0*	3.0*
Exch. Ca ($cmol_c$/kg)^{c}	2.9	6.3*	6.4	6.7	6.9	6.9
Exch. Mg ($cmol_c$/kg)^{c}	0.9	2.2*	2.5	2.7*	2.9	2.7*
NH_4-N (mg/kg)^{a}	100.0	110.0	120.0*	132.0*	132.5	132.6*
NO_3-N (mg/kg)^{a}	99.5	100.0*	129.4	129.4*	130.0	130.0*
TKN (%)^{e}	0.2	0.1	0.3	0.2*	0.3*	0.4
Sand	72.1	70.3	73.4	71.8	74.0	75.0
Silt	14.4	18.3	13.1	14.0	15.0	13.0
Clay	13.5	11.5	11.8	14.2	11.0	12.0
Texture^{e}	SL	SL	SL	SL	SL	SL
Number of samples	5	5	5	5	5	5

*Significant at p = 0.05. **Significant at p = 0.01 SL = Sandy Loam. a = Persistent increase. b = Persistent decrease. c = initial increase and terminal stabilization. d = initial decrease and terminal increase. e = stable trends.

on the basis of extraction procedures developed in USDA (1996) and Okalebo (1993). Olsen phosphorus (Olsen P (mg/kg)) was estimated by the Olsen procedure as described by Csuros (1997). Soil organic matter (OM%) content was determined using the Walkeley- Black wet combustion method (USDA, 1996; van Reeuwijk, 1993). Soil cation exchange capacity, CEC (meq/100 gm) was determined by using the ammonium acetate (CH_3COONH_4) extraction technique (USDA, 1996; van Reeuwijk, 1993) in which samples were thoroughly leached with 1 M CH_3COONH_4 and 95% ethanol to remove exchangeable cations and alkalinized by adding 1 M NaOH. Thereafter, the leachate was distilled into indicator solutions of boric acid (H_3BO_3) and the mixture titrated against 0.01HCl to determine the amount of NH_3. Estimation of exchangeable bases ($cmol_c$/kg) was conducted by using a Varian SpectrAA FS (Varian Inc., Victoria, Australia) Flame Atomic Absorption Spectrometer (FAAS) for Ca^{2+} and Mg^{2+} and the butane fuel system-based Sherwood Flame Photometer (Sherwood Scientific Ltd, Cambridge, UK) for Na^{+} and K^{+} . Total Kjeldahl Nitrogen (TKN%) was determined by using a three stage procedure that involved Kjeldahl wet acid oxidation of samples and distillation and titration of the by-products (Okalebo et al., 1993).

Data analysis

The values obtained for the different soil parameters analyzed were averaged for the five sampling points in each kraal and also for all kraals in each age-group. The standard deviation, coefficient of variability (CV) and Student's *t* statistics were calculated to assess the variability or homogeneity of parameters within each kraal and kraal group. The Analysis of Variance (ANOVA) was employed for the comparison of soil parameters between the different kraal age-groups. The Pearson's product moment correlation was performed to determine whether there was any correlation between soil nutrient levels and age (duration of use) of the active kraals. A Statistical Package for Social Scientists, Predictive Analytics SoftWare (PASW) Statistics 18 (formerly ©SPSS) and Microsoft Office Excel (Microsoft® Office 2007) were used to run all statistical operations with levels of significance being determined at 95% confidence limit.

RESULTS

Results of the soil analyses are presented in Tables 2, 3, 4, 5 and Figure 2. Table 2 and Figure 2 show the analytical soil data on the soils of the active kraals of different ages in relation to those of the control sites. Table 3 shows correlation analysis of age of kraals and soil parameters while Table 4 shows the comparative data on soil nutrient levels between the wet and dry seasons. Table 5 shows the comparative data on soil parameters between the two soil layers, 0 - 5 and 5 – 35 cm. The soils of the different kraals are very similar in texture as indicated by the outcome of the particle size analysis and determination of soil textural classes. All the soils are sandy loams, thus establishing a firm basis for the comparative analysis of the impact of organic waste accumulation on soils between the different kraal groups.

Table 3. Correlation coefficients of soil parameters and duration of active kraal usage.

Soil parameter	Pearson correlation coefficients
pH-H_2O	0.99**
CEC (meq/100 g)	-0.40
OM (%)	0.95**
Pore space (%)	-0.25
Moisture content (%)	0.90*
Bulk density (g/cm^3)	0.05
EC (µS/cm)	0.75*
Olsen P (mg/kg)	0.90*
Exch. K (cmol$_c$/kg)	0.90*
Exch. Na (cmol$_c$/kg)	0.90*
Exch. Ca (cmol$_c$/kg)	0.75*
Exch. Mg (cmol$_c$/kg)	0.90*
NH_4-N (mg/kg)	0.95**
NO_3-N (mg/kg)	0.90*

*Significant at p = 0.05 and **Significant at p = 0.01.

Table 4. Seasonal variations in soil sample extracts.

Parameter	Seasons	
	Wet summer	Dry winter
OM (%)	2.5	3.0*
Olsen P (mg/kg)	0.9	21.2**
NH_4-N (mg/kg)	153.3	313.0**
NO_3-N (mg/kg)	100.8	130.5*
TKN (%)	0.2	0.3
pH-H_2O	8.5	8.9*
CEC (meq/100g)	5.1	4.3
Exch. K (cmol$_c$/kg)	1.3	22.5**
Exch. Na (cmol$_c$/kg)	1.4	2.2
Exch. Ca (cmol$_c$/kg)	6.6	6.5
Exch. Mg (cmol$_c$/kg)	2.2	2.5
Number of sample sites	25	

*Significant at p = 0.05 and **Significant at p = 0.01.

Kraal soils versus control site soils

As to be expected, the results in Table 2 show a considerably high level of nutrient enrichment of the soils of the kraal areas from animal wastes compared with the control sites. For example, the average exchangeable Ca^{++} for control site soils is only 2.9 cmol$_c$/kg compared to values ranging from 6.0 – 6.7 cmol$_c$/kg for the kraal soils representing a 2.0 – 2.3 times (or 206 - 231%) increase over the levels in the control site soils. Mg^{++} levels in the kraal soils are 3.7 – 7.5 times (375 - 750%) greater than the average level for control site soils; Na^+ levels are 2.0 – 2.75 times (or 200 - 750%) higher; K^+ levels are 17 – 20 times (or 1700 - 2000%) higher while Olsen P levels are 24 – 28 times (or 2429 - 2828%) higher than the average level in the control site soils. Organic matter levels in the kraal soils are 286 - 372% of the average level in the control site soils. It is not surprising therefore that soil CEC values in the kraals are much higher, by 212 - 328%, than in the control sites. Such is the impact of organic waste accumulation in kraals on the soil nutrient status. The kraal soils also have higher nitrogen status than the control site soils as shown in Table 2.

The highly improved organic matter status of the kraal soils is probably reflected in the highly improved moisture content and structural characteristics (pore space% and bulk density) of the kraal soils relative to those of the control site soils. The kraal soils also are distinctly

Table 5. Surface and subsurface soil depths properties of soil sample extracts during the dry season.

	Kraal soil layers		Control sites	
Parameters	**Surface (0 – 5 cm)**	**Sub-surface (5 – 35 cm)**	**Surface (0 – 5 cm) Control sites**	**Sub-surface (5 – 35 cm) Control sites**
pH_2O	8.9	8.6	5.5	5.6
Pore space (%)	39.4	40.0	42.0	42.3
Moisture content (%)	32.0	31.5	1.3	1.4
CEC (meq/100g)	3.6	3.5	2.5	2.8
OM (%)	3.4	3.2	0.7	0.7
Olsen P (mg/kg)	19.5	19.8	0.7	0.8
NH_4-N (mg/kg)	132.5	132.0	98.9	99.0
NO_3-N (mg/kg)	130.8	130.0	100.0	99.9
Exch. K ($cmol_c$/kg)	22.4	22.1	1.3	1.3
Exch. Na ($cmol_c$/kg)	1.4	1.5	0.2	0.4
Exch. Ca ($cmol_c$/kg)	6.5	6.7	3.0	3.4
Exch. Mg ($cmol_c$/kg)	2.5	2.7	0.9	0.8
Number of sample sites	25		5	

alkaline in reaction with pH- H_2O values ranging from 7.9 in the youngest kraals to 9.0 in the over 40 year-olds. The corresponding values for pH-KCl are 7.3 and 8.6 for the youngest and oldest kraals respectively. Soil pH values for the control site soils are pH-H_2O 5.5 and pH-KCl 5.4.

Correlation between age of Kraals and Kraal soil parameters

The graphs in Figure 2 depict the trend in soil parameters through time. In general and with few exceptions, there is an upward trend in values with the age of kraals. This relationship is confirmed by the results of the correlation analysis between age of kraals and different soil parameters as shown in Table 3. The parameters that are most highly positively correlated with time (age of kraals) are pH (r = 0.99), OM and NH_4-N with the same correlation coefficient (r = 0.95) and Olsen P (r = 0.90) while pore space and CEC show negative though non-statistically significant correlations with time (r = -0.25 and r = -0.40 respectively).

Seasonal trends in Kraal soil nutrient levels

Table 4 shows the comparative data on soil nutrient levels between the dry and wet seasons. There is a discernible seasonal pattern to the concentration of nutrients in the soil although ANOVA indicates the observed differences are not statistically significant at the 0.05 probability level in respect of TKN, CEC and exchangeable Ca and Mg. With the exception of TKN, CEC and all exchangeable bases except K, all other parameters were higher in the dry than in the wet season (Table 4).

Nutrient concentrations with soil depth

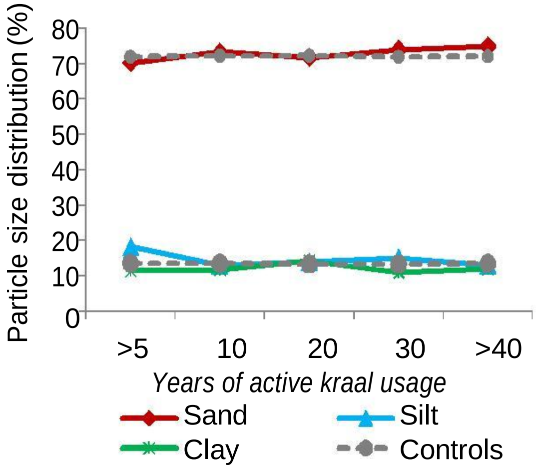
Except for OM, CEC and NH_4-N differences between soil nutrient levels at surface and subsurface soil depths were not significant (P = 0.05). This suggests that the impact of organic waste accumulation extends beyond the top 0-5cm of the soil depths to 5 – 35 cm layer.

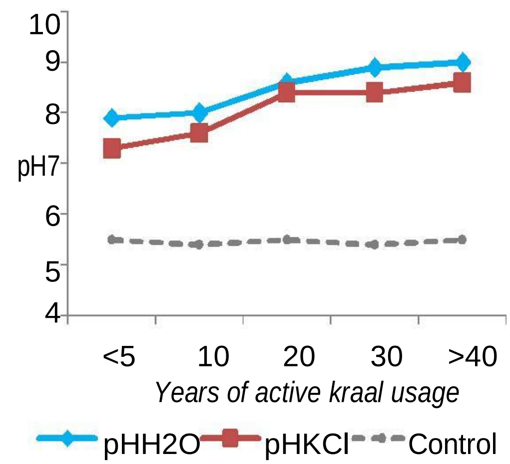
DISCUSSION AND CONCLUSIONS

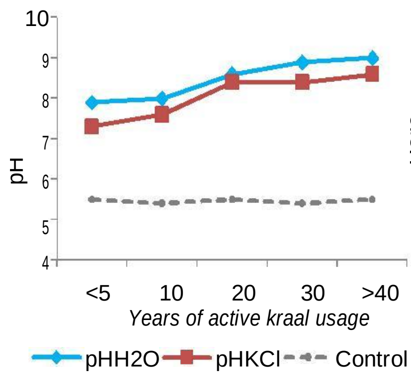
Comparative analysis of soil nutrient levels between kraals and their surrounding areas

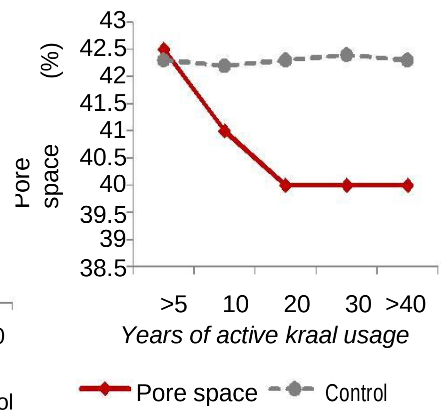
The findings of this study on the elevated nutrient levels in kraal soils relative to soils in the surrounding areas are consistent with observations in other semi-arid areas where kraals form a significant feature of the livestock management system (Turner 1998a, 1998b; Brooks et al., 2006). The kraal soils are markedly alkaline in comparison to the inherently acidic sandy soils of the surrounding areas. The characteristic soil alkalinity within kraals is consistent with the high OM content which likely influenced the observed elevated concentrations of phosphorus and total quantities of soluble exchangeable bases.

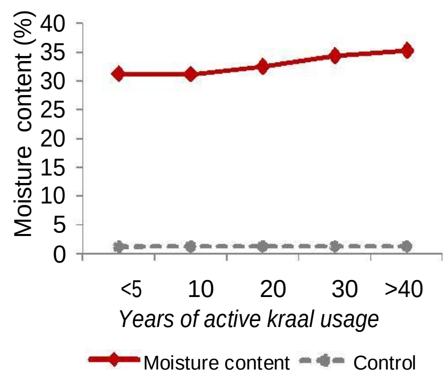
The observed difference in soil moisture content between kraals and surrounding areas is influenced by the high OM content at the kraals. OM enables the soil to retain more water because of the tiny pores present with a lower matric potential (Brady and Weil, 2002) which reduces tendency for easy flow of water. Thus, OM in kraal soils acts as a ‘sponge’ that absorbs and stores moisture. The moisture content had an influence on the total loss of N due to denitrification (Hiernaux et al., 1998), which partially accounts for the temporal trend of

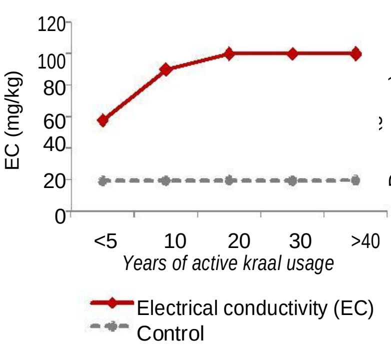

Particle size distribution (%)
Years of active kraal usage
Sand
Silt
Clay
Controls

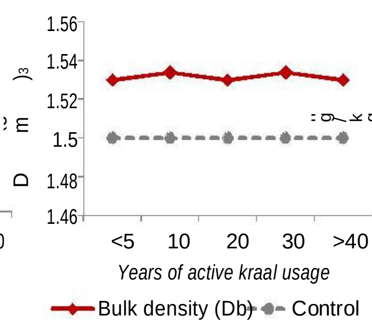

pH
Years of active kraal usage
pHH2O
pHKCl
Control

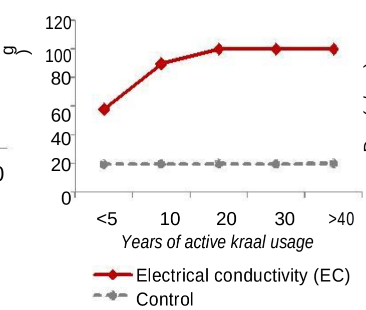

pH
Years of active kraal usage
pHH2O
pHKCl
Control

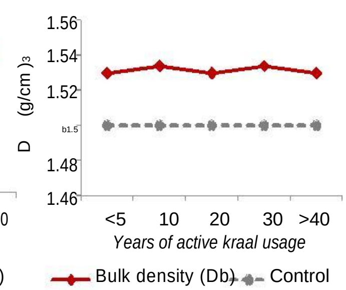

Pore space (%)
Years of active kraal usage
Pore space
Control

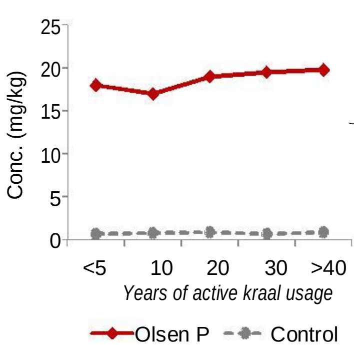

Moisture content (%)
Years of active kraal usage
Moisture content
Control

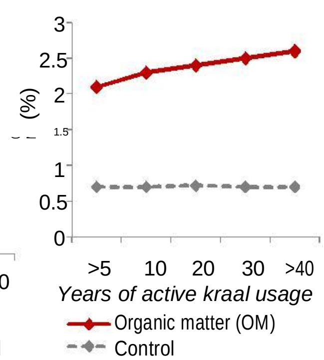

EC (mg/kg)
Years of active kraal usage
Electrical conductivity (EC)
Control

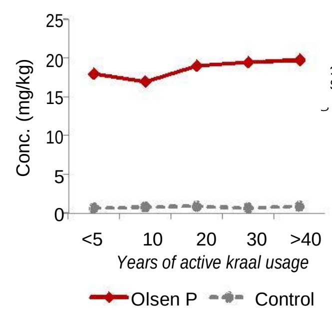

Years of active kraal usage
Bulk density (Db)
Control

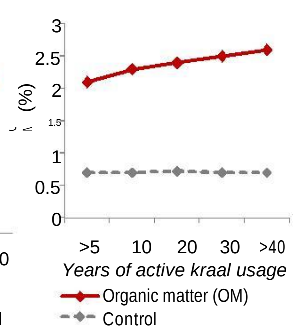

Years of active kraal usage
Electrical conductivity (EC)
Control


(g/cm)3
Years of active kraal usage
Bulk density (Db)
Control


Conc. (mg/kg)
Years of active kraal usage
Olsen P
Control


(%)
Years of active kraal usage
Organic matter (OM)
Control


Conc. (mg/kg)
Years of active kraal usage
Olsen P
Control


(%)
Years of active kraal usage
Organic matter (OM)
Control

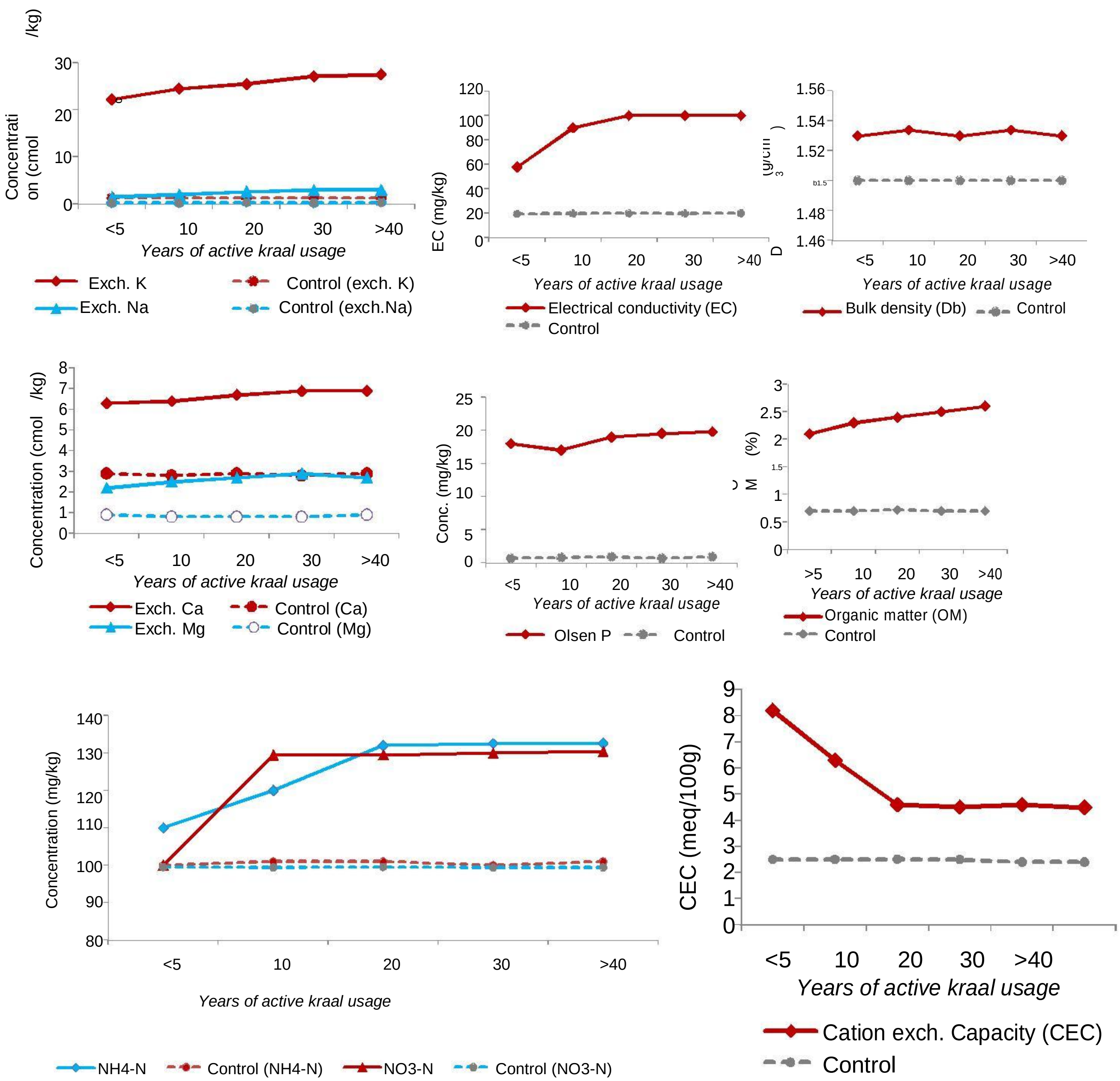


Figure 2. Trends in soil parameters with years in actively used kraal areas.

soil nutrient variations at kraals and their surrounding soils. The declining trend of porosity values with increase in years of active kraal utilization is consistent with increased compaction of the soil by the livestock. Similarly, because trampling within and around kraal areas influences soil bulk density, EC increased as reduced porosity lowered water infiltration to dilute the soil solution. In addition, the negatively charged colloidal OM with high surface area and surface charge density (Brady and Weil, 2002) enabled kraal soil environments to have increased cations that allowed more of the latter to be held in exchangeable form. Consequently, the above-neutral pH and the elevated values of EC and CEC can be explained.

Analysis of the effects of animal waste on soil after continuous active utilization of kraals

There is a direct correlation between length of years of active kraal utilization and soil nutrient concentrations. Nutrient loadings from animal waste accumulation at kraals increase over the years of active kraal utilisation. But, the impact of this nutrient loading is highly localized within the kraals judging from the comparative very low soil nutrient levels in the surrounding areas.

The CEC temporal pattern of initial increase and eventual stabilization with age of kraal is related to mineralisation rates and nutrient loading at kraals since extended organic matter mineralisation reduces CEC levels (Zech et al., 1997).

A continuous addition of OM to the soil at kraals that had been actively utilised for many years (Table 1) influences the decomposition and mineralisation rates of the OM (Zech et al., 1997) which account for the stable trends of CEC observed. Similarly, the higher nutrient status at old utilized kraals increases the labile amount of available P reserve pool (Eghball and Power, 1999) which could explain the elevated levels of available P. Since the inorganic or available P present in the soil solution is the only form which plants can utilize (Maguire and Sims, 2002), it determines the soil nutrient status to a high degree.

Seasonal variations in soil nutrient concentration levels

Seasonal trends of the generally higher concentrations of most nutrients in winter in comparison with summer were expected and point to variations in nutrient loading of the animal waste at kraals in which low summer values for most parameters suggest substantial leaching/ translocation processes during the wet summer season. Temperature and moisture content regulate nitrification, volatilisation, denitrification and mineralisation of OM by influencing microbial processes (Bastida et al., 2008). The summer high temperatures entail higher losses through OM mineralisation compared to the dry cold winter period when the very dry surface of the soil exposure the OM to desiccation in the semi-arid environment.

Similarly, the elevated wet season CEC pattern suggests accelerated humification because of this season's higher temperatures that induce the formation of carboxyl and phenolic functional groups (Zech et al., 1997). The same mechanism could explain the elevated wet-season losses of NH_4-N (Clark et al., 2005) while NO_3-N and TKN trends are indicative of the extent to which wet-season leaching can reduce the magnitude of inter-seasonal variations by undermining nutrient accumulation. NO_3- N has a short residence period in the soil partly because it is soluble and mobile (Villar-Mir et al., 2002) and also because it is easily absorbed by plants (Brandjes, 1996).

Soil nutrient variation at soil depths

The impact of organic waste accumulation in kraal soils of up to 35 cm soil depth is a function of the continuous addition of the wastes without any form of harvesting. Although, the rate of mineralization is much slower than the rate of organic waste accumulation, continuous addition of wastes over a long time would progressively lead to the infiltration of nutrient concentrations deeper into the soil. Infiltration of the accumulated waste in kraals may have implications for groundwater contamination which requires careful investigation and monitoring.

Implication of the study for agricultural development

This study has shown that sedentary kraaling where rotation of kraal sites or the harvesting of animal manure is not commonly practised leads to soil nutrient over-enrichment at scattered spots (isolated kraal sites). A linkage between soil nutrient over-enrichment at kraals and agricultural productivity is important since the nutrients in kraals have been harvested from the surrounding areas by grazing animals and transferred to the kraal sites. This concentration and localization of nutrients at kraals not only impoverishes the entire ecosystem over time, but also, creates spatial disparities in land productivity at the micro-level. These spatial differences in nutrient levels are clearly seen in the patchy nature of the vegetation in the kraal environs: the kraal sites have more lush growths than the surrounding areas. Crop productivity in such a landscape is likely to be affected by the patchy nature of soil nutrient enrichment. Sustainable agriculture particularly in nutrient poor semi arid environments can be better served by the use of the animal manure from the kraals as a management strategy to redistribute the nutrients back to the areas where they had been harvested originally by the grazing animals.

REFERENCES

Augustine JA (2003). Long-term, livestock-mediated redistribution of nitrogen and phosphorus in an East African savanna. J. Appl. Ecol., 40: 139-149.

Bastida F, Kandeler E, Moreno JL, Ros M, Garcia C, Hernandez T (2008). Application of fresh and composted organic wastes modifies structure, size and activity of soil microbial community under semiarid climate. Appl. Soil Ecol., 40: 318-329.

Brady NC, Weil RR (2002). The nature and properties of soils. 13th ed. Prentice Hall. New Jersey, USA., p. 960.

Brandjes PJ, de Wit J, van der Meer HG, van Keulen H (1996). Environmental impact of animal manure management. Livestock and the environment? Finding a balance. International Agriculture Centre, Wageningen (the Netherlands), p. 53.

Brooks ML, Matchett JR and Berry KH (2006). Effects of livestock watering sites on alien and native plants in the Mojave Desert, USA. J. Arid Environ., 67: 125-147.

Clark JE, Hellgren EC, Parsons JL, Jorgensen EE, Engle DM, Leslie DM (2005). Nitrogen outputs from fecal and urine deposition of small mammals: implications for nitrogen cycling. Oecologia 144: 447- 455.

Csuros M (1997). Determination of Phosphorous. Environmental Sampling and Analysis Laboratory Manual. Lewis Publishers, New York, p. 320.

Eghball B and Power JF (1999). Phosphorous and Nitrogen based manure and compost applications: Corn production and phosphorous. Soil Sci. Soc. Am. J., 63: 895-901.

Elias E, Morse S, Belshaw DGR (1998). Nitrogen and phosphorous balance of Kindo Koisha farms in southern Ethiopia. Agric. Ecosyst. Environ., 71: 93-113.

Gandah M, Brouwer J, Hiernaux P and Van Duivenbooden N (2003). Fertility management and landscape position: farmers' use of nutrient sources in western Niger and possible improvements. Nutrient Cycling in Agroecosystems, 67: 55-66.

Harris D (1996). The effects of manure, genotype, seed priming, depth and date of sowing on the emergence and early growth of *Sorghum bicolor* (L.) Moench in semi-arid Botswana. Soil Till. Res. 40: 73-88.

Harris F (2002). Management of manure in farming systems in semi-arid West Africa. Exp. Agric., 38: 131-148.

Hiernaux P, Bielders CL, Valentin C, Bationo A, Rivera SF (1998). Effects of livestock grazing on the physical and chemical properties of sandy soils of Sahelian rangeland. J. Arid Environ., 41: 231-245.

Kangalawe RYM., Christiansson C, Ostberg W (2008). Changing land-use patterns and farming strategies in the degraded environment of the Irangi Hills, central Tanzania. Agriculture, Ecosyst. Environ., 125: 33-47.

La Rovere R, Hiernaux P, Van Keulen H, Schiere, JB, Szonyi JA (2005). Co-evolutionary scenarios of intensification and privatization of resource use in rural communities of south-western Niger. Agric. Syst., 83: 251-276.

Maguire RO and Sims JT (2002). Measuring agronomic and environmental soil phosphorous saturation and predicting leaching with Mehlich-3. Soil Sci. Soc. Am. J., 66: 2030-2039.

Mmopelwa G (1998). Factors contributing to land fallowing in a permanent cultivation system: the case of semi-arid Botswana. J. Arid Environ., 40: 211-216.

MoA – Ministry of Agriculture (2007). Farm management survey results. Division of Agricultural Planning and Statistics, Government of Botswana, Gaborone.

Muchiru AN, David J, Western DJ and Reid RS (2008). The role of abandoned pastoral settlements in the dynamics of African large herbivore communities. J. Arid Environ., 72: 940-952.

Okalebo JR, Gathua KW and Woomer, PL (1993). Laboratory methods of soil and plant analysis: A Working Manual of Soil. TSBF/UNESCO/ROSTA, p. 88.

Powell MJ, Pearson RA and Hiernaux PH (2004). Crop–Livestock Interactions in the West African Drylands. Agron. J. 96:469–483.

Russelle MP (1992). Nitrogen cycling in pasture and range. J. Prod. Agric., 5: 13-23.

Seleka TB (1999). The performance of Botswana’s traditional arable agriculture: growth rates and the impact of the accelerated rainfed arable programme (ARAP). Agric. Econ., 20: 121-133.

Skarpe C (1991). Spatial patterns and dynamics of woody vegetation in an arid savanna, Botswana. J. Veg. Sci., 2: 565-572.

Stelfox JB (1986). Effects of livestock enclosures (bomas) on the vegetation of the Athi Plains, Kenya. Afr. J. Ecol., 24: 41-45.

SMASP (Soil mapping and Advisory Services Project) 2006: Wit, P.V. de, Bekker, R.P. Land Systems Map of the Republic of Botswana (soils and land use). Soil mapping and Advisory Services project. AG:DP/BOT/85/011.66pp FAO, Ministry of Agriculture, Gaborone.

Turner M (1998a). Long-term effects of daily grazing orbits on nutrient availability in Sahelian West Africa: I. Gradients in the chemical composition of rangeland soils and vegetation. J. Biogeogr., 25: 669-682.

Turner M (1998b). Long-term effects of daily grazing orbits on nutrient availability in Sahelian West Africa: 2. Effects of a phosphorus gradient on spatial patterns of annual grassland production. J. Biogeogr., 25: 683-694.

United States Department of Agriculture (USDA) (1996): Particle Size Analysis. Survey Laboratory Methods Manual. Soil Investigation Report, 42: 31-111.

Van Reeuwijk LP (1993). Procedures for Soil Analysis. International Soil Reference and Information Centre Technical Paper No. 1.

Villar-Mir JM, Villar-Mir P, Stockle CO, Ferrer F and Aran M (2002). On-Farm Monitoring of Soil Nitrate-Nitrogen in Irrigated Cornfields in the Ebro Valley. Agron. J., 94: 373-380.

Zech W, Senesi N, Guggenberger G, Kaiser K, Lehmann J, Miano T, Miltner A and Schroth G (1997). Factors controlling humification and mineralization of soil organic matter in the tropics. Geoderma, 79: 117-161.