Cattle Licked Soil Mineral Analyses at TswantshaCattle Post Area in the Boteti Sub-district of the Central District, Botswana

C.M Tsopito[a], M. Gubungano[b], J.C. Moreki[a]
[a]Department of Animal Science and Production, Botswana College of Agriculture, Private Bag 0027, Gaborone, Botswana
[b]Department of Veterinary Services, Ministry of Agriculture, Private Bag 11, Letlhakane, Botswana.
Corresponding author:**C.M Tsopito**

Abstract

A study was carried out in Boteti sub-district near Letlhakane village at Tswantsha cattle-post where cattle in this area have been observed for their soil licking behaviourat specific bare ground patches. Concentration levels of some mineral elements and soil pH of licked soil patches and adjacent un-licked soils were determined in a 100m^{2}area and mapped using field grid maps. Potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), zinc (Zn), copper (Cu), manganese (Mn) and iron (Fe) were present in the 10 pointsof licked and un-licked soils. Data were analysed using SAS Institute (2010) and t-test distribution tables for variances. Sodium and Mg levels differed (P<0.05), whereas K and Calevels were not different (P>0.05). Iron, Mn, Zn and Cu were the same (P>0.05) between licked and un-licked soils. Zinc, Fe and Mn levels were low and inadequate for plants and animal requirements. There was a uniform distribution of the assessed mineral elements between the sampled sites. However, a distinct variation within and outside the sampling areas was observed. Soil pHranged between weak acidityand weak alkalinity across the two sampling areas and was not correlated with the soil mineral concentrations. The most frequented lick sites were deeper than the newly formed ones, thus the extent of utilization. It is concluded that the high frequency of visits was attributed to the deficiencies of some minerals such as Zn, Fe, Mn, Na and Mg in the forage.

KEYWORDS: Cattle**,** deficiency symptoms, licked soils, minerals, Tswantsha, un-licked soils

INTRODUCTION

Grazing animals often ingest soil that may have adhered to range plants as part of their normal feeding routine. Conversely, due to some deficiencies in essential minerals such as phosphorus, iron, manganese, copper and cobalt in the consumed vegetation, grazing animals may actively seek out particular soil patches to lick to compensate for those minerals lacking in their grazed diets. Healy (1968a), Ammerman et al., (1984) and Kruelen (1985) observed such tendencies in piglets that ingest soils to derive iron from the soil. However, outright soil ingestion by grazing animals is not a common occurrence [notwithstanding the fact that range plants contain certain amounts of soil adhering to their lower plant parts (stems and leaves adjacent to ground level) most times] and it is generally an ignored activity although it is usually observed with both domestic and wild animals. Voluntary soil ingestion by grazing animals is normally considered a nutritional phenomenon (Healy, 1968; 1973). Although soil-licking may be referred to as a form of voluntary soil ingestion, it comes about as a result of pica or lack of some nutrient in the diet of the grazing animal, especially nutrients such as minerals. Mineral nutrition in grazing and herbivorous animals is very important and as such, minerals play vital role in the normal growth, reproduction, health and proper functioning of an animal's body (McDowell, 1992). Range animals depend on range forages to meet all their nutritional requirements including minerals. At the same time, range plants depend on the soils to provide them with the minerals they contain but these forages do not always provide all of the required minerals since the mineral concentration levels in the soils vary considerably from toxicity to inadequate amounts leading to differing amounts among forage species (Grusak and Dellapnna, 1999). Generally, there are 14 essential minerals that the soil must provide in the required amounts for plant growth to occur. These essential minerals are divided into macro elements (those required relatively in large amounts) and micro elements (required in relatively small amounts). Being in relatively large amounts does not necessarily mean that the particular element is more important than the one required in relatively small amount (Barak, 1995).

In Botswana, grazers and herbivores are forced to pick up fallen tree leaves as the only sources of feed during droughts and dry seasons when grazing conditions have deteriorated and thus not available in sufficient quantities and quality. In the process of picking up these fallen tree leaves, animals also ingest soil from the ground. Soil ingestion behaviour is not only peculiar to domestic animals as wild animals have also been observed to display the soil licking behaviour (Beyer et al., 1994). The reasons for soil ingestion by animals, but not only grazing animals, must always be investigated since this behaviour may result in various other unwanted effects that can be sources of heavy metals, radionucleotides and chemicals.

In semi-arid countries such as Botswana, where soils are known to be deficient in some minerals such as phosphorus (P), potassium (K) and nitrogen (N), soils may be licked as a result of depraved appetite of some minerals that are not supplied in adequate amounts in the vegetation that they grew upon. The importance of licked soils is dependent on the amounts ingested and mineral concentration levels in the soils relative to that in the vegetation including the ability of the ingesting animals to solubilize and absorb the minerals within the soil. Soil ingestion may also disrupt the absorption of some nutrients such as sodium and iron (McDowell, 1997). However, it has also been shown that there may be other factors that may influence animals to ingest soils such as soil type and structure, stocking rate, soil living organisms and soil management (Healy, 1968b).

Since there is paucity of information on soil licking by animals in Botswana, a study was carried out to determine the soil concentration levels of the different major and minor elements for possible uptake by vegetation in the licked and un-licked areas and by extension, intake by grazing animals.

MATERIALS ANDMETHODS

Study area

The study area is located near Tswantsha cattle post (21° 17' 28.3" S; 25° 31' 51.3" E), twelve kilometres north of Letlhakane village in the Boteti sub-district of the Central District in Botswana (Figures 1 and 2). The cattle post is located near an open pan that collects rain water during the rainy season. Water draining into the pan has created bare patches of ground exposing the subsoil where the cattle congregate to lick the exposed soil. According to Reed (2008), soils around Letlhakane area are characterised by sparse savannah grassland with a high proportion of bare ground known to have very few nutrients for plants to feed on. Thus, plants themselves are not very nutritious for animals, which animals may then need licks and other supplements to meet their nutrient requirements. The soil cover in this area is mainly hard veld characterised by *Acacia erioloba*, *Acacia tortilis*, *Acacia mellifera*, *Bosciaalbitrunca.* Someislands of *Hyphaene*palms are common and some *Adansoniadigitata* (Baobab) trees either solitary or in clumps. Palatable grasses include *Anthephora pubescence*, *Digitariaerianthaa*nd*Schimidtiapappophroides*. Such other grasses like the sandveld cover grasses of *Stipagrostis species* and sour grass*Schmidtiakalahariensis* that provide animals with feed for only a short time when they are still green after the rains cover vast areas of the Boteti sub-district. Since their roots are less substantial, they cannot hold the soil together in the dry season. Additionally, many annual plants provide impressive ground cover after the rains that is short-lived since after a few months, the ground becomes bare again especially in this area. The main activity in this area is mining as there are three diamond mines, with Damtshaa Mine about three kilometres south on the same road to the pan where cattle soil licking has been observed. There is a lot of prospecting and excavations going on in this cattle farming area and with Letlhakane village only 12 km away, there have been a lot other activities that have influenced soil compositional changes. Beef cattle in this area derive most (>95%) of their diet from range plants.

Figure 1. Tswantshacattlepost, Tswantsha pan and Damtsha Mine

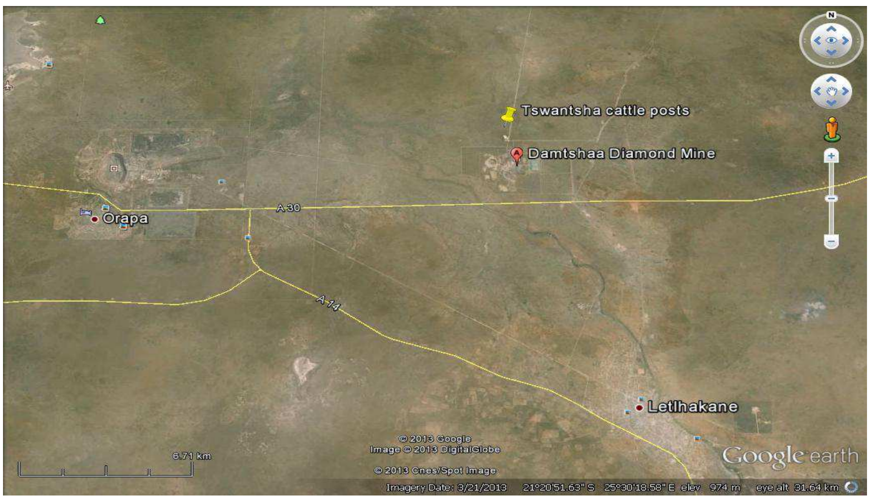

Figure 2. Tswantsha cattlepost and Damtsha Mine

Sampling procedure

Soil samples were collected in a 100 m^2 site from both cattle licked and un-licked soils. An A Z-transect was made in each sampling area and samples were collected at intervals of 10 meters apart. A total of 10 soil samples at a depth of 15-20 cm were collected in plastic bags after removing surface residues. Soil samples were then dried in an oven at 50 ^{o}C in cardboard box containers. The dried soils were then ground to pass through a 2 mm sieve and stored in bottles for subsequent analysis. Different analytical methods of element extraction were then conducted to determine elements in the soils and to compare the concentration levels of the minerals from the two soil sampling sites, to identify which minerals might be leading to soil licking.

Analytical methods

The soil pH was determined in a 1:1 weight/volume soil-water suspension with glass-electrode equipped pH meter (McLean 1982). The clay percentage was determined by the hydrometer method (Gee and Bauder, 1986) while organic carbon was determined by the Walkley and Black method (Nelson and Summers, 1982). Exchangeable basic cations (Ca, K, Mg and Na) and exchangeable acidity were determined by the 1N ammonium acetate method (Thomas, 1982). The effective cation exchange capacity (CEC) was determined by summing the exchangeable bases. Extraction of Zn, Cu, Fe and Mn were determined by the ammonium bicarbonate diethylene-triamine-penta-acetic acid (AB-DTPA) method. Inductively Coupled Plasma Optic Emission Spectroscopy (ICP-OES) instrument (Keren, 1996) was used for quantitative and qualitative analyses of soil minerals.

RESULTS AND DISCUSSION

The concentration levels for Ca and K were the same ($P>0.05$) for each of the minerals between cattle licked and un-licked soils (Table 1). The Ca and K concentrations were adequately supplied within both soils to meet both the requirements of cattle and plants. Potassium is the third most essential element after nitrogen (N) and P to limit plant productivity (Brady and Weil, 1999) and one used in large amounts. Potassium is also moderately mobile in the soil and very mobile in plants (Brady, 1984).

On the other hand, Ca is moderately mobile in the soil but highly immobile in plants. Its abundance may explain its unavailability to plants (Table 4). Calcium is also known to have a negative interaction with P which is known to be deficient in soils in Botswana (Molapong, 1986). Potassium is known to have an antagonistic effect against Ca, however, its occurrence did not to have any influence on the availability of both in the required amounts to both cattle and range plants.

The concentrations for Mg ($P = 0.0012$) and sodium ($P = 0.0015$) differed (Table 1) between the licked and the un-licked soils but were supplied in adequate amounts. Magnesium is a secondary nutrient used in moderate quantities in plant growth. It is moderately mobile in the soil and highly mobile in plants, thus ensuring that it was adequately made available for plant uptake (0.2%) to also meet Mg cattle requirements of 0.10% since the levels recorded were 14.35±0.72% licked and 13.48±1.22% un-licked soils. Moreover, Mg was provided in excess quantities in the soil. Magnesium is very important for chlorophyll formation and enzyme activation in the cytoplasm and is a constituent of the plant cell walls (Barak, 1995; Venkatesan and Jayaganesh, 2010).The Ca:Mg ratios for the two soils are 1.3:1 for licked soils and 1.15:1 for un-licked soil.TheCa:Mg ratio does not signify much but just an illustration of the proportions of the available Ca and Mg in the soil(Peters and Kelling, 2002). Potassium and Ca are antagonistic to Mg, however, their effect was not observed in this study since adequate amounts of Mg were provided to both plants and cattle. Sodium concentrations of 0.92±0.14% licked and 0.78±0.04% un-licked soils (Tables 1 and 4) were adequate for both plants (trace) and cattle requirements of 0.08%. However, animals may lick salt even if their Na requirements have been met because of its palatability. Moreover, salt (sodium chloride) is not required in large quantities by both plants and animals, whereas Ca, Mg, K and Na are normally provided in adequate amounts in arid soils, as observedin the present study. If the plant root zone concentration of any element is too high, then toxicity of that element will result in the retardation of plant growth (Brady, 1984).

There were also no (P>0.05) differences for Zn, Cu, Fe and Mg concentrations in the licked and un-licked soils (Table 2). All the four micro minerals were found to be deficient in both the licked and un-licked soils and thus inadequately supplied for proper plant nutrition that supports appropriate plant growth which plants would provide adequate amounts of the same elements to grazing animals. The concentration of these minerals was ranged from 1.45±0.15 – 2.78±0.15 ppm. Although used in small quantities in both plants and animals, these minerals are essential for appropriate growth. Copper, Zn, Fe and Mn are all immobile in the soil unless provided in chelated forms. Their chelated forms are mobile in the soil but are resistant to leaching for them to reach the root system of range plants where they are required for uptake. Within the plant tissues, these minerals are moderately mobile.

Zinc concentrations of 2.28±0.15 ppm licked and 2.04±0.13 ppm un-licked soils were below the plant requirements of 20 ppm and cattle requirements of 30 ppm. Zinc has an antagonistic relationship with Cu, Fe and Mn. Zinc uptake by plants is usually decreased by high levels of Cu, Fe and Mn and its deficiency is often associated with Mn deficiency. In the soil, Zn assists in the formation of acetate in the roots of plants to prevent rotting (Andersen, 2000) and its uptake from the soil by plants is reduced when soil pH increases (Foth and Ellis, 1988). Zinc deficiency in the soil may be due to the fact that it is easily water soluble, a fact that is exacerbated by its low availability in the soils most of the time (Sait, 2003). At the plant level, Zn is an essential constituent of many enzymes, chlorophyll formation and regulates plant growth (Andersen, 2000; Zimmer, 2000; Walters and Olree, 2006). Grazing cattle consuming range plants deficient in Zn experience a reproductive challenge since Zn is very important in the production of viable spermatozoa (Walters, 2003) and reduced performance and skin disorders (McDowel et al., 1977). Stress in cattle increases their Zn requirement. Zinc also plays a role in influencing the immune function, wound healing and disease resistance. It also assists in vitamin A transportation and utilisation including vitamin E absorption. Some deficiency symptoms of Zn are hair loss, poor growth, stiff joints and unthrifty appearance. Zinc is stored in insufficient amounts in the liver of animals, thus needing to be provided in their diets regularly (McDowell, 1997).

Copper concentration levels of 1.45±0.15 ppm in licked soil and 2.43±0.12 ppm (Table 2) in un-licked soil were far below the plant requirements of 6.0 ppm and 8.0 ppm (Table 4) for grazing cattle. Insufficient amounts of Cu in both soils are worrisome since it is an essential micronutrient for plant growth even though it is used in small quantities. Copper is one of the most essential dietary micronutrients most commonly found to be deficient among grazing cattle (Blezinger, 2002). As mentioned earlier, Cu interacts negatively with Zn, Fe and Mn (Andersen, 2000) and is immobile in soil. However, Cu becomes mobile in plants if chelated so that it can leach into the soil to reach the root system of plants. Copper interacts with several other different minerals some of which were not determined in this study such as cobalt (Co) and molybdenum (Mo). Furthermore, Cu contributes to the plant's elasticity and it is a significant component of many plant proteins such as oxidases. In addition, Cu is a nutrient to many microbes such as *Aspergillusniger*and it is known to control moulds. Copper has been observed to be involved in root metabolism (Walters, 2003) and it complexes with organic matter in the soil solutions for plant use (Foth and Ellis, 1988). Copper is required for bone formation, haemoglobin and red blood cells and proper cardiac function (Kuria et al., 2006). It promotes healthy nerves, healthy immune system and collagen formation (Walters, 2006) and it plays a role in energy transfer, prostaglandins and elastin formation and protects the body from oxidation. Copper deficiency in cattle occurs when the dietary (range plants) level of the mineral is less than 5 mg/kg dry matter or when Mo or sulphur (S) is present in the soil in excess amounts. Many other disorders in grazing cattle are blamed on Cu deficiency. It has been reported that Cu is not translocated in the plant and as such its deficiency symptoms can only be seen on new growing plant parts (Foth and Ellis, 1988). In grazing cattle, Cu deficiency causes anaemia, retarded growth, impaired reproductive performance and heat failure, retained afterbirth, difficulty in giving birth, abnormal hair growth and depigmentation (achromatrichia), and fragile bones (Blezinger, 2002).

The Fe concentration levels were 2.78 ± 0.15^a ppm licked and 2.33 ± 0.10^a ppm un-licked soils (Table 2) compared to the plant requirements of 100 ppm and grazing cattle requirements of 50 ppm (Table 4). The Fe soil concentrations for both soils represented 2.33 – 2.78 % of the actual plant Fe requirements and 4.66 – 5.56 % of the grazing cattle Fe requirements, implying a significant Fe deficiency for both plants and animals in this area. The immobility of Fe in the soil makes it not easily available for plant uptake from the soil. Iron's antagonistic relationship with Zn, Cu and Mn may also reduce its availability to plants if these minerals were present in high amounts in the soil. However, the concentration levels of Zn, Cu and Mn in licked and un-licked soils were similar (Table 2). Iron is said to be the second abundant trace mineral to aluminium since it occupies 5% of the earth's crust making it rarely absent in most soils (Andersen, 2000), however, this was not the case in this study. When forages contain less than 100 ppm of Fe, then Fe deficiency in grazing cattle will be observed (McDowell and Conrad, 1978). The functions of Fe in forages or range plants include formation of chlorophyll, aiding in photosynthesis, involved in the oxidation process that releases energy from starches and enzymes, assisting in the formation of proteins, taking part in the conversion of nitrate to ammonia in the plant tissues and being engaged in the respiration process (Andersen, 2000: Foth and Ellis, 1988). In the presence of P, Fe will bind with phosphates within the plant leading to both minerals becoming unavailable to animals (Zimmer, 2000). Iron deficiency leads to anaemia, reduced weight gain and immune suppression.

In this study, Mn concentration levels were found to be 2.50±0.16 for licked and 2.24±0.16 (Table 2) for un-licked soils, which is far below the plant requirements of 50 ppm and 40 ppm (Table 4) for grazing cattle. These Mn concentrations represented a range of 4.48 – 5.0% for plant requirements and 5.6 – 6.25% for grazing cattle from both soils. Manganese tends to be immobile in the soil and moderately mobile within the plant. It interacts negatively with Zn, Cu and Fe especially when these minerals are in high levels in the soil leading to a Mn deficiency. Contrastingly, Mn has been observed to have a synergistic relationship with Fe working together biologically in ways that are well understood, especially when together at ratios of 1:2 Mn:Fe (SoilMinerals.com, 2013). It has also been reported that an excess of Mn increases the need for Fe (Walters and Olree, 2006). As an essential micronutrient in plant growth, Mn is referred to as the element of life (Andersen, 2000). Manganese is required for chlorophyll production and photosynthesis, nitrogen and carbohydrate metabolism, redox processes, activity of several enzymes and combines with Zn, Cu and Fe to assist in plant growth processes (Walters and Olree, 2006). Lang *et al.* (1976) reported low levels of Mn in some Latin American countries. Like with Fe, Mn deficiency is seldom observed in ruminants (McDowell and Conrad, 1978) but Rojas *et al.*, (1965) reported delayed oestrus and conception, reduced fertility, abortions and calves born with neonatal skeletal deformities and reduced growth rate.

The mean soil pHfor both licked and un-licked was the same (P>0.05) and pretty normal (Table 3). However, some sampling sites recorded pH above 7.0 implying a somewhat sandy type of soil since most of the essential minerals were found. About 98% of the nutrients used by plants are taken up from the soil solution and pH has significance on this nutrient availability. Potassium is highly available at a soil pH greater than 5.5; Ca is highly available at a range of between 5.5 -9.0, whereas Mg is mostly available in higher amounts between 4.5 and 7.0. Zinc availability ranges from below 4.0 – 8.5 gradually increasing to 10.0; Fe from 4.0 – 10; Cu from 4.5 – 7.0 gradually increasing to 10.0; and Mn from 1.0 – 6.5 and significantly becoming unavailable and then increasing in availability beyond 8.0 when using Lucas and Davis (1961) scale showing the influence of pH on the availability of plant nutrients in organic soils. On the contrary, Nelson (1968) showed that all the macro and micro elements are available in varying amounts in both organic and mineral soils between a pH range of 4.5 – 9.5, and this range has been designated neutral. Generally, availability of Ca is reduced by low or acidic soil pH while Mg is reduced in sandy acidic soils. Soil pH will negatively affect the availability of Zn, Cu, Fe and Mn. Soil pH interacts with some minerals, for example, Zn uptake by plants may be reduced by an increase in pH (SoilMinerals.com, 2013). It has also been observed that both Fe and Mn become less available at pH 7.0 and above. Additionally, lowering pH may alleviate the problem of Fe binding with P to form iron phosphate resulting in Fe and P deficiency in the grazing cattle diet (Foth and Ellis, 1988). It has also been shown that in wet acid soils with a pH below 5.0 that naturally contain high amounts of Mn, toxicity to plant roots can occur from soluble Mn (SoilMinerals.com, 2013).

In the present study, it has been shown that Ca, K, Mg and Na were present in adequate concentrations in both the licked and un-licked soils, whereas Zn, Cu, Fe and Mn were very much deficient in these soils. As a result, grazing cattle that will actively look out for soil to lick are probably missing something in their diets such as minerals that are deficient in the forages that they consume in order to meet their mineral or nutrient requirements. The supply of essential inorganic elements to grazing cattle is based on the licking of the soil, the concentration and availability of the minerals in the licked soil. It should be appreciated that the licking behaviour does not start to select for those deficient minerals but that soil licked would contain all the minerals determined (there is no selective process) together with those not determined. Additionally, the actual amounts consumed are not known and only the individual animal determines its satisfaction threshold according to its nutrient need at that particular time.

CONCLUSION

Grazing cattle licked the soil in search of Zn, Cu, Fe and Mn that were not available in adequate concentrations to meet their requirements for these essential minerals. The results of this study have shown that these micronutrients are essential for both plant and animal performance. Grazing cattle performance in the present study may be greatly affected by the prevailing state of the soil in this area as it influences both plant productivity (biomass) and quality (nutritive value).

REFERENCES

Ammerman, C. B., Validivia, R., Rosa, I. V.., Henry, P. R., Feaster, J. P. and Blue, W. G. (1984).Effect of sand or soil as a dietary component on phosphorus utilisation by sheep. AnimSci 59: 1092-1099

Andersen, Arden (2000). Science in Agriculture, Advanced Methods for Sustainable Farming, Acres, USA. http://www.soilminerals.com/information.htm. Retrieved 2013/12/31.

Beyer, W. N., Connor, E. E. and Gerould, S. (1994). Estimates of soil ingestion by wildlife. The J Wildl Manage, 58(2): 375-382.

Blezinger, S. B. (2002). Some trace minerals play important role in cattle's diet. Cattle Today, Online.Howard Bros Farms, LLC.http://www.cattletoday.com/archive/2002/October/CT236.shtml. Retrieved 2013/12/31.

Brady, Nyle, C. (1984). The Nature and Properties of Soils 9th Edition, Collier MacMillan, ISBN0-02-946030-1

Brady, N. C. and Weil, R. R. (1999).The nature and properties of soils. 12th Edition, Prentice Hall, ISBN 0-13-852444-0

Barak, Phillip (1995). Essential elements for plant growth.Primary and secondary nutrients. University of Wisconsin, 17th October, 1995. http://soils.wisc.edu/facstaff/barak/soilscience326/primary.ht. Retrieved 05/01/2014.

Foth, H. D. and B. G. Ellis (1988).Soil Fertility. John Wiley and Sons, New York, pp 202-204. ISBN 0-471-82507-7.http://www.soilminerals.com/information.htm. Retrieved 2013/12/31.

Gees, G. W. and J. W. Bauder,(1986). Particle size analysis. In: A. Klute (ed.), Methods of Soil Analysis Part 1. Physical and Mineralogical Methods, 2nd Edition, 9 (1): 383-411, American Soc. Of Agron., Madison, WI.

Grusak, M. A. and Dellapnna (1999).Improving the nutrient composition of plants to enhance human nutrition and health.Annu Rev Plant PhysiolMolBiol, 50:133-161.

Healy, W. B. (1973). Nutritional aspects of soil ingestion by grazing animals, p. 567-588. In: G. W. Butler and R. W. Bailey (ed.), Chemistry and biochemistry of herbage, Academic Press, New York.

Healy, W. B. (1968a). Ingestion of soil by dairy cows. New Zealand Journal of Agricultural Research 11:487-499.

Healy, W. B. (1968b). The influence of soil type on ingestion of soil by grazing animals. International Society of Soil Science Transactions, 9th Congress 3:437-445.

Keren, R. (1996). Boron. In: D. L. Sparks (ed.) Methods of Soil Analysis, Part 3, Chemical Methods. Soil Sci. Soc. America, Book Series No. 5.

Kruelen, D. A. (1985). Lick use by large herbivores. A review of benefits and banes of soil consumption manual. Revue, 15: 10-123.

Kuria, S. G., R. G. Wahome, M. M. Wanyoike and C. K. Gachuiri (2006).Effect of mineral supplement on plasma minerals concentration of camels (Camelus dromedaries) in Kenya. Int J AgricBiol, 8(2): 168-171.

Lang, C. E., L. R. McDowell, J. H. Conrad, and H. Fonseca (1976). Estado mineral del Ganado en Guanacaste, Costa Rica. *ALPA Memoria*, 11: 79-80.

Lucas, E. E. and J. F. Davis (1961).Relationships between pH values of organic soils and availability of 12 plant nutrients. Soil Sci., 92: 177-182.

McDowell, L. R (1997).Minerals for grazing ruminants in tropical regions. Animal Science Department, Centre for Tropical Agriculture, University of Florida, Gainesville, USA.

McDowell, L. R. (1992). Minerals in Animal and Human Nutrition. Academic Press: San Diego. USA.

McDowell, L. R. and Conrad, J. H. (1978). Trace mineral nutrition in Latin America. In Ruminant Nutrition: Selected articles from World Annual Review. http://www.fao.org/docrep/004/x6512e/x6512e18.htm. Retrieved 2013/12/31.

McDowell, L. R, Fick, K. R., Houser, R. H. Conrad, J. H. and Loosli, J. K. (1977). Meeting minerals requirements for grazing livestock in the tropics.Symposium on feed composition, animal nutrient requirements, and computerization of diets, Utah State University, Logan.

McLean, E. O. (1982). Soil pH and lime requirements. In: A. L. Page (ed), Methods of Soil Analysis. Part 2.Chemical and Microbiological Properties. 2nd Edition, 9 (2): 199-224, American Soc of Agron., Madison, WI

Molapong, K. F., (1986). Phosphate sorption and its relation to soil properties.MSc Thesis, Department of Geology and Soil Fertility and Management, Agricultural University of Norway, As, Norway.

Nelson, L. B. (1968). Changing patterns in fertiliser use.Soil Science Society America, Madison, WI, USA.

Peters, J. and Kelling, K. (2002). Soil Fertility Influences on Cation Levels in Forages. Focus on Forage, Vol 4: No.2, University of Wisconsin, Madison, WI.

Reed, M. S., (2008). Stakeholder participation for environmental management: A literature review. Biological Conservation 141: 2417 – 2431.

Rojas, M. A., I. A. Dyer and W. A. Cassatt.(1965). Manganese deficiency in the bovine. J AnimSci, 24: 664-667.

Sait, Graeme (2003). Nutrition Rules Guidelines from the Master Consultants, 22 Inspiring Interviews. http://www.nutri-tech.com.au/newsletter.html

SoilMinerals.com (2013). Soil Minerals and Soil Testing for Organic Gardeners. Agricola's Best Soil Mineral Supplements. The function of soil minerals and trace elements in soil, plant, animal, and human nutrition and health.http://www.soilminerals.com/information.htm. Retrieved 2013/12/31.

Thomas, G. W. (1982). Exchangeable cations. In: A. L. Page (ed.), Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties (2nd Ed.) Agron. 9: 159-165.

Venkatesan, S. and Jayaganesh, S. (2010).Characterisation of Magnesium toxicity, its influence on amino acid synthesis pathway and biochemical parameters of tea. Res J Phytochem, 4: 67-77.

Walters, C (2003). Eco-Farm, Acres USA. Primer: The definitive guide to managing farm and ranch soil fertility, crops, fertilizers, weeds and insects while avoiding dangerous chemicals (Acres U.S.A., 3rd Revised edition, June, 2003)http://www.soilminerals.com/information.htm. Retrieved 2013/12/31.

Walters, C. and R. Olree (2006).Minerals for the genetic code, Acres, U.S.A. http://www.soilminerals.com/information.htm.Retrieved 2013/12/31.

Zimmer, Gary (2000). The Biological Farmer: A complete guide to the sustainable and profitable biological system of farming, Acres USA. http://www.soilminerals.com/information.htm. Retrieved 2013/12/31

Table 1 Mean concentrations (%) of major minerals of cattle licked and adjacent un-licked soils

Mineral	Sampling site	Sampling points										Mean	P-value
		1	2	3	4	5	6	7	8	9	10		
Ca	1	18.64±0.16	19.26±0.13	18.21±0.09	19.11±0.11	18.34±0.12	18.56±0.11	18.12±0.17	19.99±0.11	18.92±0.13	17.23±0.23	18.64±0.75[a]	0.873
	2	17.65±0.11	16.93±0.16	16.76±0.15	17.43±0.12	18.67±0.15	17.23±0.12	16.87±0.09	18.33±0.18	16.45±0.11	17.78±0.13	15.57±0.71[a]	
K	1	1.97±0.11	2.08±0.2	2.27±0.12	1.65±0.13	1.06±0.17	1.00±0.22	2.30±0.12	2.59±0.14	3.23±0.13	2.90±0.23	2.11±0.72[a]	0.1135
	2	0.99±0.09	1.23±0.1	1.46±0.11	1.76±0.14	1.87±0.08	2.03±0.10	1.08±0.13	2.11±0.15	1.99±0.11	1.34±0.11	1.59±0.42[a]	
Mg	1	14.34±0.12	14.58±0.14	13.99±0.13	14.31±0.16	13.89±0.13	14.13±0.13	14.85±0.14	13.96±0.11	14.67±0.14	14.82±0.18	14.35±0.35[a]	**0.0012**
	2	13.93±0.12	14.32±0.11	11.34±0.14	14.87±0.13	13.92±0.06	14.27±0.19	13.91±0.14	13.45±0.13	11.24±0.11	13.57±0.11	13.48±1.22[b]	
Na	1	0.86±0.11	0.86±0.11	0.83±0.13	0.84±0.14	0.84±0.14	0.85±0.12	0.85±0.12	0.85±0.12	1.18±0.10	1.23±0.11	0.92±0.14[a]	**0.0015**
	2	0.73±0.11	0.85±0.10	0.76±0.11	0.78±0.11	0.76±0.11	0.74±0.12	0.85±0.15	0.77±0.11	0.82±0.11	0.73±0.10	0.78±0.04[b]	

[a,b]Means in the same column with different superscripts are significantly different at $P<0.05$

Table 2 Mean concentrations (ppm) of minor minerals of cattle licked and adjacent un-licked soils

Mineral	Sampling site	Sampling points										Mean	P-value
		1	2	3	4	5	6	7	8	9	10		
Zn	1	1.45±0.10	2.25±0.11	2.25±0.01	3.07±0.11	2.89±0.12	1.94±0.11	2.20±0.17	2.47±0.13	2.12±0.16	2.17±0.15	2.28±0.15[a]	0.7112
	2	1.36±0.12	1.66±0.11	2.34±0.11	2.91±0.13	1.98±0.14	2.01±0.15	2.02±0.13	2.05±0.11	2.03±0.10	2.08±0.12	2.04±0.13[a]	
Cu	1	2.38±0.11	2.91±0.13	2.91±0.12	3.20±0.11	2.30±0.14	1.97±0.13	2.21±0.12	1.99±0.13	1.78±0.13	1.79±0.11	1.45±0.15[a]	0.4041
	2	2.30±0.11	2.40±0.12	2.56±0.12	3.34±0.11	2.03±0.11	2.04±0.13	2.32±0.12	2.67±0.14	2.45±0.12	2.23±0.12	2.43±0.12[a]	
Fe	1	1.82±0.12	2.54±0.11	2.89±0.13	2.89±0.14	2.71±0.11	3.02±0.11	3.00±0.16	3.15±0.13	3.32±0.12	2.04±0.14	2.78±0.15[a]	0.2062
	2	1.90±0.12	2.50±0.10	2.90±0.10	2.64±0.11	2.45±0.10	2.34±0.09	2.12±0.19	1.98±0.10	2.34±0.12	2.12±0.10	2.33±0.10[a]	
Mn	1	1.93±0.12	2.90±0.13	3.02±0.11	3.02±0.11	2.99±0.12	1.78±0.14	2.89±0.11	2.13±0.10	2.12±0.13	2.14±0.12	2.50±0.16[a]	0.9609
	2	1.56±0.12	1.58±0.15	3.06±0.17	2.99±0.15	2.46±0.14	2.12±0.14	2.01±0.17	2.24±0.17	2.27±0.11	2.10±0.11	2.24±0.16[a]	

[a,b]Means in the same column with different superscripts are significantly different at $P<0.05$

Table 3 Soil pH at different sampling points for the cattle licked and un-licked soils

Sampling point	Cattle licked soil	Un-licked soil
1	6.80±0.12	6.14±0.12
2	6.79±0.21	6.76±0.32
3	6.84±0.21	6.73±0.12
4	6.72±0.17	6.77±0.14
5	7.20±0.12	6.80±0.13
6	6.83±0.11	6.72±0.11
7	7.13±0.31	6.83±0.13
8	7.11±0.32	6.78±0.13
9	6.74±0.12	7.12±0.11
10	6.70±0.11	6.89±0.13
Mean	**6.88±0.35**	**6.75±0.34**
P-value	**0.435**	

Table 4 Comparison of mineral requirements for beef cattle and plants to mineral content of licked and un-licked soils

Mineral	Cattle requirements	Cattle requirement range	Plants requirements	Mineral concentrations: Cattle licked soil mean concentrations	Mineral concentrations: Adjacent un-licked soil mean concentrations	Adequacy for plant nutrition
Calcium (%)	0.45	0.3 – 0.6	0.5	18.64±0.75[a]	15.57±0.71[a]	Excess
Potassium (%)	0.65	0.5 – 0.7	1.0	2.11±0.35[a]	1.59±0.42[a]	Adequate
Magnesium (%)	0.10	0.05 – 0.25	0.2	14.35±0.72[a]	13.48±1.22[b]	Excess
Sodium (%)	0.08	0.06 – 0.10	trace	0.92±0.14[a]	0.78±0.04[b]	Adequate
Zinc (ppm)	30.0	20 - 40	20	2.28±0.15[a]	2.04±0.13[a]	Inadequate
Copper (ppm)	8.00	4 - 10	6	1.45±0.15[a]	2.43±0.12[a]	Inadequate
Iron (ppm)	50.0	50 - 500	100	2.78±0.15[a]	2.33±0.10[a]	Inadequate
Manganese (ppm)	40.0	20 - 50	50	2.50±0.16[a]	2.24±0.16[a]	Inadequate

[a,b]Means in the same row with different superscripts are significantly different at P<0.05
Sources: Epstein (1965); Brady and Weil (1999)