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SOIL CHARACTERIZATION IN CONTRASTING CROPPING SYSTEMS UNDER THE FAST TRACK LAND REFORM PROGRAMME IN ZIMBABWE

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ABSTRACT

Soil fertility depletion is a major limitation to crop production in sub-Saharan Africa and Zimbabwe is no exception to this phenomenon. This research was conducted to assess the soil chemical characteristics in three contrasting cropping systems of Zimbabwe. The contrasting production systems under study were communal area, A2 (large scale resettlement) and A1 (small scale resettlement).All these systems are in Manicaland province, Zimbabwe. The A1 and A2 production systems were brought about during the 2000 land reform programme. The soil samples were collected during the off season of 2006, 2007 and 2008. The following soil chemical characteristics were determined: Ca, Mg, K, Zn, pH and organic matter. There were significant differences ($P=0.001$) between the production systems and soil chemical properties. Calcium, magnesium and potassium levels were generally low in all the three production systems. This was due to low soil pH. However, A2 farms had significantly the highest ($P<0.05$) Ca, Mg and K while communal area had significantly the lowest ($P<0.05$) soil organic matter content. The soil organic matter content in A2 farms can sustain plant growth. This could also be compounded by good land management practices such as fertilisation and liming. However, there may be need for the communal and A1 farmers to apply organic matter so as to boost SOM in their fields. The optimum soil organic matter in Zimbabwe is from 1.5% to 5%. Results showed that soil pH was between 5.0 and 6.8 (slightly acidic), in all the three production systems. However, it was strongly acidic in communal areas at 0-30cm depth. Soil acidity in communal areas impacted negatively on the yield of maize and groundnut. In the A1 and A2 farms acidity levels may sustain the production of crops like tobacco and sunflower. Generally, there is need for the farmers in the three production systems to lime the soils and improve their organic matter through addition of crop residues and cattle manure.

Key words: soil nutrients, farmers, land systems

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INTRODUCTION

The problem of cation depletion is attributable to their leaching through long-term weathering and replacement by aluminium (AL) and hydrogen (H) [1]. In acid soils, which can have highly exchangeable Al, Ca concentration becomes low [2]. Liming such soils increases soil pH, through increasing saturation of the exchange complex with the Ca. In acidic sandy soils (primarily quartz sand) Ca deficiencies may be expressed [1, 3]

The other major element to crop production is potassium (K), which is an activator of enzymes that are responsible for energy metabolism, starch synthesis, nitrate reduction and sugar degradation [1, 3]. In maize and other cereals it is essential for building strong stalks and good root systems. It also helps the cereals in manufacturing sugars and starch and thus increases the carbohydrate content of the plants [4].

The magnesium (Mg) is chemically similar to the calcium ion. Nevertheless, there are important differences in the behavior of these ions in soil and plants. Magnesium is the only metallic element of chlorophyll and is vital to photosynthesis because every molecule of chlorophyll contains a magnesium ion at the core of its complex structure [1].

A monoculture production system may lead to a decline in soil fertility and an increase in soil acidity because of depletion of basic cations, especially Ca and Mg, thereby increasing the amount of heavy metals such as Iron (Fe) and Aluminum (Al) [5,6]. Both extremely alkaline and extremely acid conditions are unfavorable to plant growth and development. A high degree of acidity (below pH 5.5) may trigger the release of aluminum and manganese at toxic levels, while strong alkalinity (above pH 8.0) impairs uptake by the root of micronutrient element cations, such as copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) [3, 6]. Acid soils will make essential nutrients unavailable. Most crops tolerate pH between 5.0 and 7 [6, 7].

Zinc is found in small amounts but is essential for sucrose formation, metabolism, photosynthesis, seed maturation and growth [1, 3]. It activates certain dehydrogenase enzymes; it facilitates sugar translocation and synthesis of nucleic acids and plant hormones essential for cell division and development [3, 7]. Soil Zn concentrations of between 20 and 40 parts per million (ppm) are reasonable for most crops [1].

The other factor that may affect zinc availability is soil reaction (.1). At pH values greater than 7.4, zinc availability is low. At high pH of more than 7.7, Zn precipitates as insoluble amorphous soil zinc, $ZnFe_2O_4$ and/or $ZnSiO_4$, which reduces Zn ions in the soil [3].

Soil organic matter is a complex mixture of living, dead, and decomposing material and inorganic compounds [8]. The organic matter is a major source of plant macronutrients such as N, P and S. These nutrients can be held in covalently bonded

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compounds or be present on the soil organic matter exchange complex [3, 7]. In addition, soil organic matter contains micronutrients essential for plant growth [7, 9].

One of the most significant chemical properties of soil organic matter is its high ion exchange capacity. The mechanism of the high cation exchange capacity (CEC) of these materials is the ionization of the H^+ from a carboxyl or phenolic hydroxyl groups resulting in negatively charged sites [2,4]. Increasing the soil organic matter of a particular soil will increase the retention of the water over the range that is available to plants.

In the year 2000, the Government of Zimbabwe embarked on the fast track land reform programme (FTLRP). This fast track land reform program has brought about new crop production systems. These new systems have seen agricultural production decline by 20% [9]. The purpose of this paper was to assess the dynamics of Ca, Mg, K, Zn, soil pH and OM in the contrasting farming systems of Zimbabwe.

METHODOLOGY

Locality and ecology of the site: Mutare District is situated in Manicaland Province in the Eastern Border Highlands of Zimbabwe. It lies at an altitude of 1100 m above sea level, longitude 32° 38` E and latitude 18° 58` S. In Mutare District, rainfall is mono-modal and is received between the month of October and March of the following year. Mutare District receives an average of 760 mm per annum. Communal are farmers in communal areas, AI are small-scale farmers under The Fast Track Land Reform Programme and A2 are large-scale resettled farmers. The soils on the sites are classified as humic Ferralsols based on the FAO/UNESCO system and are equivalent to a Kandiudalfic Eutaudox in the USDA Soil Taxonomy System [10, 11].The soils are predominantly of the kaolinitic order with loamy sands of low fertility [6]. The crop production systems under study were communal farming systems (Dora farming area), large- scale resettlement (A2) and small- scale resettlement A1.

Cropping systems: Farmers in Dora communal areas grow mainly maize, paprika, groundnuts, sorghum, sunflower and bambara nuts. From 2000 to 2007, most of the communal farmers practiced either maize-maize-paprika-groundnut or groundnut-groundnut-groundnut-sunflower rotation rotations. The average yield for the past seven seasons were 0.2 t $ha^{-1}$for maize, 0.3t $ha^{-1}$for groundnuts, 0.1 t ha^{-1} for bambara nuts and 0.1 t ha^{-1} for sunflower.

The A1 farmers from Odzi grow mainly maize, sunflower and groundnuts. These farmers had an average seven-year yield of 1, 0.1 and 0.5 t ha^{-1} for maize, sunflower and groundnuts, respectively. The A2 farmers from Mutare large scale farming area grow mainly soyabeans, wheat, maize and groundnuts. These farmers had an average seven- year yield of 1.5, 0.9, 0.5 and 0.5 t ha^{-1} for maize, wheat, soyabeans and groundnuts, respectively.

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Soil sampling: The soil samples were collected during the off season of 2006, 2007 and 2008 from contrasting cropping systems, namely A1, A2 and communal. Twenty samples were randomly collected from 0-30 cm and 30-60cm depths of each farming system. These depths were chosen considering the effective rooting depths of most crops grown in the area under study. This gave a total of 60 samples. A 50mm diameter auger was used to collect the samples from each farmer's field under study. The sub-samples were mixed thoroughly to make up the composite sample. The composite sample was then rolled using a metal roller so as to break the clods in the soil. The sample was then passed through a sieve with an allowance of 2mm to obtain a fine sample for the analyses of bases, Zn and pH.

Soil analyses: The soils were analyzed for Ca, Mg, K, Zn, pH and OM. The analyses of the mentioned nutrients were done using standard procedures as described by AOAC [12].

Statistical analysis: Data were analysed by standard (ANOVA) SAS statistical package [13]. The data were inferred using $P<0.05$.

RESULTS

Calcium, Magnesium and Potassium

Levels of calcium and magnesium were significantly different ($P<0.05$) for the 0-30cm and 30-60cm depths (Table 1). The exchangeable base levels seem to increase down the profile. A2 system had the highest Ca and K contents and A1 had the highest Mg levels at 0-30cm depth. At 30 -60 cm Ca, Mg and K was highest in communal, A1 and A2, respectively.

Zinc

Figure 1 indicates that there was a significant difference ($P<0.05$) of Zn levels across the farming systems and depth. There was more Zn in the 30-60 cm than the 0-30 cm depth in each farming system. Zn levels were highest in sub-soil of small scale farming blocks, giving an average of A1 at 5 ppm. They were lowest in the top soil of commercial scale farming blocks.

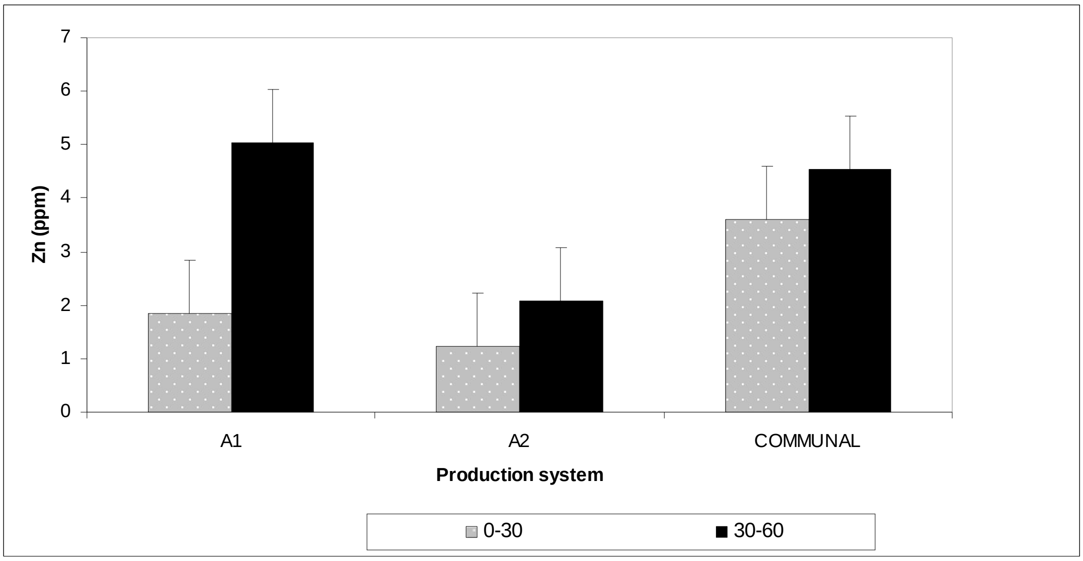

Figure 1: Zn (ppm) trends in the soil of the three production systems

Soil pH

Soil pH for communal areas was significantly different ($P<0.05$) at the two depths (Figure 2). Soils from the 3 different crop production systems are predominantly acidic in the top soil of 0-30cm (Figure 2). Some soils from communal farming areas were strongly acid and soils from A1 and A2 farms are of medium and slight acidity, respectively.

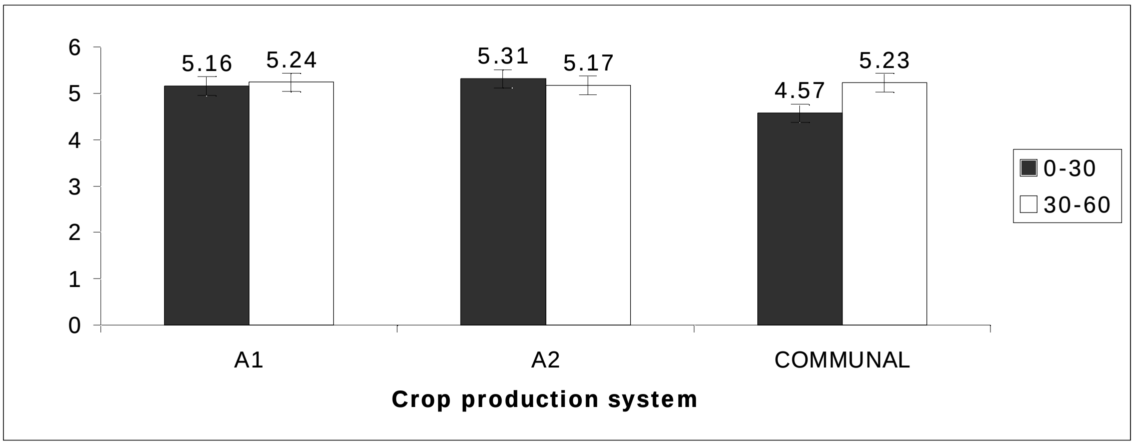

Figure 2: Soil pH levels in the different crop production systems at depths of 0-30cm and 30-60cm

Soil Organic Matter

Soil organic matter levels were significantly different ($P<0.05$) across all the production systems (Table 2). In all the production systems, SOM was higher at 0-30 cm than 30-60 cm depth as expected.

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DISCUSSION

Calcium levels were low at both the 0-30cm and 30-60cm depths in communal farms. The communal soils are prone to acidity and hence toxic metals are readily available and limit the uptake of the bases. These results are consistent with the findings by Tisdale, *et al.* [3], which showed that the acidity and toxic metals are major limiting factors on the availability of bases.

In Zimbabwe Ca deficiency in most soils is rarely observed [1, 5]. The soils in the communal areas have low calcium levels mainly because of growing groundnuts, which extract a large amount of the nutrients. The study also showed that soil pH played a part in limiting Ca availability in the soil. The high Mg in the soils may have depressed the availability and uptake of the Ca [1].

In A1 and A2 production systems Ca was deficient and Mg levels are adequate to support crop growth. Mg and Ca levels are higher on A2 farms than the other two crop production systems, perhaps due to better agronomic practices such as regular liming of the soils. The Ca: Mg imbalance in favour of Mg, perhaps due to use of a *dolomitic* lime In Zimbabwe Mg is more likely to be deficient in sandy soils that have been cropped with fertilizers alone [1, 5]. Low Mg levels are attributable to low pH levels, which are acidic in the A1 farms and the Communal farms.

The Mg levels of the A2 seem to be lower than those of communal farms. The main reason for this may be the rye grass that is grown in the A2 farms. Forage grass extracts a lot of the magnesium from soils and can heavily deplete the soils [5]. Factors such as low organic matter, crop grown and rainfall distribution may have contributed to the observed decreased Mg.

Soil pH trends

Soils from the three cropping systems have pH values between 4 and 8 [6]. Nearly all soils with pH values above 8 have high percentages of Na. Most soils with pH values below 4 contain Al and other toxic metals [4, 6]. Soil pH influences the solubility of minerals and ultimately the concentration availability and absorption of elements by plants.

In Dora, the soils are acidic perhaps due to the continuous monoculture and poor agronomic practices. The top 0-30 cm is highly acidic and, therefore, these soils need liming. Lime rate of about 600 kg ha^{-1} is recommended [1]. The results showed that when the soil is highly acidic (as in the communal production systems), OM, Ca, Zn, Mg and Cu would be less available for crop production

The study also indicated that soil acidity was not the only factor that is responsible for limiting the nutrients and organic matter in the soil. These soil fertility aspects in Zimbabwe need to be investigated further so as to determine the major factors affecting nutrient availability and organic matter content. Generally, it can be noted that exchangeable bases increase with depth.

CONCLUSION

The results clearly showed that the communal and A1 crop production systems have serious fertility problems, which need addressing. This soil fertility decline especially in communed areas could be attributed to poor farming practices, which lead to soil acidity and leaching of bases [3]. Small-holder farmers could benefit more if they addressed these soil fertility problems by using legumes and liming the soils. The results of this work have demonstrated the importance for farmers to constantly sample and analyse their soils before they plant any crop.

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Table 1: Ca, Mg and K levels (meq %) and trends in the topsoil (0-30) and sub-soil (30-60) cm in the production systems

	Top soil			Subsoil		
Production system	***Ca***	***Mg***	***K***	***Ca***	***Mg***	***K***
Communal	0.6a	0.6a	0.2a	1.8a	2.8a	1.1a
A1	0.4c	0.4c	0.5c	0.5b	1.9b	1.8b
A2	2.3b	2.1b	1.1b	1.6c	4.1c	1.2c
Sig	*	*	*	*	*	*
CV (%)	13	15	18	11	20	12

Means within the same column followed by different letters are significantly different at P< 0.05 and those followed by the same letter are non-significantly different. = significantly different at P<0.05*

Table 2: Comparison of SOM contents among the three cropping systems

Soil depth (cm)	**Communal**	**A1**	**A2**
0-30	0.08 *a*	0.07a	0.7*a*
30-60	0.01 *b*	0.03b	0.1*b*
Sig	*	*	*
CV (%)	19	17	13

*Means within the same column followed by different letters are significantly different at P< 0.05 and those followed by the same letter are non-significantly different. * = significantly different at P<0.05.*

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