Working with Communities to Improve Soil Productivity: Sadziwa Ward, Zimbabwe

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Abstract

The study was done in Sadziwa ward of Mutasa West district in Eastern Zimbabwe. The aim of the study was to establish soil fertility levels and relate them to community perceptions. Soil sampling was done together with farmers and the samples were sent for laboratory analysis. A questionnaire survey on farmers' perceptions on soil fertility was conducted concurrently. The results showed that the available levels of Nitrogen, Phosphorus and Potassium were not adequate for plant growth. The mean pH values (0.01M$CaCl_2$ scale) of sandy, loamy sandy and clay soils were 5.42±1.16; 4.75±0.21; and 5.9 respectively. Except for the clay soil the other soils require liming. While acknowledging the effect of crop removal on nutrient depletion, 70% of the respondents singled out nutrient loss due to soil erosion as the major cause of low crop yields. Interestingly all farmers interviewed did not have knowledge of soil pH. Farmers indicated that they are willing to embark on fertility management provided it increased their yields from the current mean yield of 0.5t/ha to 3 – 5t/ha for maize. It was concluded that extension should refocus and include farmer education on the concept of soil pH and fertility management based on soil tests. In addition soil erosion control should be a major component of soil management.

Key words: soil fertility, farmers' perceptions, sustainable production, empowerment.

Introduction

Whilst emergency food and agricultural input programmes remain top on the priority list of most Sub-Saharan African countries, there is need to pursue long term development opportunities. Clay, *et al* (2002) prioritises the need to reverse a generation of decline in agricultural productivity as a major challenge for Africa, particularly because prospects for sustainable development for the foreseeable future are clearly linked to the sustainability of agricultural production (Chenje *et al*, 1998).

For an agricultural system to be sustainable it must be soil restorative, that is the productivity, quality and capacity of soil must be preserved and improved (Rattan, 1995). The need for restoration of soil productivity is pertinent in Africa where 23% of the farming population ekes out a living in soils of low quality (Brady and Weil, 2002) and the situation is continuously worsening. Nutrient studies involving the major plant nutrient elements: Nitrogen (N), Phosphorus (P), and Potassium (K) on farm lands of eight Sub-Saharan African countries: Cameroon, Ethiopia, Ghana, Kenya, Malawi, Senegal, Tanzania and Zimbabwe showed a negative balance, suggesting a decline in soil quality, (Stoorvogel, *et al*, 1993). Overall Sub-Saharan African countries are losing an estimated 6.1 million Mg N, 0.74 Mg P and 4.6 Mg K each year from their cultivated lands and very low rates of fertilizer application, commonly less than 10 kg/ha, simply do not replace the nutrients removed (Stoorvogel, *et al*, 1993).

In Zimbabwe, cultivation of marginal land resulted from historical and socio-economic factors such as inequitable distribution of land (Whitlow, 1988). In these areas the levels of crop yields have either remained static or shown declining trends.

Soil sampling and testing provides a natural starting point for improvement of soil productivity. Unfortunately soil analyses for fertility determination are usually done as once off exercises without follow-ups to monitor nutrient trends in communal areas. Fertilizer application in most cases is based on general guidelines, a situation that is not conducive for sustainable nutrient management. Failure to undertake soil analyses has been blamed on lack of financial resources and ignorance by communal farmers. Participatory approaches which enable farmers to analyse their knowledge of life and conditions to plan and to act (Chambers, 1994) provide a realistic opportunity for adoption of soil testing by the rural people.

To be acceptable to farmers, soil fertility technologies have to integrate well into existing farming systems and offer something new (Mekuria and Waddington, 2002) hence it is imperative that communal farmers' perceptions on causes of low productivity are investigated so as to develop measures that are cognisant of farmers' concerns. The objectives of the study were to determine the pH and the levels of N, P and K in different soils in the study area and to assess the local community's perceptions on causes of low soil productivity in their area.

Materials and Methods

Study area

Sadziwa ward is located in Mutasa West district in Eastern Zimbabwe. The dominant soil types are granite-derived sands and loamy sands. The area receives a mean annual rainfall of 800-1000mm during the period November to April. A survey by the NRI (1993) on Communal Areas showed that more than 50% of the area is non-arable due to rugged and rocky terrain.

Sampling Procedure

Soil sampling was done for pH measurement and determination of N, P and K levels in fields planted to maize during the previous season. Maize fields were selected because they are often preferentially fertilized so their fertility levels will usually reflect the best levels attainable in cultivated lands in the area. Areas to be sampled were blocked on the basis of soil texture.

After a soil survey it was established that there were three major soil types: sand, loamy sand and clay. The maize fields were sampled as follows: Seven maize fields had clayey soils and two were sampled; eight maize fields were on loamy sands and two were sampled. The majority of maize fields (79) were on sandy soils and 9 of them were sampled. Selection of fields to be sampled was done randomly within the blocks.

Soil sampling was done in the dry season (May 2003) to allow time for corrective measures to be made before planting of subsequent crops. The sampling process was conducted together with farmers who provided valuable cropping histories of sampled fields and this was also viewed as a way of enhancing chances of adoption of the practice by the farmers. The soil samples were taken to a depth of 23cm which is the normal plough depth for an ox-drawn mouldboard plough. At least 10 samples were collected in each field and mixed to give one composite sample. From the composite samples, sub-samples weighing 1kg were taken to the laboratory for fertility tests.

In order to assess the community perception on causes of low soil productivity questionnaires were used. The questionnaires were completed by the interviewer so as to give room for some added probing and reduce errors due to interpretation. Simple random technique was used, in which each household from the study area had an equal chance of being chosen. This was done with the help of village representatives who supplied the household names after which a draw was conducted to find the households, which were to be interviewed. The total number of interviewed households was 120 out of 1027 households in the study area, giving a sampling intensity of 12 %.

Data analysis

The soil results were analysed using SPSS package Version 10. A one sample T-test was used to determine the significance of differences between the observed pH and nutrient levels and the critical limits at which soil nutrient levels become deficient.

It was assumed that the different fields were under similar management levels so that the differences in nutrient levels could be compared and averaged.

Results

The mean nutrient levels and pH values of the soils relative to critical limits at which plants do not thrive are shown in Table 1.

Table 1. Observed mean available nutrient levels, pH values and their critical limits in Sadziwa soils.

Soil type	**Nutrient status**	**Nitrogen (ppm) ±SD**	**Phosphorus (ppm) ±SD**	**Potassium (mg per 100g ±SD**	**pH ($0.01MCaCl_2$) ±SD**
Sand	Available	36.56± 11.17	25.11± 21.40	0.21± 0.12	5.42±1.16
	Critical	30	30	0.1	4.5
Loamy sand	Available	50.00±26.87	11.50 ±3.54	0.25 ±0.12	4.75±0.21
	Critical	30	30	0.2	4.5
Clay	Available	89.00±55.15	73.50 ±20.51	0.27 ±0.00	5.90±0.00
	Critical	30	30	0.3	4.5
Significance at		n.s.	n.s	*	*

* Indicates significance at 0.05 level, n.s. not significant.
Explanation of critical limits: 20 – 30ppm N low; 15- 30ppm P marginal; 0.05 – 0.1mg/100g K marginal in sandy soils; 0.1– 0.2mg/100g K marginal in sandy loams;
0.15- 0.3mg/100g K marginal in clay soil.

Although the values of N levels in the fields studied were generally above the upper value of the critical range, (30ppm) they are not significantly different from the critical limit. There was no significant difference ($p > 0.05$) between the available N levels and its critical limit in sandy soils, loamy sand soil and in clay soils. The mean levels of N were significantly different for sandy and clay soils, but were not significantly different for sand and loamy sand, and clay and loamy sand. Higher values were obtained for the heavier textured soils.

P levels were lower than the critical limit in sand and loamy sand soils and although P level exceeded the critical limit, in clay soils it did not differ significantly ($p > 0.05$) from the critical limit. This shows that in the fields studied the level of P is within the critical range. The mean levels of P were significantly different for sandy and clay soils and clay and loamy sand, but were not significantly different for sandy and loamy sand. A much higher value (73.50ppm) was obtained for the clay soil compared to 25.11 for sandy and 11.50 for the clay soils.

There was a significant difference ($p = 0.029$) between the available K nutrient levels and its critical limit in sandy soils but there was no significant difference ($p > 0.05$) between the observed P level and the critical limit for the loamy sand soil. In clay soils the available P was below the critical limit. There were no significant differences in K levels in the three soil types studied.

The results show that P has the greatest variation among the soil types, ranging from 11.50 to 73.50 ppm.

There is significant difference (p=0.044) between the pH in sand soils and the pH (=4.5) at which most plants do not thrive. The difference is not significant (p>0.05) for loamy sand and clay soils.

Perceptions of the local farmers on causes of reduced soil productivity are illustrated in Table 2.

Table 2. Local people's perception on major causes of decrease in land productivity

Causes of low soil productivity	**Percentage of respondents**
Soil nutrient depletion mainly due to deforestation	70
Recurrent drought	3
Reduced land due to gully development	5
Poor farming practice	22

Local communities (70 %) believe that the soil nutrient depletion is the major cause of a decline in soil productivity. Poor farming practices were ranked second (22%) and loss of land to gullies (5%) and recurrent droughts (3%) were ranked fourth and fifth respectively.

Deforestation is perceived to be the major cause of loss of soil productivity in the ward. Farmers alleged that there is uncontrolled cutting of trees that removes the natural protection of soil. The proportion of people experiencing a decrease in soil productivity was 76%. Average yields were as low as 0.5 tones per hectare a sharp decrease form an average of 2 tones per hectare some 10 years ago.

As a result of deforestation some people have reportedly turned to dry cow dung for fuel and this has an effect on soil organic matter.

Reaction of Farmers to Soil Analysis Results

The farmers' reaction to the soil analysis was positive, 100% of farmers showed appreciation of soil analysis and highlighted that their knowledge about soil pH was scanty. All farmers indicated that with proper advice they were keen to embark on regular soil testing for monitoring fertility trends but they pointed out that this was only possible if they could increase their maize yields from the current mean yield of 0.5t/ha to 3 – 5t/ha.

Discussion

Findings from the study indicate that soils are generally acidic. Sand soil pH (5.42±1.16) is significantly different (p = 0.04) from the critical range (pH<4.5). Loamy sands are strongly acidic (pH 4.75±0.21), and clay soils are slightly acidic (pH 5.90±0.00). For many fields, crop lime is required when pH is strongly acid (pH 4.5 - 5.0) (CSRI, 1989). Thus, for practical purposes lime is required for both sand and loamy sand soils. Sandy soils had a higher pH than expected (5.42±1.16) because the mean pH includes pH values of fields on the lower parts of soil catena whose values are usually high due accumulation of bases from upslope. The relatively high standard deviation of ±1.16 is testimony to a large variability in pH of individual samples. Similar results were obtained by Mugwira and Nyamangara (1998) in Chinamhora Communal lands where the mean proportion of fields with pH<4.5 was found to be 63%. According to Brady and Weil (2002), it is the soil pH that mainly affects the supply and availability of essential plant nutrients. In strongly acid soils the availability of the macronutrients (Ca, Mg, K, P, N and S) is reduced. According to Brady and Weil (2002), at low pH the availability of most micronutrients (Fe, Mn, Zn Cu and Co) is increased, even to the extent of toxicity to plants and microorganisms. This will hamper the growth of plants and thus lead to a reduction in crop yields even if other macronutrients nutrients are in sufficient quantities. The low pH partly explains why the available N, P and K levels are largely not significantly different from their critical limits in the fields studied. The relatively high standard deviations suggest that there is a high degree of variability in levels of management of the sampled fields.

Under conditions of low external input use, biological nitrogen fixation is the most important process by which soils gain N, but acid soils are not favourable for *Rhizobia* species (Hussein, 2000). This probably explains why the N levels are low in Sadziwa soils.

Potassium levels in sandy soils are significantly different ($p = 0.029$) from the critical limit for this textural group. As explained earlier this could be due to effect of soils from the lower parts of the soil catena. Levels of available K observed (refer to Table 1) are much lower than those for P and this is consistent with literature. Brady and Weil (1999) state that the quantity of K held in an easily exchangeable form at any one time is often very small. In high rainfall areas under acidic soil conditions K is much more readily lost by leaching than P since the cation exchange sites are occupied by the more tightly held trivalent Al^{3+} (Brady and Weil, 1999). In limed soils where calcium and magnesium are present, monovalent K is better able to replace them on exchange sites.

Phosphorus is the most deficient nutrient and exhibits greatest variability in soils studied in Sadziwa ward. Mugwira and Nyamangara (1998) obtained similar results when they observed that P deficiency in the soil was frequent but more variable.

The behaviour of P is consistent with theory, the soils are acidic and P levels are correspondingly low increasing slightly as pH rises to the slightly acid level. In strongly acid soils, enough soluble iron, aluminium and manganese ions are usually present to cause chemical precipitation of nearly all dissolved primary orthophosphate ($H_2PO_4^-$) rendering it unavailable. Most of the P fixation in acid soils probably occurs when $H_2PO_4^-$ ions react with insoluble oxides of iron, aluminium and manganese (Brady and Weil, 1999).

Overall results of the study of maize fields confirm results from surveys in Chinamhora, Mhondoro and Murehwa Communal Areas which revealed that even on maize fields, which are preferentially fertilized to other croplands, about half of the fields have depleted nutrient levels (Mugwira and Nyamangara 1998). Soil acidification and low nutrient element levels among other factors may have caused the low crop yields. Some soil fertility decline 'indicator species' were observed. In some maize fields especially in Dowera and Musodza villages witchweed (*Striga Spp.)* and *Lufolina species* were found to be growing in some maize fields. Barrow (1991) observed the appearances of witchweed (*Striga Spp.)* in some parts of Southern Africa.

Yields on depleted sands in the communal areas may be as low as 0.2t/ha without manure, and yet with proper fertilization using manure and/or fertilizer, yields can be increased and maintained in the range of 3-5 t/ha (Grant 1970, Grant 1981).

Seventy percent of the respondents believed that the soil nutrient depletion due to soil erosion is the major cause of a decline in soil productivity. Farmers' perceptions are in agreement with FAO (1993) which states that the most serious form of soil degradation is from accelerated erosion. Lack of financial resources to buy commercial fertilizers to replenish nutrients removed by cropping is also viewed by local people as a contributing factor to low soil productivity, though not the major factor (Table 2). Mugwira and Nyamangara (1998) however, assert that nutrient depletion is mainly due to continuous cultivation without adequate soil fertility input in the form of organic matter or chemical fertilizers to replenish nutrients removed by crops. Farmers also perceived the use of cattle dung as energy as being a contributory factor to decline in soil productivity. The larger part (84 %) of the respondents used dried cattle dung. Use of cattle dung in place of fuel wood contributes to loss of organic matter in soils. Agarwal (1986) estimated that for every tonne of cattle dung burnt in India, roughly 50 kg of potential food grains are lost in India on the use of dried cattle dung.

The concept of soil pH is largely unknown among farmers though it was found to be significantly low in sandy soils which are dominant in the area. This was expected since most agronomic advice by Agricultural Extension Workers is based on guidelines which specify commercial fertilizer quantities without any mention of the liming requirements guidelines. Farmers highlighted that they were willing to pay for full costs of soil testing provided maize yields increased from the current mean of 0.5t/ha to 3- 5t/ha. This is in contrast to findings by Holden and Shiferaw (2002) that Ethiopian farmers were willing to cover only 1.8 – 3.5% of the estimated costs of soil degradation.

Conclusions and Recommendations

Macronutrient levels were generally low, therefore sound soil fertilization programmes should be adopted to improve soil productivity. In addition to the use of commercial fertilizers, farmers should be encouraged to practise other sound agronomic practices such as crop rotation, conservation tillage and agroforestry in order to improve soil fertility and enhance the effects of commercial fertilizers. Farmers should also be encouraged to adopt erosion control measures. The use of cow dung as a source of energy is regrettable and efforts should be made to establish woodlots for fuel wood.

The pH of soils should be corrected through liming to the desired level in order to improve soil productivity. For practical purposes field specific pH values should be considered. Use of lime Ammonium Nitrate fertilizer instead of the conventional Ammonium Nitrate fertilizer should be adopted to manage acidity.

Farmers' reaction to the results of the survey revealed that they understand the negative effects of nutrient mining but they are not quite familiar with the concept of soil pH. Extension should direct efforts to equip farmers with knowledge of this fundamental fertility management parameter. More work is required to assess households' willingness and ability to pay to improve and sustain soil productivity before policy interventions for establishing the appropriate of intervention costs.

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