Assessment of selected soil chemical properties in Musanze district

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ABSTRACT

Decline in soil fertility is the main constraints of agricultural productivity in Africa as well as in Rwanda and Musanze district. This problem is combined with high rate of population growth; farmlands are severely depleted of nutrients since food production usually relies on available soil nutrient stocks. There was need to assess soil chemical properties in order to design possible interventions for improving the productivity of the soil of Musanze district. The overall objective of this study was to determine soil chemical properties composition such as total nitrogen (N), available phosphorus (P) and exchangeable potassium (K)and s acidity and alkalinity of soil (pH) in volcanic and non volcanic soil in Musanze district and to recommend interventional strategies on the existing challenges. The African Soil Information Services (AfSIS) method was performed for soil sampling .The collected samples were processed at RAB-Rubona laboratory before being shipped to the University of Rwanda laboratory for further analysis. Soil pH, Total nitrogen, available phosphorus and exchangeable potassium were determined. From this study it has been concluded that pH, N, P and K are limiting factors for the productivity of some important parts of Musanze district and need interventional method to overcome existing challenges.

Key Words: *Soil chemical properties, Soil nutrient, Soil fertility management, AfSIS method*

1. INTRODUCTION

Decline in soil fertility is the main constraints of agricultural productivity in Africa (Sanchez and Leakey, 1997; Stoorvogel and Smaling, (1998), since food production in the tropics and subtropics usually relies on available soil nutrient stocks (Sheldrick *et al*, 2002). About 75% of Sub Saharan Africa's farmland is severely depleted of nutrients, with the highest rates of nutrients depletion more than 60 kg ha^{-1}yearly in Guinea, Congo, Angola, Rwanda and Uganda (Hagrove, 2006).

As cited by Mukuralinda et al, (2008), the rate of population growth in Sub Saharan Africa (3.4%) is unmatched by food production, poverty is equally exceptional. Rwanda like other East African countries is seriously affected; soil fertility degradation is a major contributor to the above problem.

According to MINAGRI (2010), the Rwandan economy relies mainly on the agricultural sector, particularly food production. This sector currently accounts for less than 40% of GDP but provides employment to 80% of the population. It occupies approximately 91.1% of the active population contributing to about 70% of the country's export revenue.

The arable land in Rwanda is estimated at 1,380,000 ha, which is about 52% of the country's surface area. In case of geographical structure more than 39% of the cultivated land is on slopes which in turn occupy 25% of available land in Rwanda (DHS, 2007). Most Rwandans rely on subsistence agriculture and have limited participation in the market economy. Population pressure has forced settlement on marginal areas, resulting in overgrazing severe soil erosion, soil exhaustion and desertification (MINAGRI, 2010). This sector is fragile, however suffering from structural constraints compounded by climatic hazards and frequent external shocks. Average agricultural growth over the last 3 years has remained at 3.6% against a target of 7%. This poor growth is due to structural weaknesses decreased soil fertility, limited availability of inputs, inefficient technologies, lack of access to support services and vulnerability to external shocks. According to Henao and Banaante (2006), the depletion rates in NPK were estimated to be in order of 77 kg of nutrients per hectare translating into a reduction capacity to feed 40,000 people annually.

The high nutrients losses are the result of erosion, which according to recent estimates affect half of the country's farm land. Steep slopes, where farming often takes place are common throughout the country and heavy seasonal rains, the removal of vegetation and the neglect of infrastructure for physical and biological soil conservation are accelerating soil erosion (Clay and Lewis, 1995, 1996). The problem is compounded by population pressure which has not only pushed farmers onto fragile marginal lands but also resulted in reduced fallow periods. As Henao and Banaante (2006) pointed out, the evidence leaves no doubt that the nutrients recycling mechanisms that sustain soil fertility are insufficient to support the need growth in food production without fertilizers.

The study was conducted in Musanze district highland of Rwanda, where soil chemical properties (indicators of soil fertility) were carefully analyzed. Agriculture is the life hood of this District and at least 91% of the population is engaged in agriculture. The high altitude of the zone and the abundant rainfall lead to the soil properties change by erosion and the leaching of soil nutrients.

A careful assessment of soil chemical properties in this site is a key step in the design of possible interventions for improving the productivity of the soil of this site.

Soil is one of our most important natural resources. It is at the heart of terrestrial ecology and an understanding of the soil system is key success and environmental harmony of any human use of the land. The degree to which we are depending on soil is likely to increase not to decrease in the future. Soils will continue to supply us with nearly all of our food (except for what can be harvested in the oceans). Soil support the growth of higher plants, mainly by providing a medium for plant roots and supplying nutrient elements they are essential to the entire plant .Normally soil faces some challenges; in the sub humid tropical Africa those challenges are mainly divided into two parts: soil physical and soil chemical challenges. The chemical challenges includes low nutrients reserves, low cation exchanges capacity (CEC), aluminum toxicity, soil pH and phosphorus fixation as suggested by Sanchez and Logan (1992).

The main purpose of the study was the determination of soil nutrients especially N, P, K because they are absorbed in great quantity by plants and they are considered essentials in plants growth and they are named primary macronutrients. The study of acidity or alkalinity which is indicated by pH of soil is because they affect the availability of soil nutrients (John et al., 1985).

2. METHODS AND TECHNIQUES

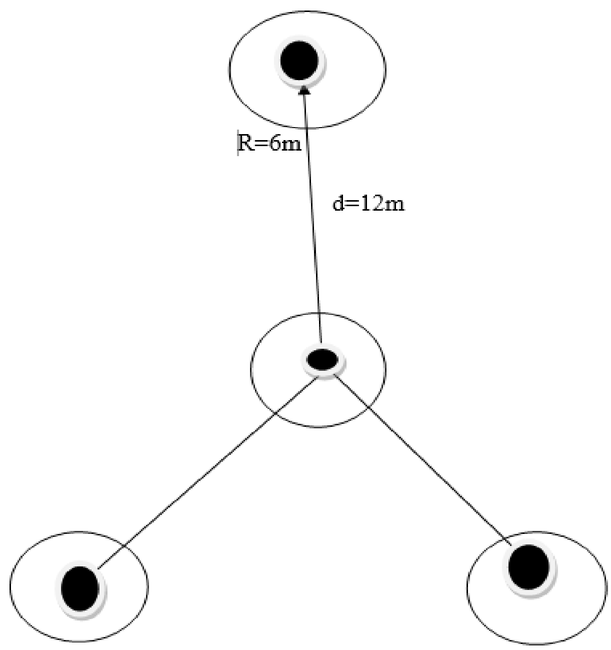
Musanze district which is one of the five districts of Northern Province of Rwanda. It is located at*1.4825 latitude° and 29.6008333°longitude*. it is characterized by abundant rainfall, the annual rainfall being between 1500 and 2000mm. It is also characterized by volcanic soil in its plane region and clayish soil in its mountainous region.

-Soil sampling procedure

African Soil Information Services have been used for Soil Sampling, to lay out the plot we used the radial arm plots recommended by LDSF (Land Degradation Surveillance Framework). Each plot had 4 subplots, the subplot centre was given by GPS (Global positioning System), latitude, longitude and elevation was recorded. Soil samples were collected using an auger with 20 cm increments clearly marked. Cumulative mass samples were taken from the centre of the sub plot one; it had to be taken at (0-20 and 20-50 cm) and then going to (0-20, 20-50, 50-80, 80-100 cm) where it was possible.

For Composite sample, Top-soil (0-20 cm) and sub-soil (20-50 cm) samples were collected and pooled into separate plastic buckets, one for topsoil, and one for subsoil. Samples from 3 subplots were thoroughly mixed in the buckets using the mixing trowel. Sub-samples were placed in a plastic bag. Soil Samples Labeling was carefully made to keep believable information and to avoid miss assigned value to samples. During soil sampling, measuring of slope, measuring of soil infiltration capacity, woody vegetation, soil texture determination, on each sampled plot were recorded on the form as recommended by AfSIS method for soil sampling AfSIS (2010)

619 Soil samples were collected and subjected to the University of Rwanda Soil laboratory analysis after being processed at soil laboratory of Rwanda Agricultural Board to determine the soil Ph, total Nitrogen, available phosphorus and exchangeable potassium. Microsoft office excel were used for data entry and management. . The Statistical Software for Social Sciences (SPSS) Software was used while performing the Kruskal-Wallis test to compare the sampling plots.



Soil sampling procedure

3. RESULTS AND DISCUSSION

Kruskal-Walli's test

	PH(0-20)	PH(20-50)	N(20-50)	P(0-20)	N(0-20)	K(20-50)	K(0-20)	P(20-50)
Chi-Square	73.892	74.133	50.731	71.832	60.821	66.318	72.297	67.326
Df	15	15	15	15	15	15	15	15
Asymp. Sig.	<0.001	< 0.001	< 0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Test Statistics[a,b]

a. Kruskal Wallis Test

b. Grouping Variable: CLUSTER

The Null hypothesis (H_0): Soil chemical property levels are the same in the Musanze district.

H_0: $\mu_1 = \mu_2$ where μ_1: Topsoil (0-20) cm μ_2: Subsoil (20-50) cm.

The working hypothesis (H_1): soil chemical properties levels differ according to cluster.

There was high statistical significant difference among all parameters: pH, Al, N, P, and K because the assumption significance value for all chemical parameters was (p<0.001) at chi-square =73.892, 74.133, 67.111, 69.907, 50.731, 71.832, 66.318, 72.297, 67,326 for pH(0-20), pH(2050),Al(0-20), Al(20-50), N(20-50), P(0-20) ,N(0-20) ,K(20-50), K(0-20), and P(20-50) respectively.

Thus we reject H_0 and accept. H_1

Approximately 69% of treated site present high values of pH in subsoil compared by topsoil. Generally the mean pH values in subsoil are higher than those of the topsoil in the range of 4.82- 6.70.

As it is observed that 37.5% of cluster present same mean % value of total Nitrogen on top and subsoil whereas 63.5% show little difference between top and subsoil but being higher on topsoil. 75% of the district, contained low amounts of TN ranging from 0.09 to 0.17 % , the mean range values of 0.22-0.32 are observed on (12.5%) of the area and they are judged to contain medium amount of %TN . And 12.5 have high % TN ranging from 0.7-1.09.

75% of this site showed low available P ranging from 1.00 to 4.34ppm, and c12.5 % with their mean available P (6.29 - 10.90) ppm have medium available P.

Only 12.5% of the total site is judged to have high available P (20.91 – 45.27) ppm. Only 12.5% of the district has moderate exchangeable potassium in top and subsoil.

For all parameters studied, for both top and subsoil volcanic soils have very high mean values compared to nonvolcanic soils. N, P, K in volcanic soils was more times 6 of those observed in nonvolcanic soils.

The PH mean value in volcanic soil was 6.52 in topsoil and 6.62 in topsoil and 5.44 and 5.55 in non volcanic soils (top and subsoil respectively) for nonvolcanic soil.

There was weak correlation between N, P, K and Slope at $p<0.001$ where r = - 0.4 and r = - 0.36 for N-Topsoil, N-Subsoil and slope respectively by order, r = - 0.3 for both P in topsoil and subsoil and slope and r = - 0.34 and - 0.3 for K- Topsoil and K- Subsoil. In most of case the soil chemical parameters were decreasing according to slope increase but at low rate.

Kruskal Wallis test for volcanic and nonvolcanic soils

	TOPSOIL	SUBSOIL
Chi-Square	439.726	436.243
Df	7	7
Assum. Sig.	< 0.001	< 0.001

a. Kruskal Wallis Test

b. Grouping Variable: factors

Mean comparison between volcanic and no volcanic soils

FACTORS	TOPSOIL	SUBSOIL
Phv	6.52	6.62
Phnv	5.44	5.55
NV	1.01	0.88
NNV	0.15	0.14
PV	39.59	30.32
PNV	4.11	3.82
KV	3.16	2.25
KNV	0.35	0.40

The above two tables present how volcanic and nonvolcanic soils differ in their chemical properties and their test statistic is shown in the table4. There was high statistical difference because the assumption significance was *$p<0.001$* for both top and subsoil.

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➢ DISCUSSION

A major soil fertility constraint to crop productivity in Rwanda is soil acidity. The laboratory analysis results of Musanze district show that the soil pH water presents a high variability among different clusters.

12.5% of the sentinel site has approximately an acceptable mean pH values for most growing crops ranging from 6.43 to 6.67 which is judged to be moderately acidic. 68.75% have the range of mean pH values of 5.31- 6.07 refereed to us as lightly acidic and 18.75% have acidic soils in the range of 4.81-5.14.

According to Gachene and Kimaru (2003), the value of pH less than 5.5 may lead to aluminum toxicity, unavailability of phosphorus and some of soil micronutrients such as molybdenum, and reduced biological activity; Adams (1984), added that both nitrification and mineralization of N are diminished making it less available to plants.

As indicated by the interpretation norms of Mutwewingabo and Rutunga (1987), Pietrowiez (1985) and Boyer (1982), the pH which ranges from 6.2-6.9 is moderately acidic, from 5.2 to-6.2 is lightly acidic and the pH range values of 4.2 to 5.2 is acidic. The pH range of 4.82-6.70 in subsoil is almost not similar to that reported by Vander *et al*. (1984), for 36% of subsoil samples in Rwanda which was more than 5.

For all the soils that have a pH H_2O less than 5.5, limestone application will be required to lower acidity and improve nutrient availability otherwise cropping of acid tolerant crops would be suggested. The high pH levels in volcanic soils compared to those of nonvolcanic soils are almost the same as those reported by Mukuralinda (1997) of pH = 5.8 and more in volcanic region where mean pH value for nonvolcanic regions of highland was > 5.0.

4. CONCLUSION

This study was concerned to assess selected soil chemical properties in Musanze district.

The following major soil fertility constraints were identified:

- Low pH: some clusters have pH less than 5.5 which are acidic; this acidity can be linked to exchangeable Aluminum toxicity to crops and has significant effect to phosphorus and Nitrogen depletion.
- Insufficient N, P and K: Where the means % of total nitrogen were less than 0.2, the means of available phosphorus being less than 5 ppm and means of exchangeable potassium less than 0.2 cmol (+)/kg the soils were low in those nutrients.
- Volcanic soils had almost acceptable levels of PH, N, P and K for proper growth of many plants.
- Weak correlation between N, P, K and slope was observed where those nutrients were decreasing according to slope increase but at very low rate.

The following recommendations are associated to those conclusions

- ✓ Applying limestone and organic matter to overcome soil acidity, using tolerant crops is also another option
- ✓ Using combined organic and organic fertilizers and the adoption of agroforestry systems as a management option for those soils which are depleted in N, P and K.
- ✓ Continuous study on soil fertility status of this region should be done to help local farmers in their land management.

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