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Assessment of Supply of Soil Nutrients in Different Land Use Types Using Plant Root Simulator Probes

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Introduction

Soil fertility in Ethiopia is currently under great challenges due to deforestation, over grazing and improper agricultural practice (Hurni, 1993). The factors that exacerbated the problem are top soil removal by erosion (approximately 137 t top soil /ha/year is removed) (FAO, 1998), soil acidification which covers 41% of the country, organic matter depletion due to competing use of crop residues and manure for livestock feed, thatching, temporary construction, fuel and others (IFPRI, 2010). The use of the livestock dung for fuel according to Zenebe, (2007) reduced Ethiopia's agricultural GDP by approximately 7%. Depletion in soil organic matter inturn resulted in the reduction of soil macro and micro nutrients and physical properties which finally resulted in poor crop harvest and food self insufficiency. According to FAO (1984), in IFPRI, (2010), 24% of Ethiopia's soil faced moderate to very severe fertility constraints affecting the key farming regions. The causes of nutrient depletion include farming without replenishing nutrients over time (lose through continuous crop harvest), leaching due to inadequate runoff management, removal of crop residue, low level of fertilizer use and unbalanced application of nutrients (IFPRI, 2010). To overcome the problems in soil fertility, only N and P fertilizers were applied even below the required rate due to high price and low availability of credit and limited reach of distribution network (IFPRI, 2010). The Northwest Ethiopian highlands which have long history of settlement and agriculture are the most severely affected in this regard. Currently, the major soil fertility issues are only understood at the higher level. However, more area specific, problem solving researches have to be carried out at a community (village) level and sustainable land use management options have to be set and recommended. Hence, prior to the recommendation of management options soil nutrient supply has to be assessed for different land use types.

Objectives

- to develop reliable methods for the assessment of nutrient supply for different land use and soil types for Northwest Ethiopia
- to evaluate the feasibility of the ion exchange membrane method for the conditions in Ethiopia

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Material and Methods

The study was conducted in Tara Gedam watershed which is located in Libokemkem district of South Gonder administrative zone in the Amhara National Regional State (ANRS), at a distance of 650 km North of Addis Ababa the capital city of Ethiopia and 90 km North of Bahir Dar the capital of the ANRS along the main road from Addis Ababa to Gonder to the east of Lake Tana. It lies between 12^0 09' N latitude and 37^0 44' E longitude in the altitude range of 1920-2550 meters above sea level with mean annual rainfall of 1175 mm and mean monthly temperature of 20 ^oC. The major soil types of the study area include: Nitisols, Cambisols, Leptosols, and Luvisols. The major land use types in the study site are: Agriculture, Church Forest (ChF), Community Protected Forest (CPF), and Grazing. Experimental plots have been established within the four land use types mentioned above with three or more replications per land use type. Four cation and four anion PRS^{TM} (plant root simulator) probes (Western AG) were buried vertically in root exclusion cylinders in the moist topsoil (15 cm) of each plot and left for six weeks during the main growing season of cereals (Fig.1). The soil was packed around the probes and soil slurry was added to create good contact between the soil and the membrane. After six weeks, the probes were removed, cleaned, stored in Zipseal plastic bags, labeled and finally stored in a Styrofoam lined box with two ice packs and sent back to Western Ag Innovations, Canada. The analysis of exchangeable macronutrients, micronutrients and heavy metals have been performed by Western Ag Innovations, including: NH_4^+-N, K^+, Ca^{2+}, Mg^{2+}, NO_3^--N, P, S, Al, Fe, Mn, Cu, Zn, B, Pb, Cd. General Linear Model (GLM) procedure of Statistical Analysis System (SAS) version 9.2 (SAS, 2002) and multiple comparison using Scheffe ($p<0.05$) were used for the statistical analysis.

Figure 1. Severely eroded part of the study site (left), PRS probes burial with minimum disturbance (right)

Results and Discussion

ANOVA and subsequent multiple comparison using Scheffe test ($p<0,05$) showed significant difference in total nitrogen, nitrate nitrogen, calcium, iron, manganese, copper, zinc, and boron supply and non significant difference for ammonium nitrogen, magnesium, potassium, phosphorus, sulphur and aluminum supply among the land use types (Fig 2 and Table 1 and 2). Hence, the maximum nitrate nitrogen supply was recorded for the church forest (682.7±85.8 µg $10cm^{-2}$/6 weeks) followed by community protected forest (149.4±70 µg $10cm^{-2}$/6 weeks), and grazing (137.9±54.3µg $10cm^{-2}$/6 weeks) with the lowest for agriculture (69.9±40.4µg $10cm^{-2}$/6 weeks). However, there was no significant difference among the land use types other than church forest in nitrate nitrogen supply (Figure 2). Except for plant available calcium, the land use types didn't vary in the supply of macronutrients (Table 1). Hence, the highest amount of Ca was supplied for CPF and ChF followed by grazing and agriculture (Table 1). Church forest had significantly higher micronutrient availability, except for boron (Table 2) while the other land use types had no significant differences. The highest supply of nitrogen and micro nutrients except boron for the undisturbed church forest may be due to the presence of high soil organic matter content and microbial activities. Generally, the results showed that disturbance has significant effects on the supply of plant available nutrients, in particular of nitrogen indicating the need for sustainable management intervention.

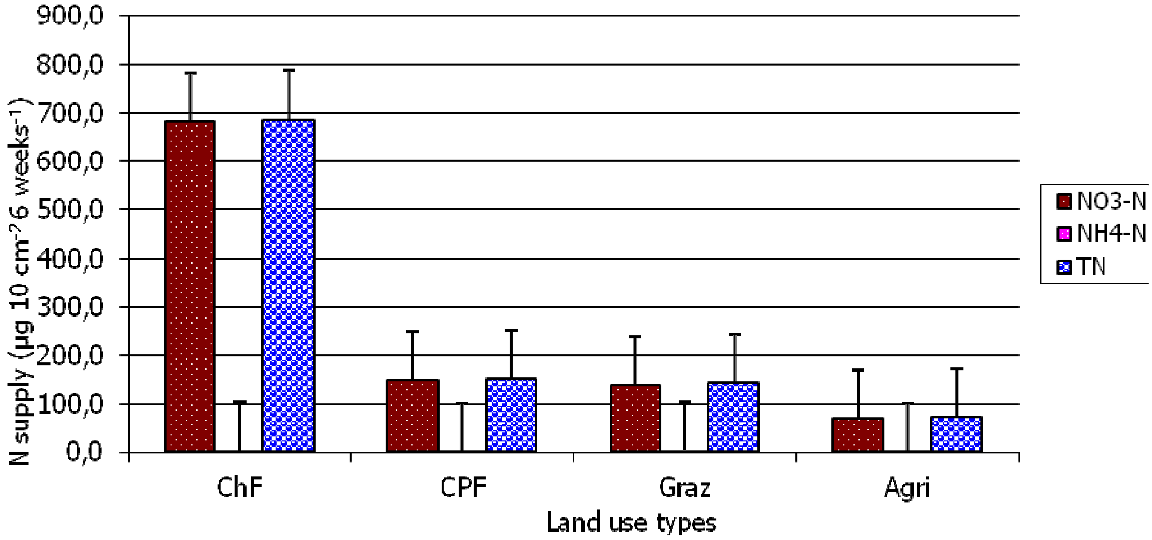

Figure 2. Nitrogen supply for different land use types at Tara Gedam

Table 1 Supply of macro nutrients for different land use types at TaraG

Treatment	Ca^{+2} (µg 10 cm^{-2})	Mg^{+2} (µg 10 cm^{-2})	K^{+} (µg 10 cm^{-2})	P (µg 10 cm^{-2})	S (µg 10 cm^{-2})
ChF	2471±168.6ab	433.4±74.7a	40.1±14.5a	1.1±2.7a	49 .2±6.9a
CPF	2558±137.7a	494.3±61a	52.2±11.8a	3.6±2.2a	34.9±5 .7a
Grazing	2163.9±106.7ab	506.1±47.2a	34.2±9.2a	1.6±1 .7a	31.8±4.4a
Agriculture	2033±79.5b	458.7±35.2a	39.1±6.8a	4.9±1.3 a	28.5±3.3a
Source of variation		Probability			
LU	*	NS	NS	NS	NS

Means in columns with similar letters are not significantly different at (p<0.05); *, p<0.05; NS, non significant difference at p<0.05

Table 2 Supply of micro nutrients for different land use types at TaraG

Treatment	Fe (µg 10 cm^{-2})	Mn (µg 10 cm^{-2})	Cu (µg 10 cm^{-2})	Zn (µg 10 cm^{-2})	B (µg 10 cm^{-2})	Al (µg 10 cm^{-2})
ChF	78±8a	10.9±1.7a	4.60±0.46a	3.00±0.35a	1.30±0.53 b	56.7±5.5a
CPF	11.9±6.6b	1±1.4b	0.53±0.38b	0.73±0.28b	3.40±0.4 3a	51.7±1.5a
Grazing	21.1±5.1b	2.7±1.1b	0.84±0.29b	0.48±0.22b	2.12±0.33b	52.8±3.5a
Agriculture	15.5±3.8b	2.1±0.8b	0.59±0.2b	0.59±0.16b	3.22±0.25b	60.1±2.6a
Source of variation						
LU	***	**	***	***	**	NS

Means in columns with similar letters are not significantly different at (p<0.05); **, significant at p<0.01; ***, significant at p<0.001; NS, non significant difference at p<0.05

Conclusions and Outlook

PRS™ probes can efficiently collect plant available nutrients with minimal disturbance in any land use and soil type at any topographic position. Multiple ions can be measured from a single test from a given sample and reduce soil sampling and handling care. Hence, PRS™-probes are essential tool in agronomy and forestry for they are convenient and economical means of quantifying nutrient supply rates for all nutrient ions simultaneously. The technology also perfectly works in the NW Ethiopian highlands where sophisticated lab facilities are usually lacking. Therefore, based on the results the following recommendations were made:

- ❖ The experiment should be repeated at the same place in different seasons and soil depths to plot the temporal dynamics of plant available nutrients
- ❖ The supply of plant available nutrients should be compared with the seasonal plant uptake
- ❖ Decentralized laboratories for the analysis of nutrients from the PRS™ probes in developing countries are essential for a wide use of the technology
- ❖ the color of the probes should be modified for it attracts kids and subject to damage

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