SOIL NUTRIENT STATUS ASSESSMENT OF SOME SOILS REPRESENTING THE GREEN BELT ZONE, SOUTH SUDAN

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ABSTRACT

Plant nutrients are chemical or organic elements necessary for plant growth often required in different amounts. Although they are taken in different quantities both micronutrients and macronutrients have the same agronomic importance and play various vital roles in plant growth. Soil testing is important and provide detailed information about nutrient variability such studies have not been conducted in the Green belt zone of South Sudan, thus the inception of this study; which would allow for the implementation of appropriate crop and soil management practices that align with the soil condition. Soil samples were collected and analyzed for pH, cation exchange capacity, organic matter, electrical conductivity, macronutrients, and micronutrients using standard procedures. The available Zn, Cu, Mn and Fe in soils was estimated using DTPA (Diethyl Triamine Penta Acetic Acid) which was found useful for separating soils into deficient and non deficient categories for Zn, Cu, Mn, and Fe by using atomic absorption spectrophotometer. Results indicated that the soils were generally, slightly acidic, slightly alkaline and alkaline (Mean = 7.03), low in CEC and medium in organic carbon, high in Ca K; and in Mg contents. The total Nitrogen and available Phosphorus at the study sites were low to medium in almost all soil samples. Also, Zn and Cu were also low to medium, respectively. Mn levels were also medium however Fe levels was below the critical limits for crop production. The study recommends supplementary application of nitrogen, phosphorus and micronutrient fertilizers for sustainable crop production in the studied soils and application of organic matter to improve the overall fertility of the soil.

Keywords: Soil Analysis; Macronutrients; Micronutrients; Green belt; South Sudan.

1. INTRODUCTION

The soil of South Sudan are divided in to ecological zones, the Nile and Sobat Corridor or Central clay plain, the Flood plains or southern clay plain, the Green belt or Equatorial plains, the Iron plateau and south eastern hills and mountains. Soil is a medium for plant growth and is of crucial importance in agricultural production. Plant nutrients are chemical or organic elements necessary for plant growth in only extremely different amounts. Although required in different quantities however, micronutrients have the same agronomic importance as macronutrients and play vital roles in the growth of plants. The transformation from the fallow and shifting cultivation practices prevalent among farmers to intensive continuous cultivation of soils and the use of improved crop varieties which take up many nutrients from the soil are major causes of deficiency of these micronutrients. In the South Sudan unfortunately the status of nutrient levels is not adequately known due to lack of soil testing. There are a number of factors that may result in the problems of soil nutrient deficiency in particular areas. Continuous cultivation on the same land with no crop residue incorporation and/or inadequate application of chemical fertilizer can greatly affect crop production. Continuous cultivation without addition of substantial amount of soil organic matter (SOM) will causes the sharp decrease in SOC and nitrogen (Shrestha et al., 2006). Soil fertility is one of the important factors that determines the productivity and profitability of crops and crops systems in agriculture. Soil fertility decline occurs when the quantities of nutrients removed from the soil in harvested products exceed the quantities of nutrients being applied. In this situation, the nutrient requirements of the crop are met from soil reserves until these reserves cannot meet crop demands. This results in a reduction of plant growth and yield. Understanding the soil chemical composition and its variation is essential for utilizing and managing the soils. Soil chemical levels such as total nitrogen, total and available phosphorus, soil organic carbon, electrical conductivity, and pH are essential in evaluating soil fertility, soil quality, and soil productivity (Bai and Wang, 2011). Furthermore, soil chemical properties play an important role in assessment and advancement of sustainable ecosystem management (Fu *et al.*, 2010). Excess nitrogen and phosphorus may lead to agricultural non-point source pollution and water quality degradation (Vervier *et al.*, 1999). Soils with high electrical conductivity values can affect soil aggregation and structure. Therefore, understanding and utilizing the spatial variability of soil chemical properties can provide a useful foundation for improving soil quality, increasing soil productivity and health, advancing agriculture, and protecting the environment. The concept of soil quality has been suggested by several authors (Lal, 1991; Granatstein and Bezdicek, 1992; Acton and Padbury, 1993) as a tool for assessing long-term sustainability of agricultural practices at local, regional, national, and international levels. Therefore, this study was to assess the soils nutrients status of some soils representing, Green belt, South Sudan, to establish maize demonstration plots for Seed for Development Project in Green belt, south Sudan based on soil nutrients status of the soils for fertilizer application using hybrids seeds of maize.

2. MATERIAL AND METHODS

2.1. Location

Table 1 the study area located in former field sites in three states of Equatoria such as Central, Eastern and Western States in selected counties, and bomas. Samples site representing Green belt zone.

Table 1 show the location of the samples sites in three states

S/N	State	County	Payam	Boma/ Samples Site
1	Western Equatoria	Yambio	Yambio	Gangora 1
2	Western Equatoria	Yambio	Yambio	Gangora 2
3	Western Equatoria	Mundri	Kotabi	Central Boma1
4	Western Equatoria	Mundri	Kotabi	Central Boma2
5	Western Equatoria	Maridi	Mabirindi	Mabirindi
6	Eestern Equatoria	Magwi East	Pageri	Loa
7	Eestern Equatoria	Magwi East	Pageri	Moli
8	Eestern Equatoria	Magwi West	Magwi	Sau 1
9	Eestern Equatoria	Magwi West	Magwi	Parjok 1
10	Eestern Equatoria	Magwi West	Magwi	Parjok 2
11	Eestern Equatoria	Magwi West	Magwi	Parjok 3
12	Eestern Equatoria	Magwi West	Magwi	Palwonganyi 1
13	Eestern Equatoria	Magwi West	Magwi	Palwonganyi 2
14	Central Equatoria	Morobo	Gulumbi	Kindi
15	Central Equatoria	Yei	Lasu	Lasu
16	Central Equatoria	Yei	Otogo	Ombasi

The Climate is Equatorial climate with high humidity and lots of rainfall. The rainy season varies but is generally between April and November the temperature are moderate but vary depending on the season.

2.2 Soil samples

The soil samples were selected randomly across the field, the material used is quick connect Auger. Soil depth is 0-20cm depth were mixed together and representative samples were obtained for air drying. A total of 41 samples (18 in Central Equatoria State, 18 Eastern Equatoria State and 5 Western Equatoria State) were collected at different bomas sites.

2.3 Soil analysis

Soil samples were collected from the three (3) States. A total of 41 samples (18 in Central Equatoria State, 18 Eastern Equatoria State and 5 Western Equatoria State). These samples were dried at room temperature and grind in powder form and analyzed in the laboratory for the analysis of different physical and chemical properties. These samples were placed in labeled bags and transported to the Crop Nutrition Laboratory Service Ltd (CROP NUTS) Nairobi, Kenya for the analysis of pH, Cation Exchange Capacity (CEC) organic matter, electrical conductivity (Ece), macronutrients, and micronutrients using standard procedures. The available Zn, Cu, Mn and Fe in soils was estimated by the method developed by Lindsay and Novell (1978) using DTPA (Diethyl Triamine Penta Acetic Acid) which was found useful for separating soils into deficient and non deficient categories for Zn, Cu, Mn, and Fe by using atomic absorption spectrophotometer.

3. RESULTS AND DISCUSSIONS

3.1 Chemical soil characteristics

The soil properties of the soil in the study were analyzed according to site of the of the soil samples in the project site in Green belt zone, South Sudan (Table 1). The most universal effect of pH on plant growth is nutritional. Soil pH has an important influence on soil nutrient availability, solubility of toxic nutrient elements and cation exchange capacity (Arain *et al.*, 2000). Chaudhari *et al.* (2012) stated that some nutrients become unavailable if the soil pH is extremely acidic or alkaline. This is due to the fact that they become insoluble at specific pH levels. Usually the optimum pH is somewhere between 6.0 and 7.5 because all plant nutrients are reasonably available in that range.

The data revealed that most of the soil samples were slightly acidic to slightly alkaline. Table 1 show the soil pH varied from slightly acidic, slightly alkaline and alkaline. Only two samples from Morobo and Yei counties, Central Equatoria State in Green belt, South Sudan were acidic with pH values of 5.71 and 5.84 respectively. Soil acidity is formed due to mineral leaching, acid rains and certain form of microbiology activity. The minimum value of pH was found to be 5.71 in sample site of Ombasi and maximum was 8.35 in sample site of Sau 1. The pH of the soil samples was found to be 75 % of sample showed range from 6.0 to 7.5 which is the optimum for nutrients uptake and 12.5 % of soil samples was shown moderately alkaline nature above 7.5 and rest was 12.5 % shown slightly acidic. High pH content may lead to development of phosphate, iron, manganese deficiency while low pH can cause deficiency of calcium and magnesium and can lock- up phosphate also reduces biological activities in the soil. Table 1 shows that CEC values in soil of the study areas were ranged from 6.93 to 20.8 Cmol kg -1. The cation exchange capacity is a value given in soil analysis report to indicate its capacity to hold cation nutrients. Higher CEC soils might be due to moderately amount of organic matter in surface layers. Soil organic matter content in all soils ranged from 3.35 to 4.87 the mean value 4.11. Usually the optimum organic matter is somewhere between 2.0 to 8.0. The soil samples were moderately category in organic matter content. Further the differences in the amount of soil organic matter are probably due to the differences of litter decomposition rate in the study soils. Electrical conductivity (EC) values of the study of soils varied from 35.0 to 185 uS/cm and exchangeable sodium percentage range from 1.11 to 3.83 and in accordance with the EC rating, the soils of the study areas were nonsaline and nonsodic soils (Scianna, et al., 2007).

Table 1: Soil properties of studied soils in Central Equatoria, Western Equatoria, and Eastern Equatoria sites.

Sample Site	pH			CEC			O.M			Ec		ESP		
	Result	Guide Low	Guide High	Result	Guide Low	Guide High	Result	Guide Low	Guide High	Result	Guide High	Result	Guide Low	Guide High
Gongara 1	6.87	6.00	6.80	19.2	15.00	30.00	4.87	2.00	8.00	162	<800	1.15	0	5
Gongara 2	6.97	6.00	6.80	20.8	15.00	30.00	4.87	2.00	8.00	185	<800	1.11	0	5
Central Boma1	7.13	6.00	6.80	7.27	15.00	3.00	3.35	2.00	8.00	60.0	<800	3.17	0	5
Central Boma2	6.90	6.00	6.80	6.93	15.00	30.00	3.54	2.00	8.00	59.0	<800	3.83	0	5
Mabirindi	6.45	6.00	6.80	19.8	15.00	30.00	4.59	2.00	8.00	176	<800	1.37	0	5
Loa	7.68	6.00	6.80	14.7	15.00	30.00	4.25	2.00	8.00	157	<800	1.45	0	5
Moli	6.80	6.00	6.80	12.5	15.00	30.00	4.74	2.00	8.00	70.0	<800	1.52	0	5
Sau 1	8.35	6.00	6.80	17.6	15.00	30.00	4.11	2.00	8.00	174	<800	1.16	0	5
Pajok 1	6.94	6.00	6.80	11.1	15.00	30.00	3.95	2.00	8.00	68.0	<800	1.37	0	5
Pajok 2	6.98	6.00	6.80	11.4	15.00	30.00	3.99	2.00	8.00	88.0	<800	1.17	0	5
Pajok 3	6.73	6.00	6.80	10.9	15.00	30.00	3.71	2.00	8.00	90.0	<800	1.70	0	5
Palwonganyi 1	6.78	6.00	6.80	8.92	15.00	30.00	4.63	2.00	8.00	66.3	<800	2.17	0	5
Palwonganyi 2	6.61	6.00	6.80	11.4	15.00	30.00	5.00	2.00	8.00	80.0	<800	2.35	0	5
Kindi	5.84	6.00	6.80	8.63	15.00	30.00	4.45	2.00	8.00	54.0	<800	2.75	0	5
Lasu	6.23	6.00	6.80	9.90	15.00	30.00	4.90	2.00	8.00	35.0	<800	1.84	0	5
Ombasi	5.71	6.00	6.80	9.52	15.00	30.00	4.50	2.00	8.00	51.0	<800	1.19	0	5

3.2 Macronutrient status of studied soil samples

Table 2 the result indicates the availability of Nitrogen in different soil samples were ranged (0.11 to 0.25, Average: 0.18%). Most of the sample was shown the lower availability of nitrogen. The availability of nitrogen is not only an essential part of carbohydrates, fats and oils but also an essential ingredient of proteins. The available nitrogen is an important factor to increase the soil fertility. The deficiency of nitrogen shows uniform yellowing of older leaves including veins, leaves that will eventually turn brown and die. The value of Phosphorus in different soil samples were ranged (8.09 to 153, Average: 80.45). Phosphorus is a constituent of the cell nucleus, essential for cell division and the development of tissues at the growing points. The deficiency of phosphorus in soil may cause dark leaves with reddish purple tips and margins of young plants whereas the excess of phosphorus will not have direct effect on the plant but may show visual deficiencies of Zn, Fe, and Mn. Result of the studied soils in the study areas indicated that soils in the three states had higher soil potassium content more than (66 ppm) and the highest value content between (238 -555 ppm) in Mabirindi. Potassium is necessary to plants for translocation of sugars and for starch formation. It is important for efficient use of water through its role in opening and closing small apertures (stomata) on the surface of leaves based on Palijon (1998) guideline for potassium. This high potassium levels can affect the plants ability to use micro nutrients and that is probably the reason the plants are showing those symptoms. Excess potassium does not appear to have a toxic effect on plants. It can however, induce deficiencies of other nutrients particularly nitrogen, calcium and magnesium. Calcium is also secondary macronutrient and is vital for healthy plants and it is required for the formation of new cells so is needed in order for roots, stems and leaves to grow. It is also used by plant when they respond to pest and disease attacks.

Table 2: Macro nutrient properties status in studied soils of central Equatoria, Western Equatoria, and Eastern Equatoria sites

Sample Site	Nitrogen (ppm)			Phosphorus (ppm)			Potassium (ppm)			Calcium (ppm)			Magnesium (ppm)		
	Result	Guide Low	Guide High	Result	Guide Low	Guide High	Result	Guide Low	Guide High	Result	Guide Low	Guide High	Result	Guide Low	Guide High
Gongara 1	0.16	0.20	0.50	15.9	25	60	283	66	177	2860	681	794	330	68	109
Gongara 2	0.13	0.20	0.50	15.5	25	60	411	66	177	3040	681	794	407	68	109
Central Boma1	0.20	0.20	0.50	21.5	25	60	103	66	177	1110	681	794	110	68	109
Central Boma2	0.25	0.20	0.50	17.8	25	60	67.5	66	177	5010	681	794	100	68	109
Mabirindi	0.22	0.20	0.50	8.09	25	60	555	66	177	2450	681	794	392	68	109
Loa	0.16	0.20	0.50	60.8	25	60	284	66	177	2210	681	794	266	68	109
Moli	0.15	0.20	0.50	18.1	25	60	286	66	177	1570	681	794	342	68	109
Sau 1	0.11	0.20	0.50	78.2	25	60	272	66	177	2890	681	794	213	68	109
Pajok 1	0.19	0.20	0.50	153	25	60	237	66	177	1300	681	794	393	68	109
Pajok 2	0.19	0.20	0.50	17.1	25	60	315	66	177	1360	681	794	373	68	109
Pajok 3	0.21	0.20	0.50	15.1	25	60	247	66	177	1290	681	794	328	68	109
Palwonganyi 1	0.14	0.20	0.50	56.3	25	60	238	66	177	1170	681	794	188	68	109
Palwonganyi 2	0.12	0.20	0.50	80.5	25	60	308	66	177	1420	681	794	244	68	109
Kindi	0.15	0.20	0.50	5.49	25	60	104	66	177	922	681	794	158	68	109
Lasu	0.14	0.20	0.50	13.6	25	60	145	66	177	1290	681	794	166	68	109
Ombasi	0.14	0.20	0.50	7.91	25	60	109	66	177	860	681	794	184	68	109

The soils in the three states also had higher soil calcium content of more than (794 ppm) and the highest value of 5,010 ppm was recorded in Central Boma 2. Excess calcium is unlikely to cause toxicity by itself however, it can reduce the uptake of other nutrients mostly cations and can potentially cause deficiencies of other nutrients. High calcium level severely reduces the availability of phosphorus and micronutrients. Magnesium is essential for plants and is deemed a secondary macronutrient. It is an important constituent of chlorophyll and is therefore required for for photosynthesis, it is also a component of many plant enzyme systems and aids in their function. Results also showed high levels of magnesium content of more than 109 ppm and the highest value content is 407 ppm in Gangora. High magnesium levels can result to calcium deficiency.

3.3 Micronutrient status of studied soil samples

Micronutrients are nutrient required by plant in small quantities and also known as minor or trace elements. These are eight in number they are, Manganese, Iron, Zinc, Copper, Boron, Molybdenum, Chlorine and Cobalt. The value of manganese content was found to be ranged from (64 to 152 ppm, Average: 108 ppm) in different soil samples (Table 3). Low manganese content level cause interveinal chlorosis of young leaves and gradation of pale green color with darker color next to veins, no sharp distinction between veins and interveinal areas as with iron deficiency. Table 3 show the value of copper nutrient was found to be ranged from (0.53 to 3.93 ppm, Average: 2.23 ppm) in different soil samples. The deficiency of copper cause stunted growth, poorer pigmentation, wilting and eventual death of leaf tips, where as excess copper shows Fe deficiency may be induced with very slow growth. Roots may be stunted.

The value of zinc content ranges from (1.08 to 3.64 ppm within the average of 2.36 ppm in different soil samples (Table 3). In the deficiency of Zinc decreasing in stem length and resetting of terminal leaves, reduced fruit bud formation, mottled leaves and interveinal chlorosis.

Table 3: Micronutrient (ppm) status in soils of central Equatoria, Western Equatoria, and Eastern Equatoria sites.

Sample Site	Manganese			Copper			Zinc			Iron		
	ppm											
	Result	Guide Low	Guide High	Result	Guide Low	Guide High	Result	Guide Low	Guide High	Result	Guide Low	Guide High
Gongara 1	67.7	100	300	2.79	2.00	10.00	1.79	2.00	20.00	67.2	80	300
Gongara 2	78.0	100	300	2.81	2.00	10.00	2.47	2.00	20.00	64.0	80	300
Central Boma1	86.2	100	300	1.33	2.00	10.00	1.92	2.00	20.00	62.7	80	300
Central Boma2	91.5	100	300	1.04	2.00	10.00	1.65	2.00	20.00	55.7	80	300
Mabirindi	176	100	300	2.18	2.00	10.00	1.28	2.00	20.00	61.1	80	300
Loa	96.0	100	300	0.85	2.00	10.00	2.83	2.00	20.00	75.5	80	300
Moli	87.5	100	300	2.18	2.00	10.00	1.63	2.00	20.00	117	80	300
Sau 1	64.7	100	300	0.84	2.00	10.00	1.93	2.00	20.00	64.4	80	300
Pajok 1	152	100	300	3.79	2.00	10.00	3.64	2.00	20.00	77.4	80	300
Pajok 2	157	100	300	3.64	2.00	10.00	3.56	2.00	20.00	71.4	80	300
Pajok 3	150	100	300	3.93	2.00	10.00	3.04	2.00	20.00	74.9	80	300
Palwonganyi 1	67.0	100	300	2.00	2.00	10.00	3.00	2.00	20.00	115	80	300
Palwonganyi 2	57.5	100	300	0.53	2.00	10.00	2.20	2.00	20.00	131	80	300
Kindi	88.4	100	300	2.14	2.00	10.00	1.79	2.00	20.00	114	80	300
Lasu	76.7	100	300	2.24	2.00	10.00	1.36	2.00	20.00	116	80	300
Ombasi	116	100	300	1.08	2.00	10.00	1.08	2.00	20.00	128	80	300

Upper leaves will show chlorosis on midrib. The excess of Zinc shows the Fe deficiency will develop. The value of Iron content was found to be ranged from (55.7 to 116 ppm, Average: 85.85 ppm) in different soil samples (Table 3). The deficiency of iron shows veins remain conspicuously green and other leaf portion turn yellow and tending towards whiteness.

4. CONCLUSION

The present study have indicated that the soils were generally, slightly acidic, slightly alkaline and alkaline (Mean = 7.03), low in CEC and medium in organic carbon, high in Ca K; and in Mg contents. The total Nitrogen and the available Phosphorus indicated Low and Medium contents in almost all soil samples. Generally, Zn and Cu were found to be low and medium category respectively in some of soils. Supplementary application of nitrogen, phosphorus and micronutrient fertilizers will be required for sustainable crop production and application of organic matter to improve the overall fertility of the soil.

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