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Full Length Research Paper

Productivity index rating of some soils in the Tolon/Kumbungu district of the Northern region of Ghana

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Productivity indices (PI) provide a single scale on which soils may be rated according to their suitability for crop production. The study was to assess the productive potentials of selected soil series in the Northern region of Ghana viz, Nyankpala series (NS), Changnayili series (CS) and Kpelesawgu series (KS), to evaluate the current and future suitability of these soils and to suggest possible amendments for improvement in productivity. Maize, soybean, cowpea and groundnut were used as the test crops. Soil samples were taken from 0 to 20 cm and 20 to 40 cm depths, and soil and crop data were rated and scaled using 100% as the optimum and the Productivity index (PI) ratings for the series were computed. The results indicated higher PI values for KS while the lowest values were observed at NS based on the parameters measured. This might mean that KS has higher productivity potential than both CS and NS. All three soil series showed low current suitability for crop production, however, given prudent soil management practices, the soils would be potentially suitable for crop production. It is recommended that soil management practices such as amendment of pH levels and incorporation of organic residue into the soil could improve productivity.

Key words: Soil series, productivity index, soil productivity, productivity potential.

INTRODUCTION

Soil productivity is the capacity of a soil producing a specified plant or sequence of plants under a specified system of management. Productivity emphasizes the capacity of soil to produce crops and should be expressed in terms of yields (Brady and Weil, 1999). To quantify soil productivity, there have been several attempts at devising systems that provide a productivity index, or rating, by means of numerical or parametric methods or approach (Delgado and Lopez, 1998). The productivity index (PI) model is a derived measure of soil productivity. Productivity index is an algorithm based on the assumption that crop yield is a function of root-growth, including rooting depth, which is controlled by the soil environment (Lindstrom et al., 1992). The productivity index is based on the use of simple easily measurable soil properties to predict the effect of soil environment on root growth. Productivity index ratings usually consist of empirically derived equations for relating productivity to parametric values assigned to soil properties. For every property, the full spectrum of value is split into convenient ranges, each of which is then assigned a numerical value to insert into the equation (Ilaco, 1981). The combined effect of individual factors is more nearly multiplicative than additive. Productivity indices have the advantage of being less vulnerable to changes in technology than are expressions of productivity based on yields. They are, however, soil evaluation methods of local importance

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Abbreviations: PI, Productivity index; **NS,** Nyankpala series; **CS,** Changnayili series; **KS,** Kpalesawgu series; **SOM,** Soil organic matter; **ECEC,** Effective cation exchange capacity; **FAO,** Food and agriculture organization; **SARI,** Savanna agricultural research institute; **ANOVA,** Analysis of variance; **DMRT,** Duncan's multiple range test.

rather than universal application (Russell, 1988).

In most parts of Ghana and in the Northern Ghana in particular, inadequate information on productive potential of different soil series exists. This situation has led to the random and haphazard cultivation of crops on any type of soil leading to some of the soils becoming virtually less productive and therefore, the erratic nature of crop yield. Although, the environmental factors often outweigh soil conditions in the selection of a particular crop or the application of a management level, most crops and even trees have specific site preferences for optimal production. Some plants are very peculiar and site-specific; others are less demanding and more versatile in this regard. The productivity index model would permit assessment of the relative productive potential of such soils by using measurable soil characteristics. This will enable periodic evaluation of the continuing ability of these soils to produce food and fiber for the nation.

Consequently, the objectives of the study were to assess the productive potential of the selected soil series in the Northern region of Ghana and to suggest amendments with respect to soil productivity improvement.

Methods for evaluating soil productivity

A plethora of evaluation methods are under diverse philosophies and techniques. Some methods are concerned with the degree of suitability of the properties, while others place more emphasis on the possible limiting factors for soil use. Some systems group soils into a series of levels of importance (order, class and type, etc.) and are referred to as hierarchical systems. Other systems have one category, and these are frequently parametric. In these later systems, mathematical formulae are applied such that the final result is expressed in numerical terms. These can be additive or with a multiplicative scheme, the latter offering better results. It is generally accepted that the parametric methods are according to the study of McRae and Burnham (1981), simple, objective, quantitative, reliable, easy to understand and apply even by the non-specialist and easy to modify and adapt to new uses. Pierce et al. (1983) used the productivity index model to predict crop productivity from soil water-holding capacity, pH, and resistance to root growth. Wilson et al. (1991) used the model to estimate crop yields from SOM and $CaCO_3$.

The general PI applied is calculated with the following multi-factional model (Delgado, 1998).

$$PI = \sum_{i=1}^{n}\left(A_i,\ B_i,\ C_i,\ K_i \right)$$

Where PI = Productivity index; A_i = Conditions that regulate the air-water relations of horizon i. B_i = Conditions that determine mechanical resistance (impedances) to crop root exploration in horizon i. C_i = Conditions that regulate the potential fertility of horizon i. K_i = Relative importance of horizon i and also soil depth.

The soil stores the water and air used by plants to sustain life. The amount of soil water that can be used by the plant varies, due to the characteristics of the soil, for example, soil texture of the plant, root distribution and depth (Tolk, 2003). These models use physical and chemical soil parameters such as bulk density, soil moisture content, and soil texture, depth to iron pan/concretions, effective rooting depth, Soil Organic Matter (SOM), Effective Cation Exchange Capacity (ECEC) and pH to quantify the productivity of soils. Most of these models do not consider all the physical and environmental factors that affect soil productivity. Also, their applicability is limited by lack of necessary soil and environmental data that would help increase their authenticity.

MATERIALS AND METHODS

The study area

The study was conducted in the Tolon/Kumbungu district of the Northern region of Ghana. It lies between latitude 10 to 20 North and Longitude 10 to 50 West and shares border with West Mamprusi district in the North, West Gonja district in the West and South and the East with Savelugu/Nanton district and the Tamale Municipal Assembly (www.ghanadistricts.com). According to the 2000 population census, Tolon-Kumbungu district has a total population of 132,833 people representing 7.3% of the total population of Northern region. The census also revealed that 111,953 people in the district are rural people and are mainly Dagombas.

The district experiences a unimodal annual rainfall of 1034 mm distributed fairly from April to late November with a uniform mean monthly temperature of 22ºc during the rainy season and maximum of 34ºc during the dry season. The relative humidity in the study area is at its maximum during the rainy season with mean monthly value of 80% and a sharp decrease to a minimum monthly value of 53% during the dry season (SARI, 2004). The people of the area are mostly farmers growing crops like maize, rice, sorghum millet, yam, groundnut and soybeans.

Soil sampling and samples preparation

Systematic samples were taken from sites that are equidistant from each other. Samples were taken from three soil series, viz, Nyankpala, Changnayili and Kpelesawgu. Five sites were selected on each of the soil series. At each site, a maximum of twenty-five (25) core soil samples were randomly taken at about 30 normal walking-steps and bulked to constitute a representative sample (Cochran, 1977). The samples were taken with soil auger at standard depths of 0 to 20 cm and 20 to 40 cm. The samples were air-dried for two weeks after which they were carefully ground and sieved through a 2 mm mesh to obtain a fine earth (Braize, 1993).

This fine earth was then stored in well labeled clean poly-bags for analysis in the laboratory.

Laboratory analyses

Soil moisture content was determined by the oven dry method, the

Table 1. Classification of the soil series.

Series	FAO-UNESCO (1988)	USDA Soil taxonomy
Nyankpala	Plinthic acrisols Ferric luvisols	Paleustults
Changnayili	Gleyic plinthosols	Plinthustalfs
Kpelesawgu	Dystric plinthosols	Plinthustalfs

FAO-UNESCO, 1988; Soil map of the world (Revised legend).

pipette method (Gee and Bauder, 1986) was employed in the determination of the particle size distribution, Organic Matter Content (Walkley and Black, 1934) and Soil pH was measured in 1: 2.5 soil-water suspensions with glass electrode pH meter. Cation Exchange Capacity (CEC) and bulk density were also determined in the laboratory. Depth to iron pan and effective rooting depth were determined *in situ* in the field using mini-pits.

Data analyses

The data collected was then subjected to analysis of variance (ANOVA) to evaluate the effect of the soil series on the properties selected and also on the yield of the test crops. Simple descriptive statistical analyses such as means, means separation by Duncan's Multiple Range Test (DMRT), standard deviation as well as coefficient of variation were also performed. Correlations among some of the variables were as well carried out. The statistical package used to analyze the data was MSTAT-C.

Classification of the soil series

The soil series under investigation are classified in Table 1 according to FAO-UNESCO (1988) and USDA Soil Taxonomy.

Model used

The Storie (1978) model with minor modifications was used. The following measurable parameters were selected and determined:

$$PI = H \times T \times B \times D \times E \times O \times A \times S,$$

Where; H = soil moisture content; T = soil texture; B = bulk density; D = depth to iron pan; E = effective rooting depth; O = organic matter content; A = cation exchange capacity (CEC); S = soil reaction (pH).

The choice of the aforesaid parameters was based on the conditions pertaining to the soil environment of the study area.

Test crops used

In order to evaluate the productivity (yield) of the soils under consideration using the model aforesaid, four test crops were considered; maize, soybean, cowpea and groundnut. The crops were grown as monocrops on each of the soil series and their growth patterns monitored. Some of the growth parameters measured included plant height, number of leaves/plant, leaf width, and leaf length. The yield was then determined after the crops were harvested. Measurements started three weeks after germination and continued every two weeks till maturity/harvesting. After the crops were harvested, 1000 grains of each were weighed for the determination of the yield.

RESULTS AND DISCUSSION

Some physical and chemical properties of the soils

Effect of moisture content on soil characteristics

The moisture contents of 0.06, 0.10, and 0.08 g/100 g within the 0 to 20 cm sample location for NS, CS and KS respectively, are generally low. Also in the 20 to 40 cm depth moisture contents of 0.14, 0.33 and 0.29 g/100 g for NS, CS and KS respectively, were observed and which were relatively higher than that of 0 to 20 cm depth. With the use of ANOVA test, it was observed that moisture content of the samples differed among the soil series. Duncan's multiple range test however revealed no significant difference of moisture content among the series at 1% significance level. It was observed from the results that the moisture content of the soils differed with depth. Thus, the 20 to 40 cm depth had greater moisture content in all the series than the 0 to 20 cm depth.

Rawls et al. (2003) reported that, in coarse soils, an increase in organic carbon increases the water retention. In soils with clay content greater than 19%, the average group water retention grows as the clay content increases. The low moisture contents of the soils in the 0 to 20 cm could therefore, be attributed to the low clay and organic matter contents. Also, the relatively higher moisture contents of CS and KS at the 20 to 40 cm could be ascribed to the slightly high clay and organic matter contents as against the clay and organic matter contents of NS (Table 2). Hudson (1994) produced the data of plant available soil water holding capacities as affected by organic matter. The slightly higher moisture content of CS and KS as against NS could also be attributed to the difference in altitude. CS and KS soils are developed in the valley and on lower slopes (lower altitude) and could retain more moisture than NS soils, which are developed over uplands (higher altitude) and therefore, could be subjected to high evaporation rates due to high temperatures.

The depth of a soil can have an influence on its moisture retention capacity. According to Webster and Wilson (1980), deep soils hold appreciable amount of moisture than the shallow ones. This may explain why moisture content increases with depth as observed in this study. However, CS soils that happened to have shallow depths indicated slightly higher moisture retention capacity than NS and KS whose soils were relatively deeper. The reason could be that because CS soils are shallow they could easily become saturated with the little amount of moisture in the soil especially, in the wet season when compared to NS and KS soils respectively, which are relatively deeper and would therefore, take some time to retain enough moisture.

Table 2. Some physical properties of Nyankpala, Changnayili and Kpelesawgu series at 0 to 20 and 20 to 40 cm sampling depths.

Soil series	SL (cm)	Soil properties						E (cm)	D (cm)
		Clay (%)	Silt (%)	Sand (%)	TCL	H (g/100 g)	B (g cm^{-3})		
NS	0-20	8	42	5 0	Sandy-loam	0.06	1.59	51.0	39.0
	20-40	7	37	56		0.14	1.67		
CS	0-20	9	25	66	Sandy-loam	0.10	1.53	47.6	32.6
	20-40	8	24	68		0.33	1.60		
KS	0-20	11	34	55	Sandy-loam	0.08	1.59	55.2	61.2
	20-40	9	33	58		0.29	1.65		

SL **=** Sample location, TCL **=** Textural class, H = Moisture content, B = Bulk density, E = Effective rooting depth, D = Depth to iron pan.

Effect of texture on soil characteristics

The results of the study showed that the soils from the three series were sandy loam throughout the 0 to 20 cm and 20 to 40 cm depths. Percent clay and silt were noted to decrease with depth while the percent sand increased with it. Generally, percent sand of the soils at the two depths were high, followed by the percent silt which also was quite high and the least was clay (Table 2). The high percent sand of the soils confirms the work done by D'Hoore (1968) and Ashaya (1969), which indicated that soils in the tropics are dominantly sandy loam to loamy sand. Analysis of variance (ANOVA) revealed that the clay fraction was significantly affected by the type of soil series. Duncan's Multiple Range Test (DMRT) showed that the clay fraction in the KS was significantly higher than that of NS but no significant difference was noted between both KS and NS in one hand and CS on the other at 5% significant level. The generally high sand and silt fractions and the low clay fractions of the soils could also be explained by the dominance of granitic parent material. The more highly weathered the soil, the lower the silt content.

Reicher et al. (2010) stated that soils with a greater silt/clay ratio are indicative of less weathered soils. The silt contents of 42.0, 25.0 and 34.0% for NS, CS and KS respectively, within the 0 to 20 cm depth and 37.0, 24.0 and 33.0% within the 20 to 40 cm depth indicated that the soils are less weathered. However, CS and KS soils appeared to be relatively highly weathered than NS soils. Also, the silt: clay ratios of 5.25, 2.77 and 3.09% for NS, CS and KS in the 0 to 20 cm depth respectively, and 5.25, 3.00 and 3.30% within the 20 to 40 cm sample location show a similar trend. The silt contents stated previously also indicates that weathering of the soil decreases with depth. Using ANOVA test, it was indicated that the mean content of the silt fraction differed among the soil series. At 1% significant level, DMRT revealed that the silt fraction within the 0 to 20 cm depth in all the series was significantly different from each other. However, within the 20 to 40 cm depth, the analysis revealed some significant differences of the silt fraction between NS and CS but no significant difference between NS and KS was observed. The predominantly sandy nature of the soil as observed in the study presupposes that the soils will have little inherent fertility and will not be able to retain high moisture content and plant nutrients. According to Bruand et al. (2007), sandy soils unlike other soils, the elementary fabric can be easily loosened by tillage practices, thus greater porosity can be produced easily by tillage but its stability is very weak. This leads to a decrease in the water retention properties.

The relatively high moisture content of CS soils could be explained by the highly weathered nature of the soils when compared to NS and KS soils. The sand fraction of the samples was revealed to have been significantly affected by the series type upon ANOVA test. Duncan's multiple range tests at 1% significance level, however, showed no significant difference of the sand fraction between NS and KS but some significant difference was noted between CS on one hand and NS and KS on another. A general observation of the particle size analysis of the series revealed that the sand fraction is dominant in all the series followed by the silt fraction and then the clay fraction.

Effect of soil bulk density on soil characteristics

The bulk density range of 1.53 to 1.59 g cm^{-3} in the 0 to 20 cm and 1.60 to 1.67 g cm^{-3} in the 20 to 40 cm depth are both below the critical value of 2.1 g cm^{-3}, beyond which plant root growth is severely limited. The bulk density values presented in Table 2 are within the limits given by Bowen (1981) and Kar et al. (1976), beyond which root growth is impeded and crop production is reduced. Using ANOVA test, the bulk densities of the series were observed not to be significantly influenced by the different series investigated. However, soils from NS tend to have higher bulk density values in both 0 to 20 cm and 20 to 40 cm sampling locations. The general high bulk density values of the three series especially in the 20 to 40 cm depth could be attributed to texture and continuous cultivation coupled with the activities of grazing animals. Low organic matter contents of the soils could be accountable for the high bulk density values. The results of the study also revealed bulk density values at the 0 to 20 cm depth to be lower than that of the 20 to 40 cm sampling depth. This conforms to the findings of Tsimba et al. (1999) that, bulk density tends to increase with soil depth mostly as a result of low organic matter (OM), less aggregation and root penetration as well as, pressure exerted by overlying layers.

Effect of depth to iron pan/concretions on soil characteristics

The presence of iron pan in the rooting zone of the soil serves as obstacles or resistance to crop root growth and this may affect the productive potentials of the soil. The mean depths of 39.0, 32.6 and 61.2 cm to iron concretions of NS, CS and KS soils respectively, show the development of iron pan towards the soil surface especially, the NS and CS soils and this can have strong resistance to root penetration and development. The presence of the iron pan at those shallow depths could be accounted for by the weatherability of the parent material and also the practice of continuous cultivation especially, at the same depth consecutively (Waddington, 1991; Unger and Kasper, 1994). The effect of erosion could also be a contributing factor since the thickness of the soil decreases as a result of erosion. KS soils tend to have deeper depth to iron pan and this could be due to translocation of the eroded soil from other places. Analysis of variance revealed that there was a significant influence of the soil series on the depth. DMRT indicated that there was no significant difference in the depth to iron-pan between NS and CS. However, KS was noted to be significantly different from the other two.

Effect of effective rooting depth on soil characteristics

The mean rooting depths of 51.0, 47.6 and 55.2 cm for NS, CS and KS soils respectively, showed that the soils are shallow (Table 2). KS soils appeared to be relatively deeper. Analysis of variance showed a high significant difference among the depths of the series. DMRT revealed no significant difference in rooting depth between NS and CS but that of KS was significantly higher than the other two. The general shallow nature of the soils could be ascribed to the nature of the parent material and its weatherability and the cropping history of the sites. Soil erosion could also be a factor since the soils are almost always left bare after cropping. The relatively deeper nature of KS soils may be attributed to translocation pileup of soil other locations as a result of erosion.

Effect of organic matter content on soil characteristics

The results of the study indicated low organic matter content in all the three series in the 0 to 20 cm and 20 to 40 cm sample depths (Table 3). Using ANOVA test, it was revealed that the SOM content was significantly influenced by the soils within the 0 to 20 cm depth but no significant difference was noted among the series within the 20 to 40 cm depth. Duncan's multiple range test at 5% significant level revealed some significant differences between KS and NS and CS but no significant difference between NS and CS. Several factors may be responsible for the low organic matter content though, it has been reported that total O.M of the topsoil of semi-arid zone is between 0.5 and 1.0% (Young, 1976) and sandy soils are regarded to have less O.M content than clay soils (Biswas and Mukherjee, 1994). The low organic matter content may be due to the fact that the study sites have been intensively cultivated or are young fallow areas (2 to 5 years), where basically organic matter production or accumulation is low. Contributing to this low organic matter content may also be the continual removal of plant material for human and animal consumption with relatively little returned to the land. It could also be respiration losses due to high temperatures (Brady and Weil, 1999), and erosion losses due to high intensity rains. According to Atkinson and Wright (1968), O.M contents of soils generally decrease with continuous cropping. Dalal and Mayer (1990) also reported similar findings.

The lower level of organic matter in the 20 to 40 cm depth when compared to the 0 to 20 cm depth is in agreement with work done by Nelson et al. (1994). This difference is mainly the result of organic matter accumulation mostly due to the presence of plant and animal residue in the 0 to 20 cm depth. The relatively high organic matter content in the KS soils as compared to that of NS and CS is attributable to their high clay contents (Table 2). The positive and significant correlation between organic matter content and clay content of the soils indicated that the amount of clay mineral in a particular soil affects the organic matter content probably due to the organic-inorganic soil mineral bonding effect. The mean CEC range of 8.04 to 15.36 $cmol_c\ kg^{-1}$ in the 0 to 20 cm depth and 3.33 to 4.92 $cmol_c\ kg^{-1}$ in the 20 to 40 cm depth fall within the range of 3 to 15 $cmol_c\ kg^{-1}$ (Müller-Sämann and Kotschi, 1994). The range of 3.33 to 4.92 $cmol_c\ kg^{-1}$ is low when compared to the lower limit of average CEC at 5 $cmol_c\ kg^{-1}$ (Landon, 1991) but within the range 1 to 10 $cmol_c\ kg^{-1}$ (Foth and Ellis, 1997), which are common for kaolinitic clays. The main clay mineral in the area is kaolinite. It was observed from the results that the CEC is low across the three series. Analysis of variance indicated no significant treatment effect on the CEC of the soils. Mean CEC was higher in the KS soils in both the 0 to 20 cm and 20 to 40 cm depths followed by CS soils. Blanchart et al. (2007)

Table 3. Some chemical properties of the soil series investigated within the sample depths of 0 to 20 cm and 20 to 40 cm.

Soil serie	Sample location (cm)	Soil property							pH	
		O. M (%)	Ex. Ca^{2+} (cmol$_c$ kg^{-1})	Ex. Mg^{2+} (cmol$_c$ kg^{-1})	Ex.K^{+} (cmol$_c$ kg^{-1})	Ex. Na^{+}(cmol$_c$ kg^{-}	Ex. acidity(cmol$_c$ kg^{-1})	ECEC (cmol$_c$ kg^{-1})	H_2O	KCl
NS	0-20	0.70	0.97	1.46	0.13	0.08	5.40	8.04	5.0	4.4
	20-40	0.43	0.82	0.97	0.11	0.04	1.40	3.33	4.4	4.1
CS	0-20	0.80	1.89	1.81	0.10	0.06	4.60	8.46	5.2	4.7
	20-40	0.44	1.49	1.29	0.70	0.03	1.20	4.08	5.0	4.3
KS	0-20	1.00	1.85	1.23	0.18	0.10	12.00	15.36	5.2	4.5
	20-40	0.56	1.20	1.07	0.13	0.03	2.60	4.92	4.7	4.2

reported that tropical sandy soils (or upper sandy horizons of tropical soils) have low cation exchange capacity. The general low CEC of the soils however, could be attributed to several factors. The low organic matter and clay contents of the soils could contribute to the low CEC. According to Landon (1991), the CEC as a property of the colloidal fraction of the soil is derived mainly from the clay and organic fractions. This presupposes that low organic and clay contents in any particular soil will mean low CEC. In addition, the type of clay mineral could have an influence on the CEC values. Landon (1991) reported that kaolinite clay minerals tend to have very low CEC values and consequently, most tropical soils are basically kaolinitic as indicated earlier. Furthermore, the low CEC could be ascribed to the low pH values of the soils. At low pH values, the CEC is also generally low. CEC values at the 0 to 20 cm depth from the results were higher than that of the 20 to 40 cm sampling location and this could be attributed to the relatively high organic matter, clay content and high pH values. The same explanation could be given to the relatively high CEC values of KS soils when compared to NS and CS soils.

Effect of soil pH on soil characteristics

The mean soil pH across the three series varies from very strongly acidic to strong acid in reaction in the 20 to 40 cm depth (4.4 to 5.0) and 0 to 20 cm depth (5.0 to 5.2) (Table 3). These pH ranges are below the average value of 6.5 (Foth and Ellis, 1997) as being ideal for good availability of plant nutrients in mineral soils. Brady and Weil (2002) stated that soil pH affects all chemical, physical and biological soil properties. Analysis of variance showed no significant influence of the soil series on the pH values. The analysis indicated that the pH values of the soils decreased with depth. Also, pH values in water appeared higher than that in the potassium chloride (KCl) solution. This could be due to differences in buffer capacity. The general low pH or high acidity of the soils could have been caused by a number of factors. In the first place, the low soil pH observed may be as a result of high leaching resulting from high intensity rains. It may also be the influence of parent material since many soils are naturally acidic because of the parent material from which they are formed. The low pH values could also be ascribed to removal of cations such as calcium, magnesium, potassium and sodium in the harvested crop and the fact that no replacement is made since the residues are always burnt through wild bush fires. Application of nitrogen fertilizers could also be a contributing factor. The results also indicated higher pH values in the 0 to 20 cm relative to that in the 20 to 40 cm sampling location which could be attributed to bonding activity of organic matter and clay.

Soil series and the PIs

The PI of a soil is presumed to be an indicator of the productive potential of that soil. High PI value will mean high productive potential. At the end of the experiment, the higher soil PI value of 8.32×10^{-4} was recorded at KS while NS registered the lowest of 0.72×10^{-4} (Table 4). These results presuppose that KS soils have higher productive potential. Productivity indices of 3.2×10^{-4}, 3.2×10^{-4} and 19.2×10^{-4} for the 0 to 20 cm depth and 0.4×10^{-4}, 1.6×10^{-4} and 1.6×10^{-4} for the 20 to 40 cm depth indicate that productivity potential of the soils decrease with depth. The higher PI for KS could be attributed to the relatively favorable soil

Table 4. Computed Productive index of soil series and the yield of test crops.

Soil series	Maize	Crop yield (kg/ha)			Productive index
		Soybean	Cowpea	Groundnut	
Nyankpala	5984	1073	552	1000	0.72×10^{-4}
Changnayili	5776	1047	224	1056	0.96×10^{-4}
Kpelesawgu	6864	773.3	344	1192	8.32×10^{-4}

$$\text{ø} = \left[\sum_{(20)} \left(H,\ T,\ B,\ O,\ A,\ S \right) + \sum_{(40)} \left(H,\ T,\ B,\ O,\ A,\ S \right) \right] * D * E$$

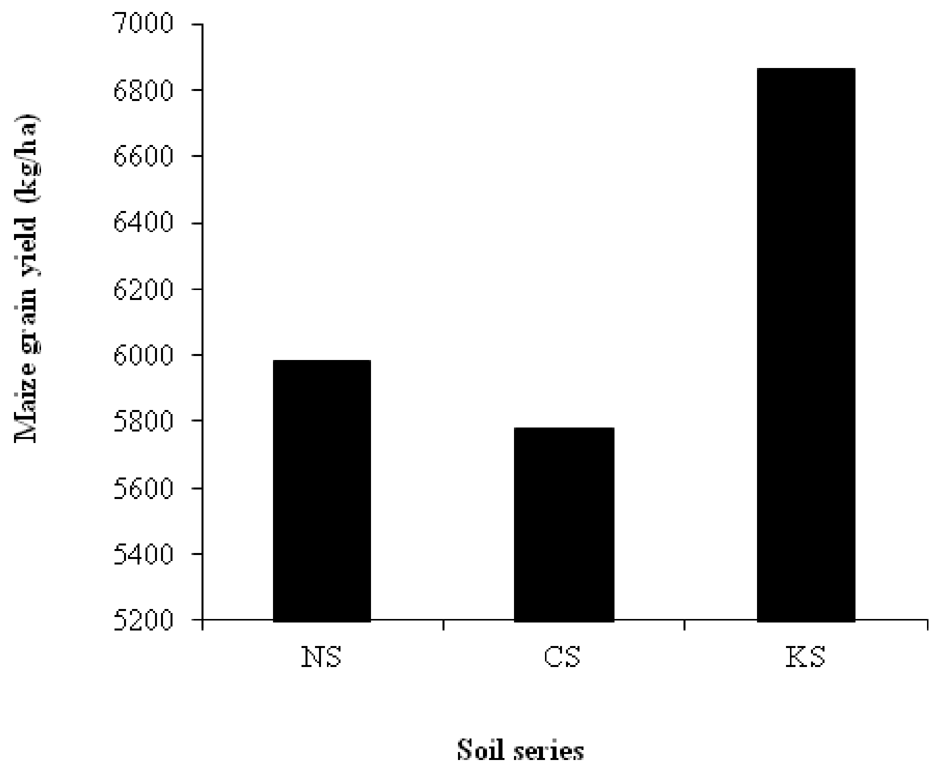

Figure 1. The yield (Kg/ha) of maize in the soil series.

properties since organic matter content, CEC and deeper rooting depth were higher compared to the other soil series.

Evaluation of plant growth and grain yield of test crops as depicted by the different soil series

Grain yield of maize and soybean in the different soil series

The grain yields of maize and soybean are given in Figures 1 and 2 respectively, according to the performance of the three soil series. The mean grain yield for maize ranged from 5776 to 6864 kg/ha and 773.3 to 1073 kg/ha for that of soybean. The highest mean grain yield of maize was recorded from KS while CS registered the lowest mean grain yield value. In the case of soybean, the lowest mean grain yield value was observed for KS and NS had the highest.

Grain yield of cowpea and groundnut in the different soil series

The highest mean cowpea yield was registered at NS while CS had the lowest. KS however, had the highest mean groundnut yield followed by CS. The mean grain yield for cowpea and groundnut ranged from 224 to 552 kg/ha and 1000 to 1192 kg/ha respectively. The yields of

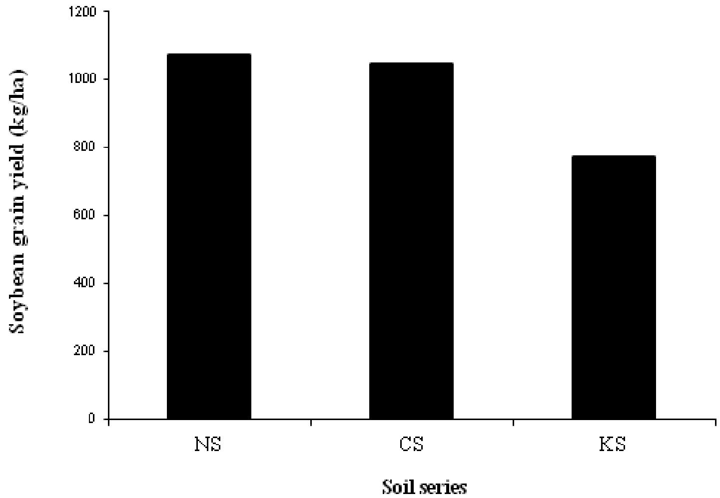

Figure 2. The yield (Kg/ha) of soybean in the soil series.

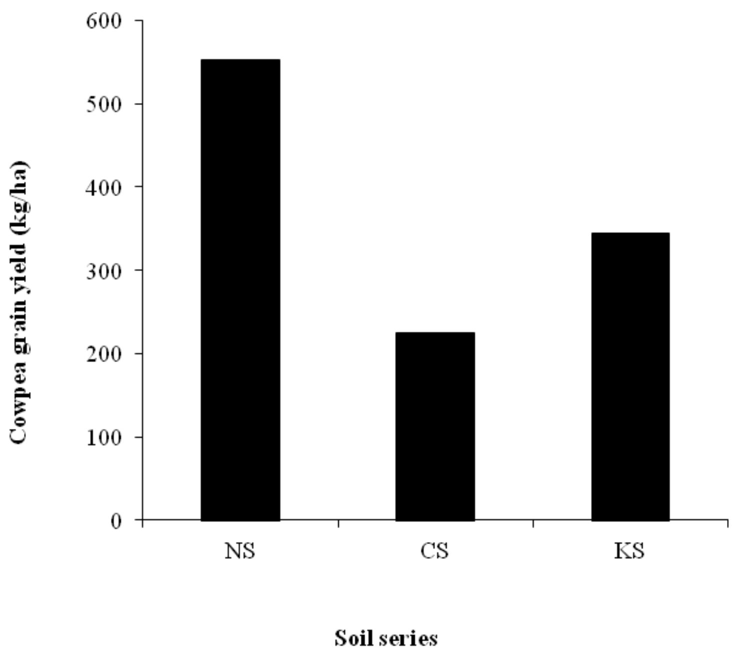

Figure 3. The yield (Kg/ha) of cowpea in the soil series.

cowpea and groundnut are shown in Figures 3 and 4 respectively, according to the performance of the three soil series.

CONCLUSION AND RECOMMENDATION

The results of this study indicated that soil physical and chemical properties could be used to quantify the productivity of soils. Though, Storie (1978) productivity index was effective in quantifying soil productivity, its modification proved to be more efficient especially, with the inclusion of organic matter content, soil pH and cation exchange capacity and the use of different soil series. This study therefore, increased the validity of the model. Hence, it is recommended that soil management practices such as amendment of acid soils through liming, incorporation of organic residue into the soil to improve upon the organic matter status, addition of inorganic fertilizers and crop rotation could be adopted.

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We acknowledge the contributions of Mr. Ibrahim K. Antwi,

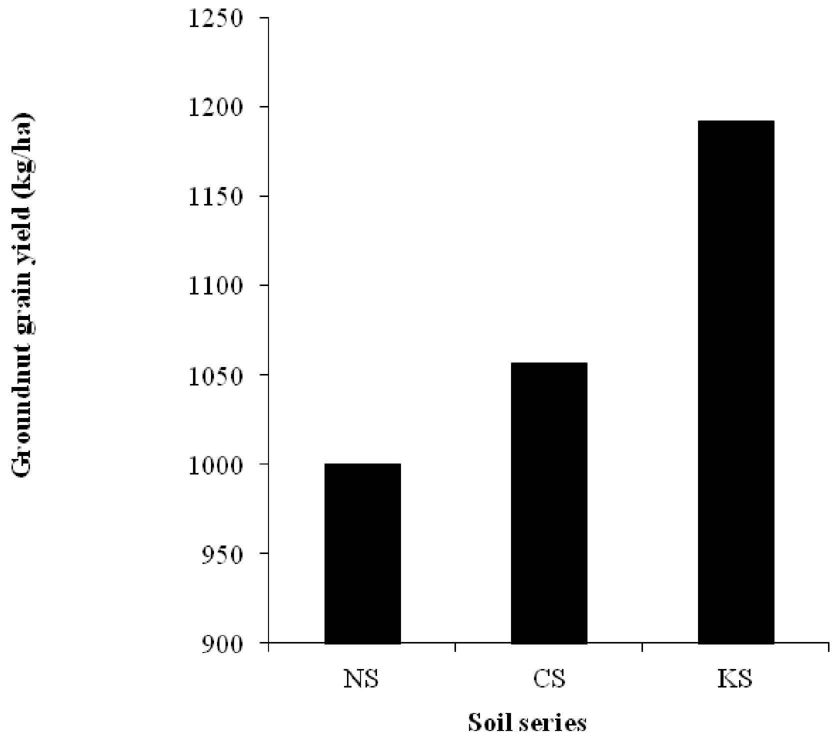

Figure 4. The yield (Kg/ha) of groundnut in the soil series.

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