Journal of Forestry Research and Management. Vol. 17(1).119-125; 2020, ISSN 0189-8418

www.jfrm.org.ng

Fertility Capability Classification of upland soils around Forestry Research Institute of Nigeria (FRIN), Ibadan

Fawole O. A[1]; Ojedokun R. O[1]; Smart M. O.[2] and Adesida O. A[2]

[1]Forestry Research Institute of Nigeria P.M.B 5054 Jericho, Ibadan Oyo State
[2]Federal College of Forestry, P.M.B 5087 Jericho, Ibadan, Oyo State.
Correspondence E: mail: fawole.oa@frin.gov.ng

ABSTRACT

Sustainable crop production and protection of soil resources as a results of rapid increase in population growth in Nigeria which has led to increased pressure on the available land for agricultural uses requires a proper understanding of the soil resources as well as allocation of land units to uses that are not adversely affected by the limitations posed by the land area. The study was carried out to evaluate the fertility capability of the soils around Forestry Research Institute of Nigeria (FRIN) using the Fertility Capability Classification (FCC) approach. A total of 20 composite soil samples at different physiologic position across the study area which was about 5km by 5km from a depth of 0-20cm were collected and analyzed for macronutrients, selected micronutrients, organic matter, pH, effective cation exchange capacity and particle size composition. The FCC system was used to evaluate the soils based on physical and chemical fertility constraints and limitations for general arable cropping. The soil falls under SCkeh fertility capability classes with the major constraints been the sandy nature of the soils and low exchangeable bases. The study therefore provided evidence that most of the soils could be effectively utilized for massive production of the common arable crops in the area if the appropriate land management strategies are applied at each point along the physiographic position as evidenced by the fertility capability classes.

Keywords: Agriculture, fertility capability classification, Micro nutrients, Macro nutrients

Introduction

Soil plays a vital role in the sustenance of human and animal existence on earth. As a renewable resource, however, the period of renewal is long spanning hundreds of years, often losing the topmost layer at a rate that far exceeds the capacity of its natural process of regeneration. Within the last decade, inventories of the soils' productive capacity indicate severe degradation on more than 10% of the earth's vegetative land as a result of soil erosion, atmospheric pollution, excessive tillage, overgrazing, land clearing and desertification (Wood *et al.*, 2010)

Soil quality has been defined as "the capacity of a soil to function within land use and ecosystem boundaries, to sustain biological productivity, maintain environmental quality and promote plant, animal and human health (Doran and Parkin 2004; 2006). This concepts departs from the traditional agricultural approach focusing on the productive functions of soils, shifting to a more holistic one that recognize the various roles soils play on agro-ecosystems and natural systems (Karlen, 1997; Swift, 1999). Soil quality attributes are biological, chemical and physical parameters that can be quantified at specific temporal scales.

The variability in soil influences the use of different soils for different purposes and application of suitable management practices for maximizing the agricultural production. Site-specific knowledge of these resources is necessary for sustainable developmental activities (Rao and Jose

2003). As the sub-surface soil characteristics cannot be manipulated within the limited management practices, any management activity is confined only to the surface layer. In recent times, a variety of attempts have been made to further counter the problem of soil infertility. One major attempt in this direction is the advent of the fertility capability classification (FCC) which is the first technical soil classification that categorizes soils according to their fertility constraints in a qualitative manner (Rao and Jose 2003). It was discovered that the upper few centimeters of the soil are excluded from soil taxonomic consideration (Soil Survey Staff, 2009). In actual fact, properties in the top soil have been more significant to growth than subsoil properties. The FCC aids in the identification of the fertility status of the soils through the discovery of its fertility constraints (chemical and physical). This is with the aim of proffering appropriate soil management techniques which are compatible with the soil in question (Geissen *et al.*, 2009)

The concept of Soil Fertility Capability Classification (SFCC) system was developed as an attempt to bridge the gap between sub-disciplines of soil classification and soil fertility, especially to interpret soil taxonomy and additional soil attributes in a way that is directly relevant to the plant growth. (Buol *et al.*, 1995; Buol and Couto, 1999; Sanchez *et al.*, 2002 and Geissen *et al.*, 2009). It is thus, a classification of soils on the basis of fertility constraints, quantified from condition modifiers (Rao and Jose 2003).

Several studies have used FCC to group soils in smaller regions as the basis for further technology transfer and research (Avilan, 1999). It has however been noted that in all these studies, not all the needs of the users were satisfied by the FCC resulting in slight modifications being made. This is understandably so since specific needs vary from user to user and location to location. The main aim of the FCC is however to group soils that are homogenous enough in properties that soil management decisions are the same in kind within groups and different between groups. The ultimate test of the FCC appears to be in an evaluation of the use of the system in the delivery of soil management information to the user. The FCC has great potentials for producing results which provide a less sophisticated comprehension of soil terminology and information relevant to the area. This is extremely necessary as this is expected to be useful to the local farmers. It is against this background therefore, that this study was carried out on Fertility Capability Classification of soils around Forestry Research Institute of Nigeria, Ibadan. This is with the aim of determining the extent of the applicability of the classification to the farmers in the environment in question and also to further determine the relevance and importance of the various criteria involved in the classification.

Materials and methods

The study area

The research was conducted around Forestry Research Institute of Nigeria, Ibadan, Oyo State. The area used was about 5km by 5km in diameter and located between latitude 7^o 21 N and 7^o 23 and Longitude 3^o.50 and 3^o 51 E. It comprises of notable places such as Odo-ona, NIHORT and Ile-tuntun within Ibadan municipal. The area enjoys the Tropical Equatorial climate with the mean annual rainfall of about 1250mm and 32^oC temperature while average relative humidity is between 80 - 85% (FRIN Meteorological Station). The area is underlain by Precambrian basement complex as other part of south west Nigeria (Rahaman, 1988). The relief in the area is generally a slopping, gently undulating plain. The vegetation is characterized by the lowland Tropical Rainforest with an irregular structure. The forest is endowed with series of both natural and planted tree species among which are *Nuclear diderichi*, *Triplochiton scleroxylon*, *Milicia excelsa*, *Kaya senegalensis* and many more. The ecology climate of the area experience rainfall with two distinct season, dry season usually from November- March and raining season usually from April-October (Soil Survey Staff, 2006). The soils consists of well- drained sandy loam over coarse sandy clay loam subsoil. Agricultural practice among the peasant farmers in the area is mainly through traditional farming practices and the main food crops grown includes cassava, maize, yam and plantain. The major cash crops in the area are varieties of tree species among which are listed above, majority of which are found in the arboretum of Forestry Research Institute of Nigeria

Sample and Data collection

A semi detailed survey method which has been described elsewhere by Orimoloye *et al.* (2015), was adopted to collect data for the purpose of this study. Samples were collected at a predetermined depth of 0 – 20cm. The approach of sampling at the predetermined depths was adopted in order to ensure comparability between samples collected across the area (Aweto, 1978) using the vegetation pattern, slope and observed physiological characteristics as an indicator of the variations. Five (5) replicates samples were collected within each identified points and mixed to form a composite sample representative of each sampling point. In all, twenty (20) composite soil samples were collected from the identified areas for physical and chemical analyses in the laboratory. The purpose of this procedure is to minimize the influence of any local non- uniformity of the soil (Tisdale *et al.*, 1985)

Laboratory analysis

Samples collected were air dried, crushed and sieved with a 2mm sieve. Samples lesser than 2mm were then used for routine laboratory analysis to determine the physical and chemical properties of the soils. The particle size distribution was evaluated by the modified Bouyoucos hydrometer method (Bouyoucos, 1951) using 5% w/v sodium hexametaphosphate (calgon) as the dispersing agent. The soil pH was determined electrometrically in 1.0 M KCl (1:1 soil: solution ratio) using glass electrode pH meter (Kent model 720) after equilibration for 30 minutes (Thomas, 1982). Organic carbon was determined by the Walkley-Black wet oxidation method (Allison, 1965) and total nitrogen was obtained by the micro-Kjeldahl method (Bremner, 1965). Available phosphorus were extracted with Bray-1solution and the P contents were determined using the ammonium molybdate-blue method (Bray and Kurtz, 1945). Exchangeable cations (Ca, Mg, K and Na) were extracted with neutral, normal ammonium acetate solution. Calcium (Ca) and Mg were determined by atomic absorption spectrophotometry while K and Na were determined by flame emission photometry. Exchangeable acidity was extracted with a molar solution of KCl and determined titrometrically. Effective cation exchange capacity, exchangeable sodium saturation and base saturation were calculated. Extractable micronutrients namely: copper (Cu), zinc (Zn), iron (Fe) and manganese (Mn) were extracted with 0.1M solution of HCl and the concentrations determined by atomic absorption spectrophotometer.

The results from the physical and chemical properties of the soils (Table 1) were then used to determine the Fertility Capability Classification (FCC) of the soil in the studied area. The soils were placed into their various Fertility capability class using the Sanchez *et al.* (2002) employing the criteria in Fertility Capability Classification version4 (Table 2). Following which recommendations were made on the use and management of the soil for optimum production and sustainability over a long period of time.

Results and Discussions

The physical and chemical properties of the representative samples of the study area are presented in Table 1. A greater extent of the studied area is under fallow having a mixture of different vegetation. Soil sampling point 1 is located on an elevation of 224m above mean sea level (amsl), the highest elevation encountered in the study area. There is slight evidence of human interference with no detailed management practices in the area. Soil sampling point 2 is located on an elevation of 196m amsl, vegetation around the area are trees like *Gliricidia sepium*, shrubs and ad- mixture of bush regrowth. Soil sampling point 3 is located on an elevation of 202m amsl, vegetation around the area are trees like *Terminalia superba* and weed like *Tridax procumbens*. Soil sampling point 4 is located on an elevation of 214m amsl and vegetation around the area include *Musa sapientum* (banana), *Elaeis guinences* (oil palm), *Mangifera indica* (mango), *Carica papaya* (pawpaw). Each sampling point has a total of five composite samples. All the soils encountered in the area are classified as Egbeda association according to Smyth and Montgomery (1962) with different soil series along the area.

Average sand content of the soils under investigation Table 1 ranged between 68.7-86.9%, the silt content ranged between 3.9-10.3% and Clay content ranged between 9.20-22.5%. Generally, the silt content is low, a characteristic which the soils shared with most Nigerian soils (Ojanuga, 1979).

The soils studied fall within the slightly acid to very strongly acidic class (. The results shows that pH values ranged from 4.32 - 6.75, Organic Matter values ranged from 1.72-6.12%, total Nitrogen ranged from 0.07- 0.31%, available Phosphorus ranged from 1.04- 52.42%, Sodium ranged from 0.6-7.9cmol/kg, Potassium ranged from 0.23-2.61cmol/kg, Calcium ranged from 1.2- 4.44cmol/kg, Magnesium ranged from 4.85- 46.46cmol/kg, and Micronutrients contents of the soil ranged from 5-142mg/kg (Table 1). It was observed that the soils position affects the composition of the soil at each sampling unit. This indicated that landscape in the study area affects the process of soil formation and its mineral contents. The predominant pedogenic processes that might have affected the process of soil formation are weathering and leaching of the exchangeable bases.

The soils were classified based on the Fertility Capability Classification (Table 2). The FCC according to Sanchez *et al.* (1982), consists of categorical levels. They include three basic criteria and levels for classification which include Type (top soil texture), Substrata (sub-soil texture) and Modifiers. The class designations therefore, for each of these three levels are combined to form an FCC unit. Where more than one criterion is listed for each modifier, only one is meant to be met. . It was observed that some of the criteria had the possibility of being inferred from any of the others.

Textural properties of the soils (Table 1) revealed that soil of the area is comprised mainly of loamy sand and sandy loam. The physical impact of soil physical properties on the potentials of these soils for agricultural use will be two fold; first is the difference in the ability of the soils to retain water and nutrients as observed in the drainage state of the soils of the area. Topography affects drainage water and therefore is one of the critical factors in the development of different soils within a given locality (Pai *et al.*, 2007). Secondly, the workability and additional tillage cost may be incurred when dealing with soils with higher clay contents on the surface. It has been noted that clay is involved in almost every reaction in soils which affects plant growth. Both chemical and physical properties of soils are controlled to a very large degree by type, content and properties of clay (Raheb and Heidari, 2012). Some of the chemical properties also vary across the area as described above. The allocation of the representative soil units into various FCC units according to the Sanchez *et al.* (2002) Fertility Capability Classification system are shown in Table 2. FCC units are according to the fertility related limitations. The soil therefore, falls under SCkeh fertility capability classes (Table 2).

The general fertility constraints of the soils were the loose nature of the soils (texture), the inherently low nutrient capacity, acidic nature and their position on the topography.

Conclusion

Decrease in Agricultural land owing to increase in human population which brought about competition for available land resources, has thus made survival of the earth and sustenance of ecosystem become critical. Developing countries are more likely to be affected with this development as it progresses and by implication the local populace. In a bid to salvage the situation before it goes out of hand and lead to food insecurity, the applicability of Fertility Capability Classification (FCC) is recommended to solve various problems posed by the available agricultural land to food production with the sole aim of sustaining the land for continuous productivity over a long time. Several classifications has been carried out in the past, however, not many has been able to effectively connect with the indigenous smallholder farmers. This study hence demonstrated the possibility of the FCC being carried out in a localized small area as against larger area such as whole countries and continents. It has also demonstrated the ability of determining the specifics as it pertain to nutrient deficiencies of the soils in question.

The results of the study shows that the soils position as well as other soil formation processes such as weathering and leaching of the exchangeable bases affects the composition of the soil at each sampling point as indicated by the agronomic constraints of the soils assessed using the (FCC) system, which are the loose nature of the soils (texture), the inherently low nutrient capacity, acidic nature and their position on the topography.

Nutrient deficiencies can be corrected with appropriate organic and inorganic fertilizers. Other management strategies such as drainage, flood control practising cross slope farming system and possibly sub-soiling would mitigate the major limitations to crop production in this area. Application of potassium (K) rich fertilizer and drainage practices should be encouraged for healthy performance of many arable crops in the area as evidenced by the fertility capability classes.

References

Allison, L. E. (1965). Organic Carbon. Pp 1367-1378. In C.A. Black *et al.*, (edition). Methods of soil analysis. Part 2. Agronomy Monograph 9 ASA. Madison, WI.pp

Avilan L., (1999): In PA Sanchez *et al.*, the fertility capability soil classification system. Interpretation, applicability and modification. Geoderma 27:283-309.

Aweto, A. D. (1978). Secondary succession and soil regeneration in a part of SW Nigeria. Unpublished Ph.D. Thesis. Department of Geography UI. Ibadan.pp 319-331

Bouyoucos, G. H. (1951). A Recalibration of hydrometer for making mechanical analysis of soil. *Agronomic Journal* 43: 434 – 438.

Bremner, R. (1965). Fabric and Mineral analysis of Soils. John Wiley and Sons Inc. New York. Pp470.

Bray R.H and Kurtz, L.T (1945) Determination of Total Organic and Available Forms of Phosphorus in Soils. *Soil Science*, 59, 39-45.

Buol, S.W. and Couto, W. (1999): Soil fertility capability assessment for use in the humid tropics. In *Characterization of Soils in Relation to their Management for Crop Production: Examples from the HumidTropics* (D.J. Greenland, Ed.), pp. 254-261. Clarendon Press, London.

Buol, S.W., Sanchez, P.A., Cate, R.B. and Granger, M.A. (1995): Soil fertility capability classification. In *Soil Management in Tropical America* (E. Bornemisza and A. Alvarado, Eds.), pp. 126-141. North Carolina State University, Raleigh.

Doran J.W., and Parkin M.A., (2004): “Methods for assessing soil quality.” Soil Sci. Soc. Am., Madison, pp. 5-18.

Doran J.W., and Parkin M.A., (2006): Soil health and sustainability. Adv. Agron., 56:154.

Geissen, V., Sánchez-Hernándeza, R., Kampichlerb, C., Ramos-Reyesa, R., and Sepulveda-Lozadaa, A. (2009): Effects of land-use change on some properties of tropical soils — An example from Southeast Mexico. *Geoderma*151, 87-97.

Karlen D.L., (1997): Crop rotation effects on soil quality at three northern corn/soy bean belt locations. *Journal of Agronomy* 98: 484-495.

Ojanuga, A. G. (1979). Clay mineralogy of soils in the Nigerian tropical savanna regions. *Soil Science Society of America Journal*,. 43, 1237–1242.

Orimoloye, J. R., Nwachokor, M. A., Obazuaye, E and Balogun O. O. (2015): The potentials of some soils in Moro Local Government area of Kwara State for crop production. Paper Presented at 38th Soil Science Society of Nigeria. 5th – 9th March, 2015. Landmark University, Omu-Aran. Kwara State, Nigeria.

Pai, C. W., Wang, M. K. and Chiu, C. Y. (2007). Clay Mineralogical Characterization of a Toposequence of Perhumid Subalpine Forest Soils in Northeastern Taiwan. *Geoderma*, 138(1-2): 177-184.

Rahaman, M. A (1988). Recent advances in the study of the basement complex of Nigeria. *In: Geological Survey of Nigeria (Ed) Precambrian Geol Nigeria*, 11–43 pp.

Raheb A. and Heidari A. (2012). Effects of clay mineralogy and physico-chemical properties on potassium availability under soil aquic conditions. *Journal of Soil Science and Plant Nutrition*, 12 (4), 747- 761.

Rao, D.V. and Jose, A.I. (2003): Fertility capability classification of some soils under rubber in Kerala. *Journal of the Indian Society of Soil Science* 51, 183-188.

Sanchez, P. A., Couto, W. and Buol, S.W. (1982). The fertility capability soil classification system: interpretation, applicability and modification. Geoderma 27(4): 283-309

Sanchez, P.A., Palm, C.A. and Buol, S.W. (2002) Fertility capability soil classification: a tool to help assess soil quality in the tropics. *Geoderma*114, 157-185.

Smyth, A. J. and Montogomery, R. F. (1962). Soils and land use in central western Nigeria. Western Nigeria Government, Ibadan Pp 265.

Soil Survey Division Staff, (2006). Soil Survey Manual. USDA Handbook No. 18. Govt. printing office, Washington D.C. Pp 279.

Soil Survey Staff. 2009. Soil survey field and laboratory methods manual. Soil Survey Investigations Report No. 51, version 1.0. R. Burt (ed.). USDA Natural Resources Conservation Service.

Swift, M.J., (1999): Integrating soils, systems and society. Nature and Resources 35 (4), 12– 20.

Thomas, G. W. (1982). Exchangeable cations. Pp. 159–165. *In* A.L. Page *et al.*, (ed.) Methods of soil analysis. Part 2. 2nd ed. Agron.Monogr.1 9. ASA and SSSA, Madison, WI.

Tisdale, S. L., Nelson, W. L., Beaton, J. D. and Haulin J. L., (1985). Soil fertility and fertilizers. Macmillan Publishing Company. 5th Edition. New York.

Wood, S., Sebastian, K., Scherr, S.J., (2010). Pilot analysis of global ecosystems: agroecosystems. International Food Policy Research Institute and World Resources Institute, Washington. 110 pp.

Table 1: Physical and Chemical Properties of soils under investigation

	Sampling location			
Soil properties	Point 1	Point 2	Point 3	Point 4
Sand (%)	75.60	68.70	86.90	69.90
Silt (%)	10.30	8.8	3.90	9.4
Clay (%)	14.10	22.5	9.2	20.7
pH	4.32	6.75	6.12	6.06
Org. matter (%)	0.99	1.72	1.80	6.12
Total N (%)	0.07	0.29	0.31	0.28
Avail. P (mg kg^{-1})	10.00	1.04	16.61	52.42
Na ($cmoKg^{-1}$)	7.90	7.40	7.60	0.60
K ($cmoKg^{-1}$)	0.52	0.43	2.61	0.23
Ca ($cmoKg^{-1}$)	1.70	1.20	1.22	4.44
Mg ($cmoKg^{-1}$)	5.51	4.85	7.89	46.46
Mn (mg kg^{-1})	104.00	142.00	35.00	110.00
Fe (mg kg^{-1})	38.00	76.00	43.00	67.00
Cu (mg kg^{-1})	5.00	13.00	10.00	7.00
Zn (mg kg^{-1})	75.00	60.00	56.00	80.00

Source: Authors field work (2019)

Table 2: Fertility Capability Classifications (FCC) Units of the Soil Studied

Sample Points	Top soil	g	k	E	h	FCC units
1	SC	-	+	+	+	SCkeh
2	SC	-	+	+	+	SCkeh
3	SC	-	+	+	+	SCkeh
4	SC	-	+	+	+	SCkeh

Keys;

S=sandy, C=clayey, h=acidic reaction, e=low cation exchange, k=low nutrient reserve, g=gleying, +=present, and -=absent.