Tropical and Subtropical Agroecosystems 2006 (6): 49 - 55

Tropical and Subtropical Agroecosystems

FROM LAND CAPABILITY CLASSIFICATION TO SOIL QUALITY: AN ASSESSMENT

[DE LA CLASIFICACIÓN DEL POTENCIAL A LA CALIDAD DEL SUELO: UNA EVALUACIÓN]

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SUMMARY

Soil quality assessment and land capability classification are two ways by which the potentials of land for a particular kind of use can be known. Soil quality is a recently developed phenomenon while land evaluation has been in use since at least 1961. Assessment of land capability classification and soil quality for crop production functions were conducted on 12 mapping units. Soil quality was assessed using Multiple Variable Indicator Transform (MVIT) technique. The USDA land capability classification method was used. The results showed that the soils are of medium to high quality for crop production with percentage quality rating of 42 - 75%. The capability classification ranged from II - VI indicating good to fairly good value for arable use, with limitations such as low fertility status, high gravel content and shallow effective soil depth. An attempt to find relationship between soil quality and the land capability method showed a significant positive correlation ($r = 0.71$ $p < 0.001$) between soil quality and land capability indicating that the two approaches are related in the assessment of the land for crop production. Where soil survey and land evaluation data base are lacking or limiting, as is the case in Nigeria, determination of soil quality will strengthen the information base, provide ability to formulate workable solution to land issues and likelihood of adoption of best management practices that ensure sustainable land use.

Key words: soil assessment, land capability, soil quality.

RESUMEN

La evaluación de la calidad del suelo y la de su potencial son dos formas de conocer la vocación del mismo. La evolución de la calidad del suelo es un fenómeno más reciente que la evaluación del potencial el cual ha estado en uso al menos desde 1961. Se evaluó la clasificación del potencial del suelo y la su calidad para diversos cultivos en 12 unidades de suelo. La calidad del suelo se evaluó por medio del la técnica MVIT. Se empleó el sistema de clasificación del potencial del suelo de USDA. Los resultados mostraron que los suelos fueron de mediana a elevada calidad para producción de cultivo con un % de calidad del 42 al 75%. En la clasificación de potencial los suelos fueron de II a VI indicando un buen valor para cultivos, con limitaciones como bajo nivel de fertilidad, elevado contenido de grava y reducida profundidad del suelo. Se encontró una correlación positiva ($r= 0.71$, $P<0.001$) entre ambos indicadores. Se concluye que cuando existen vacíos de información en calidad o potencial del suelo, como es el caso de Nigeria, la determinación de calidad del suelo fortalecerá la información y proveerá la habilidad de formular soluciones posibles a los diversos problemas, a la vez que facilitaría la adopción de mejores prácticas de manejo para obtener un uso más sustentable de la tierra.

Palabras clave: evaluación del suelo, potencial del suelo, calidad del suelo.

INTRODUCTION

Soil, water and air are the three basic natural resources upon which plant life depends. The balance between economic viability and destruction of a nation often depends on how the land resource base is managed. Proper land management cannot be done without land use planing. An essential part of land use planing is land evaluation. Land evaluation is the assessment of the potential of land for alternative uses using systematic comparison of the land use requirements (LURs) with land quality / characteristics (Dent and Young, 1981). Land quality as defined by FAO is a complex attribute of land which affects its suitability for specific uses in a distinct way (FAO, 1983). According to FAO, land evaluation is the assessment is the assessment of the present performance of the land, particularly as this affects changes in the use of

land and in some cases changes in the land requirement and qualities (FAO, 1976).
Land evaluation forges a link between the basic survey of resources and the taking of decision on land use planing and management. It puts at the disposal of users relevant information about land resources that are necessary for planing development and taking management decisions (FAO, 1976).

There are several methods of physical land evaluation. These methods aim at assessing land qualities or suitability for a specific land use as conditioned by biophysical parameters (Beek, 1978). However, soil quality assessment is becoming increasingly popular and it is now being used as advisory tools for farmers in the USA (USDA, 2001). The effort to assess soil quality could have been stimulated by:

- The fact that soil varies in quality and the quality changes in response to use and management.
- Assessment of soil quality is useful for optimizing land use planing.
- Assessment of soil quality is useful for addressing environmental problems.

An international conference on assessment and monitoring of soil quality (Rodale Institute, 1991) observed that defining and assessing soil quality is complicated. There is need to consider the multiple functions of soil to integrate the physical, chemical and biological soil properties that define soil functions. Soil quality encompasses three major issues of concern with respect to soil functions; they are productivity, environmental quality, and animal health. Thus, soil quality is the capacity of the soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health (Doran and Parkin, 1994).

Bouma (1996) referred to soil quality as a certain assemblage of land characteristic values, which should better be referred to as FAO-style land qualities such as 'workability' and "erodibility". He further pointed out that soil quality is defined without reference to a specific land Utilization Type (LUT), ignoring one of the basic principles of the land evaluation approach. The concepts of 'quality' are therefore based on the essential characteristics of soil and land to fulfill human land use requirements.

As a contribution to the debate on whether soil quality assessment should replace land evaluation, this study aimed at finding out if there is any correlation between soil quality assessment and land evaluation method. Thus a high positive and significant correlation between soil quality assessment and land evaluation method would mean that the two approaches can be used interchangeably, and the choice between them will depend on other peculiar situations.

METHODOLOGY

The study site

The study was conducted on the soils at a site in Idoffa, within Yewa north local government area of Ogun state in Southwestern Nigeria. Idoffa is within the northwestern part of the state near the border between Nigeria and the Republic of Benin. It lies roughly between latitudes 7^o 9' and 7^o 12' N and longitudes 3^o 18' and 3^o 22' E of the Greenwich Meridian.

The topography is gentle with slope gradient of $< 3\%$. The terrain generally slopes gradually towards the River Yewa which is the major river in the area. The geology consists mainly of sedimentary rocks deposited in a coastal basin which extends from Nigeria westwards across Republic of Benin and Togo to the Volta river in Ghana. Three distinct topographic forms closely related to the geology of the sediments can be recognized. Basically, the site lies near the boundary between sedimentary deposits (sandstone) and Basement Complex rocks.

The climate is humid tropical with marked wet and dry season. The average annual rainfall ranges from 1016cm to 1270cm and spans seven months (April to October). The raining season has two peaks, one in July and the other in September with a break in August. The vegetation is derived woody savanna with bush regrowth dotted with trees and some herbacious plants like *Acacia sp, Daniella oliveri, Ficus capensis* etc. The main food crops grown are yams, maize, rice, sorghum, cassava, groundnuts. Cashew and citrus are also found. Mixed cropping is dominant with maize as the major cereal intercropped with cassava and yam. Upland rice is normally grown as a sole crop.

The soils

The soils belong to the order Ultisols (USDA), Lixisols (FAO) and Entisols (USDA) Arenosols (FAO). The upper horizons of the soils have dark reddish brown / dark red sandy loam / loamy sand texture, becoming reddish fine textured (sand clay loam or clay) at depth. All the profiles have granule/ crumbs topsoil texture over weak sub angular blocky texture at depth. In most profiles, the distribution pattern of clay content shows an initial increase and then a decline with depth. Silt values are low in all profiles. Percentage total sand content are high for all the profiles and decrease with depth. All the profiles except 3 and 5 show clay accumulation in their horizons. The average gravel contents of the soils increased with depth to 150cm. Depth of gravel varied widely for all the profiles with values ranging between zero at topsoil and 68% at depth.

Most of the soils are slightly to moderately acid with pH values ranging from 5.2 to 6.7. Effective cation exchange capacity (ECEC) values ranges from 1.7 to 16.1cmol/kg soil. Vertical distribution pattern of ECEC is similar to the distribution pattern of clay. The total exchangeable bases are low with Mg dominating the exchange site. Available P ranges between 2.2mg/kg and 19.1mg/kg. Total N ranges between 0.1g/kg and 0.8g/kg. These values are low. The data set of the area was obtained from a previous work (Oluwatosin, 1986). They consist of laboratory physical, chemical and field morphological properties of 12 profiles representing 12 mapping units of the area.

Land Capability Classification

The land evaluation method used was the simplified form of the USDA system of land capability classification suggested by Young (1976) (Table 1). Classification is based on physical soil and land properties with CEC as the only chemical property involved. Using the conversion table (Table 1), soil limitations in terms of these properties are used to place the soils into different classes with classes I - IV as arable and V - VIII as non- arable. The classification depends more on the severity of the limitations than the number of limitations.

Table 1: Simplified conversion table of USDA land capability classification

Limitations	Arable				Non-Arable		
	I	II	III	IV	VI	VII	VIII
Slope angle (degree)	1	3	5	10	18	35	Any
Rock outcrops and boulders	0	1	2	5	10	25	Any
Wetness class	Nil	Nil	Slight	Slight	Mod.	mod.	Severe
Effective soil depth (cm)	150	100	60	30	20	20	0
Texture	SCL-C	SL- - C	SL - C	LS - C	LS - hc	LS - hc	any
Soil permeability	Mod.	R - S	R - S	R -S	Any	Any	any
A. W.C. (cm)	25	20	15	10	5	2	0
CEC (meq/100g)	20	15	10	5	5	2	0

Source: Simplified USDA System as suggested by Young (1976)
SCL = sandy clay loam, LS = loamy sand, C = clay, hc = heavy clay, SL = sandy loam, Mod.= Moderate
R- S = Rapid to slow, AWC = Available water capacity, CEC = Cation exchange capaciy

Soil quality assessment for crop production function

Selection of soil quality indicators

Soil quality indicators for crop production function were selected using the approach suggested by Cameron et al. (1998). The approach is based on the equation:

A = (S,U,M,I,R)

Where :
A = Acceptance score for indicators.
S = Sensitivity of the indicators to degradation or remediation process.
U = Ease of understanding of indicator value.
M = Ease and / or cost effectiveness of measurement of soil indicators.
I = Predictable influence of properties on soil, plant and animal health, and productivity.
R = Relationship to ecosystem processes (especially those reflecting wider aspects of environmental quality and sustainability).

Each parameter in the equation is given a score (1 to 5) based on expert's opinion and experience of it. The sum of the individual scores gives the level of Acceptance (A) score, which is ranked in comparison to other potential indicators, thus aiding the selection of indicator for a site. For example, organic carbon received the following score (S = 5, U = 4, M = 4, I = 3 and R = 2) given A value of 72% i.e.

A = 18/25 X100 = 72%

The 'A' is high, so organic carbon is selected to be one of the indicators for soil quality assessment for crop production function. The following indicators are then selected based on the above approach: 1. pH, 2. Organic Carbon, 3. Total Nitrogen, 4. Available Phosphorus, 5. Exchangeable bases, 6. Cation exchange capacity, 7. Texture, 8. Structure, 9. Effective rooting depth (ERD), 10. Soil respiration, 11. Available water capacity (AWC). These indicators are similar to those used by Lal (1994) in assessing sustainability of soil quality in the tropical region.

Soil quality assessment

The quality of the soil for the function of crop production was assessed using Multiple Variable Indicator Transform (MVIT) by Smith *et al.* (1994). The indicators were transformed on the basis of their ability to attain a critical level or range. Any indicator that is equal to or above the critical level for crop production is scored 1 and any one below the critical level is given 0. These were later integrated into percentage quality ratings:

$$\% \text{ Q. rating} = \frac{\text{no. indicators that attain C.L.}}{\text{Total no. of indicators assessed}} \times 100$$

Where C.L. is Critical Level

The critical levels (Table 2) were based on information from the literature (e.g. Lal, 1994, Adeoye and Agboola, 1984), expert opinion, and on comparison of measured values of indicators with expert judgement of limitation to sustainable land use. Relationship between soil quality and assessment method and land evaluation method was determined using Spearman's coefficient of rank correlation.

Table 2: Soil quality indicators for crop production function.

Mapping Unit	P^H	OC g/kg	E K cmol/kg	TN g/kg	AP mg/kg	BS %	Soil Resp.	Text.	AWC	ERD (cm)	Stc	Con
1	5.2	18.3	0.12	0.80	4.32	71.75	IV	SCL	41.6	>100	2,m,sb	mfr
2	5.7	11.4	0.10	0.60	4.69	71.43	IV	LS	41.4	>100	1,m,cr	mfr
3	6.5	61.4	0.16	0.80	11.94	96.88	IV	LS	41.8	>100	1,f,cr	mfr
4	5.7	23.8	0.11	0.80	4.32	80.92	IV	LS	32.10	>100	1,f,cr	mfr
5	6.5	29.6	0.26	0.80	19.05	92.15	IV	LS	32.20	>100	1,f,g	dl
6	5.9	17.6	0.20	0.60	11.30	74.23	IV	LS	15.60	>100	1,f,cr	dl
7	5.8	17.6	0.13	0.60	11.81	88.35	IV	LS	55.60	>100	2,m,cr	mfr
8	6.7	10.0	0.26	0.30	8.45	92.06	IV	LS	15.20	<100	1,f,cr	dl
9	6.1	29.6	0.25	0.60	10.73	94.64	IV	LS	27.80	>100	2,f,cr	mfr
10	6.3	10.0	0.26	0.80	6.48	77.06	IV	LS	44.80	20	3,m,cr	mfr
11	5.2	16.6	0.12	0.60	18.42	59.35	IV	SL	42.00	15	2,m,cr	mfr
12	5.7	27.3	0.13	0.50	6.92	70.76	IV	LS	15.50	70	1,f,cr	mfr

Texture: SCL = sandy clay loam, SL = Sandy loam, LS = Loamy sand
Stc = Structure: m = medium, cr = crumb, f = fine, g = gravelly, sb = sub-angular, 1 = weak, 2 = moderate, 3 = well developed.
Con= Consistence: m = moist, fr = friable, d = dry, l = loose
OC = Organic carbon, EK = Exchangeable potassium, TN= total Nitrogen, AP = Available Phosphorus, B.S. = Base saturation, Soil Resp. = Soil respiration, Text. = Texture, AWC = Available water capacity, ERD = Effective rooting depth

RESULTS

Assessment of soil quality for crop production function

Table 2 shows the soil quality indicators for crop production function. The soil quality ratings for crop production function are shown in Table 3. In mapping units 1, 5, 7, and 10, eight indicators each met the threshold value requirement for crop production function, so they have 67% rating. In mapping units 3 and 9, nine indicators met the threshold value, and they have 75% ratings. Mapping units 2 and 6 have 58% ratings, mapping units 4, 8, and 11 have 50% quality rating with six indicators meeting the threshold value; and mapping unit 12 has 42% quality rating with five indicators meeting the threshold value. With these results, the soils have medium to high inherent quality for crop production function.

Land Capability Classification

Table 4 shows the indices of land capability classification of the study site. Land capability classes ranged from II - VIsfg indicating good to fairly good for arable to non-arable. Mapping units 1, 2, 3, 4, 5, 6, 7, 8, and 9 are fit to a varying degree, for arable (II - III), mapping units 10, 11, and 12 are non-arable lands (VIsfg). The major limitations to capability of the soils are low CEC and poor physical soil properties (i.e. high gravel content).

Table 3: Soil quality ratings for crop production function.

Mapping Unit	pH	OC	EK	TN	AP	B.S.	Soil Resp.	Text.	AWC	ERD	Struc	Cons.	% Q.R
1	0	1	0	0	0	1	1	1	1	1	1	1	67
2	0	1	0	0	0	1	1	1	1	1	0	1	58
3	1	1	0	0	1	1	1	1	1	1	0	1	75
4	0	1	0	0	0	1	1	0	1	1	0	1	50
5	1	1	1	0	1	1	1	0	1	1	0	0	67
6	1	1	1	0	1	1	1	0	0	1	0	0	58
7	1	1	0	0	1	1	1	0	1	1	0	1	67
8	1	1	1	0	0	1	1	0	0	1	0	0	50
9	1	1	1	0	1	1	1	0	1	1	0	1	75
10	1	1	1	0	0	1	1	1	1	1	0	1	67
11	1	1	0	0	1	0	1	1	1	0	0	1	50
12	1	1	0	0	0	1	1	1	0	0	0	1	42

High = > 65%, Medium = 35 - 65% , Low = < 35%
OC = Organic carbon, EK = Exchangeable potassium, TN= total Nitrogen, AP = Available Phosphorus, B.S. = Base saturation, Soil Resp. = Soil respiration, Text. = Texture, AWC = Available water capacity, ERD = Effective rooting depth, Struc= Structure, Cons= Consistence

An assessment of relationship between soil quality and the land evaluation classes showed a significant positive correlation ($r = 0.71$ $p < 0.1$) between soil quality and land capability classification. This shows that the two methods are convergent in the assessment of the soils of the study.

Table 4: Land capability indices of the study site

Mapping unit	Land capability Classes
1	IIf
2	IIf
3	IIf
4	IIif
5	IIIsf
6	IIIsf
7	IIf
8	IIIsf
9	II
10	VIsfg
11	VIsfg
12	VIsfg

II - III = arable
VI = non-arable
s = soil texture and structure
f = fertility status
g = gravel content /effective soil depth

DISCUSSION

Soil quality assessment rated mapping units 1, 3, 5, 7, 9, and 10 as high for crop production function (Table 3). The other mapping units were rated medium. The assessment was not meant for a particular crop, although the indicators are useful in practical farming in the developing countries (Chen, 1999).

Land capability classification rated the land area as 50% arable, 25% moderately arable, and 25% non-arable. The major limitation to arable use is fertility status (f) which in this case is low CEC. Low CEC is as a result of low activity clay as well as low soil organic matter. Other limitations are effective soil depth (s) and gravel content (g), which are more difficult to remove either culturally or mechanically because they are more permanent in nature. Similarly, most of the limiting indicators in soil quality assessment are related to fertility status (f), soil texture and structure. This could in a way explain the significant positive correlation obtained between soil quality assessment and capability classification. They both assess soil broadly and did not include climatic data as an indicator of assessment. For agricultural land evaluation, climate determines the suitability of a given crop, since climate or weather influences all components of a farming system (Zheng et al. 1989).

Though there was a significant positive correlation between soil quality and capability classification method, the coefficient of determination was just 0.50. This implies that only 50% of soil quality could be predicted by capability classification method. Factors that may have prevented a higher level of relationship between the two methods of soil rating may include the differences in the indicators used for both methods. Indicators of capability classification are mainly centered on land quality workability and erosion hazard (e.g. rock outcrops, slope, wetness class, effective soil depth, texture), whereas in the tropical areas where tractorization is very limited, any rating based on these characteristics will give a false rating of the land. Also, land capability classification emphasizes only CEC as land quality for fertility status. Although, this is very relevant in the tropics because of low activity clay, yet, the use of CEC alone as land characteristics for fertility excluding soil organic matter (SOM) will rate the soil low especially in the acid soils of the tropics where pH is a limiting characteristic. This is because SOM can act for both nutrient retention and nutrient availability. Organic matter also has properties which facilitates aggregation of mineral particles particularly clays, and in turn modify soil physical structure and influence water regimes. Looking at the indicators of soil quality, it would be seen that all the indicators fix in to major land qualities as defined by FAO e.g. nutrient retention, nutrient availability, workability, and so on. Thus, where land evaluation studies are lacking, assessment of soil quality using minimum data set becomes handy for land use planning.

Furthermore, land capability classification emphasizes slope as an important land characteristic. Oluwatosin and Ogunkunle (1995) stated that in a landscape where the risk of erosion is taken care of by a cropping system (e.g. mixed cropping under minimum or zero tillage system), the predictive value based on the risk of erosion due to slope might be very low. Nevertheless, slope is an important land characteristic for sustainable land use in the tropics. Thus, to successfully use land capability classification in the developed countries where full mechanization is practised, slope gradient remains a major land characteristic in land capability classification. However, in the developing countries where full mechanization is not a common practice and the risk of erosion is, in general, taken care of by the multiple cropping system, slope becomes less important characteristic in capability classification.

In tropical ecosystem, soil quality assessment will likely be more favourably used because there is inclusion of more relevant agricultural related soil properties as soil quality indicators. For instance, organic matter and pH, which are very crucial in sustainable agriculture, are included as soil quality indicators. Increase in organic matter content by reducing tillage is a fundamental practice for reducing erosion, soil degradation, and thus improving soil quality. Also, properties that are mostly affected by continuous cultivation are those emphasized in soil quality assessment. Soil quality assessment can be made to help identify areas where problems occur, identify areas of special interest, or compare fields under different management systems. Also soil quality data can be used by land managers to make management decisions USDA (2001).

Unlike land capability classification, soil quality can be monitored. For example, the inherent quality of the soils of the study area ranges between medium to high. The indicators of soil quality are sensitive to change in the environment. Monitoring of soil quality indicators over time in the area will identify changes or trends in the functional status or quality of the soil. Monitoring can be used to determine the success of management practices or the need for additional management changes or adjustment to achieve sustainable crop production.

CONCLUSION

A significant correlation was observed between soil quality rating and land capability classes. This result seems to indicate that soil quality assessment and land capability classification are convergence in the assessment of the soils of the study area. They both assess soil broadly without special consideration for any particular crop. However, the costs of carrying out soil survey and land evaluation studies are enormous. Soil quality is being recommended for developing countries especially Nigeria where land evaluation studies are lacking because of funds. The determination of soil quality will strengthen the information base, ability to formulate workable solutions to crop production and the likelihood of adoption of best management practices.

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Submitted June 13, 2005 – Accepted January 24, 2006
Revised received February 14, 2006