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Between Soil Quality Index and Soil Mapping Units

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ABSTRACT: Application of the soil quality index in soil maps would be a good idea to quickly guide management decisions. Soil quality index was deduced for each of six mapping units of three locations in three southeastern Nigerian soils namely Imo, Abia and Akwa Ibom States. Rigid grid soil survey technique was used to cut traverses abound the three states that fell on a straight transect. A profile pit was dug in each of the grids, described and sampled according to the guidelines of FAO (2006). Soil samples were prepared in the laboratory and analysis was carried out for 12 minimum data set of parameters that made up the indicators for a quality index. Soil quality index was calculated by a simple mathematical formular using the scoring functions according to a procedure by Obi *et al*. (2016). Soil mapping units were delineated based on differences in the soil quality index which emanated from the soil quality indicator differences. Results showed that geomorphology of the areas that were designated soil mapping unit A had gently sloping landform of 2 to 4 % slopes with slight sheet erosion, soil mapping unit B had strongly sloping landscapes of 4 to 8 % slopes with severe sheet erosion and gullies while soil mapping unit C were on a flat valley bottom with alluvial or coastal deposits with slopes ranging from 2 to 6 % having moderate sheet erosion and gullies. Most of the soil profiles were deep (≥ 140 cm) and well drained. Soils that fell under mapping units A, B and C had; high (SQI = 0.76), intermediate (SQI ≥ 0.51 ≤ 0.61) and a low (SQI ≥ 0.40 ≤ 0.43) quality index respectively. Classification based model in digital soil mapping where soil quality index will be used as the predictor variable would give an immediate understanding of the knowledge of soil or its environmental history.
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INTRODUCTION

Soil quality has been widely researched by soil scientists since the past century. Recently, interest has dropped among scientists as to how to harmonize it to a common and generally accepted standard majorly because of spatial-temporal variability of soil quality indicators. Application of the quality index in the decision making process has rather been difficult because policy makers have not seen the need between using the soil quality index and the quantitative values of the physical, chemical and biological indicators in a soil survey inventory. Because soil quality indicators are sensitive to environmental dynamics such as land use change, conservation or management it would be a good idea to, at intervals, put on maps the quantitative soil quality index of different areas to immediately indicate where soils differed in their quality. Soil quality has been defined as the capacity of a soil to function within ecosystem and land use boundaries, to sustain biological productivity, maintain environmental quality, promote plant and animal health" (Doran and Parkin, 1994). Doran and Parkin (1996) stated that a quantitative assessment of soil quality is needed to determine the sustainability of land management systems as related to agricultural production practices, and to assist government agencies in formulating and evaluating sustainable agricultural and land use policies. Soil quality indicators are measurable (mainly quantitative) soil attributes that influence the capacity of soil to perform crop production or environmental functions and are sensitive to changes in land use, management or conservation practices (Obi *et al*., 2016). An additive index of soil quality (SQI) has been deduced by many researchers (Marzaioli *et al*., 2010; Onweremadu, 2008 and more recently Obi *et al*., 2016). A modified and better scoring for the index was done by Obi *et al*. (2016) which gave the studied soils a better fit to the understanding of soils and their quality. Digital soil mapping and modeling techniques have proliferated during the past decade to address soil data and information needs (Grunwald, 2009) and have the potential to overcome limitations encountered by traditional soil survey methods. Traditional soil mapping have limited capacity to spatially represent many soil properties that vary continuously within the soil mapping unit and are therefore not suited for addressing site-specific issues. The inability to express spatial variability through categorical mapping means that the utility of traditional soil mapping has limited application in spatially-explicit environmental modeling. Classification based model in digital soil mapping where soil quality index will be used as the predictor variable would be able to give an immediate understanding of the knowledge of soil or its environmental history. Soil degradation was the bane for carrying out this research since calculation and application of the linear function (SQI) in the soil inventory would be able to guide management decisions in bringing about aggradations in the study areas. The objective of the study was therefore to apply the soil quality index of the areas in mapping soils of three southeastern Nigerian soils including soils in Imo, Abia and Akwa Ibom State.

MATERIALS AND METHODS

Description of the Study Area

Three major southern states in Nigeria constituting soils from different parent materials were used for this study. The states include Imo, Abia and Akwa Ibom which have a straight transect of road network connection. Soils of these three states cut across different parent materials including; coastal plain soils, false bedded sandstones, clay-shales, upper coal measure and lower coal measures. In Imo, different locations for the study included; Emeabiam, Egwe and Amuro; and prevalent land uses in areas sampled include; crop land, secondary and thick forest land respectively. Because soil quality indicators are majorly sensitive to changes in land use, management or conservation practices, higher priority was given to them for site selection than to the differing parent materials or soil classes. Imo state is located approximately between longitudes 6˚50'E and 7˚25'E and latitudes 4˚45'N and 7˚15'N. In Abia State, different locations for the study include; Isuochi, Uturu and Arondizuogu and the same land uses- crop land, secondary forest and thick forest soils respectively were identified. Abia state is located between longitudes 7˚10'E and 8˚25'E and latitudes 4˚40'N and 6˚14'N. Again, three areas (Uyo, Abak and Etinam) in Akwa Ibom State were used for the study where same land uses were prevalent. Akwa Ibom State is located approximately between longitudes 7˚25'E and 8˚25'E and latitudes 4˚32'N and 5˚33'N. The three states lie within a tropical climate characterized by rainy season (February/March – November) and dry season (November – February/March). Annual rainfall in the three states ranges from 3000 mm along Atlantic coast to 2000 mm in the hinterland. Average annual temperature of the three states ranges from 25 to 27˚C. Most of the crop lands in the locations were non-irrigated to cash crops such as oil palm plantation, and annual and perennial crops.

Soil Sampling and Laboratory Analysis

Rigid grid procedure was used to cut traverses for conventional soil survey of each of the sampling sites which made up the whole research areas. In each of the sampling sites, six grids were sampled by digging a profile pit in each of the grids to be able to detect differences in mapping units. Soils profiles were described and sampled according to the guidelines of FAO (2006). A minimum of four samples were collected from each of the pedons based on horizon differentiation. All the samples collected were bagged in fresh clean polyethene bags and were prepared in the laboratory for analysis of the important soil quality indicators as outlined by Obi *et al*. (2016).

In the laboratory, sampled were air dried and major soils were got ready by a simple sieving process with a 2mm sieve. The indicators of soil quality which were collected into a 12 minimum data set (MDS) of parameters according to Obi *et al*. (2016) were all analyzed using standard procedures. Bulk density was determined using the core method as described by Blake and Hartge (1986). Hydraulic conductivity was determined using the constant head permeameter method as described by Topp and Dane (2002). The coefficient of linear extensibility (COLE) was calculated as the difference in bulk density of undisturbed core samples when moist (33kPa or 10kPa if coarse sandy soil) and when oven dried (Esu, 2010). Exchangeable base cations (Ca, Mg, K, and Na) were extracted with 1 N NH_4OAc (pH 7) (Thomas, 1982). Exchangeable calcium and magnesium were determined by ETDA complexio-metric titration while exchangeable potassium and sodium were determined by flame photometry (Jackson, 1962). Cation Exchange Capacity (CEC) was determined by ammonium saturation (NH_4OAc) displacement method conducted at pH 7.0 as was explained in the Laboratory Manual for Agronomic Studies in Soil, Plant and Microbiology, University of Ibadan (Odu *et al*; 1986). Base saturation was calculated as a percentage of the value of the summation of exchangeable bases over cation exchange capacity. Soil organic carbon was analyzed by Walkley and Black wet digestion method (Nelson and Sommers, 1982). Soil pH was measured potentiometrically in both water and 0.1 N KCl at the soil- liquid ratio of 1:2.5. Total nitrogen was determined by micro Kjedahl digestion method (Bremner and Mulvaney, 1982) and available phosphorous was determined by Bray II method (Olsen and Sommers, 1982).

Soil Quality Index

Soil quality index was deduced from an additive index of the scoring functions (an arithmetic function) and was divided by the total number of the parameters in the minimum data sets according to a procedure described by Obi *et al*. (2016). The formula for calculating the soil quality index was given as:

$$SQI = \sum_{i=0}^{n} \frac{Si}{n}$$

Where,

SQI = Soil quality index

Si = the score assigned to each indicator

n = the number of indicators included in the MDS

RESULTS AND DISCUSSION

Table 1 shows the landform and major soil characteristics of the different mapping units in the studied States. The geomorphology of the areas that were designated soil mapping unit A showed that the landform of the locations were mostly gently sloping flats of 2 to 4 % slopes with slight sheet erosion. Geomorphology of areas has been known to influence soils, their biogeochemistry and hydrology (Pankaj *et al*., 1994). Soils of the soil mapping unit A that had gently sloping flats and well drained profiles would percolate and infiltrate more water, thus, constituting slight soil degradation such as erosion. The soils had a loamy sand texture and a sub-angular blocky structure. The soil mapping unit B had strongly sloping landscapes of 4 to 8 % slopes with severe sheet erosion and gullies. This could be because the slopes were steep that high intensity of rainfall would increase the surface flow velocity of water on the soil surface which would scour channels as it transports soil materials down the slopes. The soils had textures ranging from having loamy sand to sandy clay loam. The soil mapping unit C was on a flat valley bottom with alluvial or coastal deposits with slopes ranging from 2 to 6 % having moderate sheet erosion and gullies. The soil had well drained profiles but their landform was limited by steepness of some of the slopes. Table 2 show results of the linear function (SQI) deduced from the scoring functions and the mapping units. Each of the mapping units was designated with alphabets showing differences in soil properties. From the results, soil mapping unit A in Imo state had the best properties (scores of Ca = 0.32, Mg = 3.00, K = 0.30 and CEC = 12.00), looking at the 12 quality indicators, when compared with other mapping units in all the states. It would have been said that instead of making judgment by examining each of the properties, a single numerical index of soil quality (SQI = 0.76) would give an easy comprehensible information about the soil fertility. Even when a map legend gave an information about major soil characteristic of an area, it would be a good idea to include the soil quality index as this would foster easy management decisions when large areas are to be conserved by few persons. The soil mapping unit B extended from Imo state to Abia State and the derived soil quality index that fell under the mapping unit B were at the intermediate level (SQI ≥ 0.55 ≤ 0.70) of soil quality according to a research by Obi *et al*. (2016). The soil quality indicators in the soil mapping unit B got scores ranging from 0.16 to 0.26 for Ca, 0.06 to 0.37 for Mg, 0.07 to 0.68 for K and 0.28 to 0.42 for CEC. Soil properties or quality indicators that defined the soil mapping unit B were not as high as that that defined the soil mapping unit B. Some part of the study area in Abia State fell under the soil mapping unit C including all the locations studied in Akwa Ibom State. It was observed that the mapping units of the different states that gave a proportional significance of their soil quality index. Soil mapping unit C as well had lowest value of the quantitative soil quality indicators as most of the parameters in the MDS scored low giving a low quality index according to the ratings of Obi *et al*. (2016) and Marzaioli *et al*. (2010).

CONCLUSION

Soils of the soil mapping units B and C had major limitations as sheet and gully erosions. The soils were not designated to their respective mapping units using the major morphological characteristics but also based on the soil quality index of the respective States. The soil quality indexes were suitable for placement in maps because the index was drawn from a linear function that was gathered from the scores of the respective soil quality indicators that were collected into a minimum data set of important 12 parameters for defining soil fertility. We can rather make soil maps while including the numeric soil quality index in it so that we can make immediate management decisions and recommendations.

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Table 1: Landform and Major Soil Characteristics of the Different Mapping Units in the Studied States

Map Unit Symbol	Landform	Major Soil Characteristic
A	Gently sloping flats of 2 to 4 % slopes with slight sheet erosion	Well drained profile, hue of 7.5 YR, value of 3 and chroma of 2 in most of the upper horizons having mostly loamy sand texture and a moderate sub-angular blocky structure.
B	Strongly sloping landscapes of 4 to 8% slopes with severe sheet erosion and gullies	Well drained profile, hue of mostly 10 YR, value of 3 and chroma of 1 in the upper horizons having loamy sand to sandy clay loam textures and a moderate sub-angular blocky structure.
C	Flat valley bottom with colluvium-alluvial or coastal deposits with slopes ranging from 2 to 6% having moderate sheet erosion and gullies	Well drained profiles, hue of 7.5 YR, value of 2 and chroma of 5 in most of the upper horizons having mostly loamy sand and sandy loam textures.

Table 2: The 12 MDS, Scale, Scores, SQI and Mapping Units in the States

Parameters	HC	BD	COLE	Ca	Mg	K	CEC	BS	pH	OC	TN	Av.P	**SQI**	**Mapping unit**
	cm/min	g/cm^3		--------Cmol/kg---------				%		----g/kg----		mg/kg		
Scale	0.10	1.60	0.06	5.00	3.00	0.30	12.00	60.00	6.60	10.00	0.20	10.00		
Imo State														
Thick Forest														
Scores	0.50	0.81	1.00	0.32	0.35	0.53	0.38	1.00	0.76	0.29	1.00	0.66	0.76	A
Crop Land														
Scores	0.50	1.00	1.00	0.26	0.20	0.07	0.41	0.69	0.85	0.56	0.80	0.64	0.58	B
Secondary Forest														
Scores	0.80	0.93	1.00	0.23	0.16	0.27	0.35	0.71	0.82	0.60	0.75	0.69	0.61	B
Abia State														
Thick Forest														
Scores	0.50	0.94	1.00	0.18	0.06	0.07	0.28	0.66	1.00	0.32	0.85	0.25	0.51	B
Crop Land														
Scores	0.70	0.93	0.83	0.16	0.37	0.68	0.42	0.70	0.64	0.72	0.10	0.24	0.54	B
Secondary Forest														
Scores	0.50	0.93	1.00	0.12	0.08	0.10	0.23	0.62	1.00	0.32	0.15	0.29	0.45	C
Akwa Ibom State														
Thick Forest														
Scores	0.61	0.71	0.74	0.02	0.14	0.23	0.38	0.72	0.79	0.20	0.37	0.02	0.41	C
Crop Land														
Scores	0.78	0.89	0.70	0.02	0.16	0.40	0.36	0.70	0.75	0.10	0.33	0.02	0.43	C
Secondary Forest														
Scores	0.70	0.61	0.80	0.13	0.05	0.40	0.30	0.68	0.72	0.10	0.11	0.03	0.40	C

<0.55 – low quality, 0.55 - 0.7 – Intermediate quality, >0.7- High quality

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