International Journal of Plant & Soil Science
14(4): 1-10, 2017; Article no.IJPSS.31890
ISSN: 2320-7035

SCIENCEDOMAIN ***international***
www.sciencedomain.org

Application of the Concept of Minimum Data Sets to Soil Quality Assessment for Crop Production in Southwestern Nigeria

O. D. Adeyolanu[1*]

[1]Institute of Agricultural Research and Training, Obafemi Awolowo University, P.M.B. 5029, Moor Plantation, Ibadan, Nigeria.

Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/IJPSS/2017/31890
Editor(s):
(1) Yong In Kuk, Department of Development in Oriental Medicine Resources, Sunchon National University, South Korea.
Reviewers:
(1) Anibal Condor Golec, Organic Plant Production, Calle Francisco de Cuellar, Monterrico, Lima, Peru.
(2) Valentin Kosev, Institute of Forage Crops, Pleven, Bulgaria.
Complete Peer review History: http://www.sciencedomain.org/review-history/18061

Original Research Article

Received 29th January 2017
Accepted 22nd February 2017
Published 6th March 2017

ABSTRACT

Indicators for soil quality assessment are many; some major and some minor. The more the indicators, the more reliable the assessment, but the more costly it becomes. Hence the need for selection of the most relevant indicators as minimum data set (MDS). The study examined the application of the concept of MDS to soil quality assessment for crop production under tree and arable land use in three states (Oyo, Osun and Ekiti) in southwestern Nigeria.
Twelve (12) soil quality indicators were selected for the assessment. The indicators were reduced to the bearable minimum using the land requirement for each crop and product-moment correlation. Soil quality assessment was carried out on the land use types using the initial 12 indicators and the MDS. The relationship between soil quality indices of the two (with minimum vs with 12 indicators) assessments was established using correlation analysis at $\alpha_{0.05.}$
Active carbon, potentially mineralizable nitrogen (PMN), pH, CEC, effective soil depth, aggregate stability and bulk density qualified as MDS for soil quality assessment of tree crops while active carbon, PMN, pH, CEC, aggregate stability, available phosphorus and bulk density qualified for arable crops. Under tree crops, soil quality indices with 12 indicators and MDS ranged from 63–87% and 61–86%; and 60–72% and 61–71% under arable crops. Relationship between indices of

**Corresponding author: E-mail: olatejuadeoyolanu@gmail.com;*

the two sets of indicators shows high positive correlation (r = 0.83 and 0.74 for tree and arable crops respectively).
With the concept of MDS in place, soil quality assessment will be less costly and therefore more affordable for farmers.

Keywords: Minimum data sets; soil quality; application; concept; assessment.

1. INTRODUCTION

Tropical soils are generally delicate in nature due to low organic matter content, low activity clay, high erodibility and low resilience. In addition, there is population pressure on the available land and this has become a great challenge for sustainable agriculture and land management. There is need to put in place efficient assessment method that will make monitoring of land use impact on land resources possible in order to avoid degradation. One method that is efficient and popular among scientists and land users is soil quality assessment which is the assessment of the capacity of soil to function in a productive and sustained manner while maintaining or improving the resource- base, environment, and plant, animal and human health.

Assessing soil quality and health can be likened to a medical examination of humans in which certain measurements are taken of the quality of certain parameters as basic indicators of system function. Many indicators comprising of physical, chemical and biological characteristics sensitive to change in the environment have been identified for the assessment of soil quality. However, not all the soil attributes can be used as indicators for assessing soil quality because many of them are not able to meet some set criteria for soil quality indicators [1]. Including such attributes will only be a waste of effort and money. A minimum data set (MDS) is the minimum set of indicators required to obtain a sufficient knowledge and reliable estimate of the quality of the soil. A MDS helps to identify locally relevant soil indicators and to evaluate the link between selected indicators and significant soil and plant properties [2]. More importantly, MDS serves as a useful tool for screening the condition, quality and health of soil [3,4,1]. For smallholder farmers, these tools need to be simple measures of soil health and soil quality such as consistency, color, and workability [5]. For extension and policy personnel, they provide basic information needed to arrive at management decisions [6]. For researchers, there is need to conduct sufficiently detailed tests while controlling for variation in order to develop meaningful assessments of soil status, often expressed as an index of soil quality [7]. Due to these complexities, there is need to develop diagnostic measures and indicators of soil quality changes in order to derive classifications from the minimum data set that can better assist farmers and inform research and extension to target solutions at farm level [5].

To select a minimum data set, two main methods have been established: (i) Expert opinion and (ii) Statistical data reduction [8]. Expert opinion, by definition, requires expert knowledge of the system. Using a hierarchical framework for choosing the indicators may help make selection more systematic. Management goals dictate the soil functions or processes of interest, which in turn, suggest related indicators. For instance, if animal waste disposal is a goal for a particular field, filtering and buffering is an important soil function or process. Under filtering and buffering, organic matter content and pH are potential indicators. The indicator set must be further refined according to climate, soil, and plant community or other factors. This is the method used by the Soil Management Assessment Framework. Statistical data reduction has been demonstrated to effectively choose indicators in a number of soil systems [8,9,10]. This method can eliminate bias that could be a problem with expert selection of indicators. Another way to select a MDS is the use of information on land requirement for crop production.

This study examined the concept of minimum data set in comparison with the conventional approach for assessing soil quality under tree and arable crops in southwestern Nigeria.

2. MATERIALS AND METHODS

2.1 Study Site

The study was conducted in selected Local Government Areas (LGAs) in three States (Oyo, Osun and Ekiti) in Southwestern Nigeria under tree and arable land use. In Oyo State, the study was carried out in locations within Oluyole LGA of the State within latitudes 7°10' N and 7°20' N and longitudes 3°45' E and 3°55' E. In Osun State, the study was carried out in selected locations within Aiyedire, and Egbedore LGAs of the state within latitudes 7°30' N and 7°45' N and longitudes 4°10'E and 4°30' E. The study was conducted in locations within Ikole LGA in Ekiti State within latitudes 7°47' N and 7°51' N and longitudes 5°25' E to 5°30' E.

The climate of the study locations can be described as humid to sub-humid tropical with distinct dry and wet seasons. The dry season runs from early November to the end of March or early April, while the wet season is from end of March or early April to about middle of November. There are two rainfall peaks in June and September with a dry spell in August (August break) which produces the bimodal rainfall pattern in southwestern Nigeria. The average annual rainfall is 1,279 mm, 1,276 mm and 1,289 mm for Oyo, Osun and Ekiti States respectively. The mean annual temperature ranged between 26°C and 32°C, relative humidity is high and ranged between 60% and 90% at 16.00 hrs [11,12].

The soils of the study sites in Oyo State were formed on Crystalline Basement Complex rocks with coarse-grained granite gneiss as dominant parent rock. In Osun state, medium-grained granite gneiss is the dominant parent rock while fine-grained granite and gneiss are the dominant parent rock for Ondo State. The soils encountered at the sites were classified into Iwo association, Egbeda association and Ondo association in Oyo, Osun and Ekiti states respectively [13]. The vegetation of the study locations in Oyo State falls within the forest zone in Oyo and Ekiti states and derived savanna zone in Osun state.

2.2 Field Study

Four agricultural land use types (two tree and two arable) were selected from each of the three states. In each of the locations, the quality of the soil was assessed by collecting soil samples randomly from ten sampling points at 0 – 15 cm and 15 – 30 cm depths. The samples were processed and subjected to laboratory analysis of soil quality indicators for quantitative assessment.

2.3 Minimum Data Sets for the Different Crops

Soil quality indicators selection for Minimum Data Sets for each of the land use type was done using the modified approaches of [14,15,16]. Land requirement (LR) for each of the crops was obtained from [17] and statistical data reduction of [8]. The relationship between pairs of selected indicators was established byproduct-moment correlation to further reduce the number of indicators to the minimum and the minimum ‘r’ value for any two or more indicators to be selected interchangeably is 0.60 according to [8].

3. RESULTS

3.1 Minimum Data Sets for the Four Crops

Based on a combination of the approach of [14,16], land requirements for the different crops and correlation coefficient, 7 (seven) soil quality indicators qualified as the minimum data sets (MDS) for assessing soil quality under tree and arable crops. The correlation matrix (Tables 1 to 6) produced from inter-correlation coefficients between pairs of the indicators showed that some of them are very highly correlated; hence two of such need not be used. Thus the removal of one of the two highly correlated indicators further reduced the number in the MDS. Active carbon had very high correlation with total organic carbon in all the sites; hence, either of the two can be included. PMN and Total Nitrogen were also highly correlated. Aggregate stability correlates with water holding capacity. Bulk density highly correlated with porosity.

The 7 indicators that qualified as MDS for assessing soil quality under tree crops are active carbon, potentially mineralizeable nitrogen (PMN), pH, cation exchange capacity (CEC), effective soil depth, aggregate stability and bulk density with acceptance scores of 88%, 84%, 88%, 84%, 84%, 80% and 84% respectively (Table 7). For the arable crops, the MDS are active carbon, PMN, aggregate stability, CEC, pH, bulk density and available phosphorus with acceptance scores of 88%, 84%, 88%, 84%, 84%, 80% and 76% respectively (Table 8).

3.2 Relationship between Conventional Indicators and Minimum Data Sets for Tree and Arable Crops

Table 9 shows overall soil quality indices using conventional indicators and minimum data set under tree and arable crops. Under tree crops, the values ranged from 63 to 87% and 61 to– 86% for Conventional and MDS respectively. Under arable crops, the values ranged from 60 to

72% and 61 to 69% for Conventional and MDS respectively. The relationship between conventional indicators and minimum data set shows high positive correlation with r values of 0.82 and 0.74 for tree and arable crops respectively.

Table 1. Product-moment correlation coefficients between pairs of soil quality indicators under tree crops in Oyo State (n = 20)

	Act. C	Agt. Stab	Av. P	B.S.	B.D.	ECEC	PMN	Porosity	Total C	Total N	WHC	pH
Act. C												
Agt. Stab.	0.79*											
Av. P	0.89*	0.84*										
Base Saturation	0.76*	0.93*	0.88*									
Bulk Density	0.84*	0.56	0.58	0.64*								
ECEC	0.85*	0.50	0.63*	0.57	0.99*							
PMN	0.82*	0.27	0.96*	0.89*	0.82*	0.87*						
Porosity	0.81*	0.85*	0.34	0.54	0.72*	0.34	0.40					
Total Carbon	0.89*	0.70*	0.64*	0.64*	0.98*	0.97*	0.78*	0.50				
Total Nitrogen	0.90*	0.66*	0.67*	0.60*	0.99*	0.98*	0.81*	0.48	0.99*			
WHC	0.63*	0.96*	0.87*	0.69*	0.76*	0.24	0.34	0.99*	0.85*	0.75*		
pH	0.62*	0.88*	0.56	0.63*	0.21	0.18	0.17	0.94*	0.92*	0.79*	0.72*	

*Note: Act. C – Active Carbon, Agt. Stab. – Aggregate Stability, Av.p. – Available Phosphorus, CEC – Cation Exchange Capacity, PMN – Potentially Mineralizable Nitrogen, WHC – Water Holding Capacity, * = Significant at 0.05 level of probability*

Table 2. Product-moment correlation coefficients between pairs of soil quality indicators under tree crops in Osun State (n = 20)

	Act. C	Agt. stab	Av. P	B.S.	B.D.	ECEC	PMN	Porosity	Total C	Total N	WHC	pH
Act. C												
Agt. Stab.	0.81*											
Av. P	0.22	0.80*										
Base Saturation	0.58	0.49	0.17									
Bulk Density	0.21	0.76*	0.38	0.29								
ECEC	0.97*	0.06	0.18	0.61*	0.14							
PMN	0.97*	0.03	0.18	0.57	0.22	0.91*						
Porosity	0.01	0.96*	0.66	0.74*	0.78*	0.05	0.06					
Total Carbon	0.81*	0.24	0.71*	0.82*	0.66*	0.77*	0.71*	0.79*				
Total Nitrogen	0.58	0.44	0.40	0.65*	0.59	0.72*	0.82*	0.68*	0.99*			
WHC	0.06	0.87*	0.66	0.84*	0.74*	0.03	0.17	0.94*	0.93*	0.92*		
pH	0.52	0.60	0.69	0.09	0.51	0.64	0.33	0.63*	0.98*	0.87**	0.15	

*Note: Act. C – Active Carbon, Agt. Stab. – Aggregate Stability, Av.p. – Available Phosphorus, CEC – Cation Exchange Capacity, PMN – Potentially Mineralizable Nitrogen, WHC – Water Holding Capacity, * = Significant at 0.05 level of probability*

Table 3. Product-moment correlation coefficients between pairs of soil quality indicators under tree crops in Ekiti State (n = 20)

	Act. C	Agt. Stab	Av. P	B.S.	B.D.	CEC	PMN	Porosity	Total C	Total N	WHC	pH
Act. C												
Agt. Stab.	0.70*											
Av. P	0.53	0.71*										
Base Saturation	0.62	0.93*	0.99*									
Bulk Density	0.58	0.78*	0.57	0.49								
CEC	0.70*	0.94*	0.97*	0.04	0.50							
PMN	0.98*	0.05	0.76*	0.19	0.96*	0.15						
Porosity	0.52	0.74*	0.17	0.55	0.63*	0.50	0.66*					
Total Carbon	0.99*	0.78*	0.62	0.65	0.64*	0.74*	0.90*	0.56*				
Total Nitrogen	0.70*	0.85*	073*	0.08	0.60*	0.88*	0.35	0.90*	0.67*			
WHC	0.25	0.26	0.88*	0.11	0.77*	0.16	0.50	0.84*	0.26	0.03		
pH	0.28	0.22	0.89*	0.08	0.25	0.13	0.45	0.81*	0.30	0.02	0.99*	

*Note: Act. C – Active Carbon, Agt. Stab. – Aggregate Stability, Av.p. – Available Phosphorus, CEC – Cation Exchange Capacity, PMN – Potentially Mineralizable Nitrogen, WHC – Water Holding Capacity, * = Significant at 0.05 level of probability*

Table 4. Product-moment correlation coefficients between pairs of soil quality indicators under arable farms in Oyo State (n = 20)

	Act. C	Agt. stab	Av. P	B.S.	B.D.	CEC	PMN	Porosity	Total C	Total N	WHC	pH
Act. C												
Agt. Stab.	0.53											
Av. P	0.89*	0.44										
Base Saturation	0.95*	0.86*	0.14									
Bulk Density	0.95*	0.12	0.16	0.99*								
ECEC	0.26	0.72*	0.89*	0.51	0.46							
PMN	0.20	0.68*	0.48	0.52	0.49	0.36						
Porosity	0.93*	0.76*	0.03	0.96*	0.94*	0.63*	0.62*					
Total Carbon	0.95*	0.81*	0.07	0.99*	0.98*	0.57	0.57	0.99*				
Total Nitrogen	0.88*	0.79*	0.05	0.96*	0.94*	0.58	0.65*	0.99*	0.99*			
WHC	0.53	0.71*	0.22	0.72*	0.69*	0.49	0.93*	0.84*	0.79*	0.85*		
pH	0.76*	0.88*	0.84*	0.64*	0.62*	0.88*	0.60*	0.83*	0.73*	0.85*	0.62*	

*Note: Act. C – Active Carbon, Agt. Stab. – Aggregate Stability, Av.p. – Available Phosphorus, CEC – Cation Exchange Capacity, PMN – Potentially Mineralizable Nitrogen, WHC – Water Holding Capacity, * = Significant at 0.05 level of probability*

Table 5. Product-moment correlation coefficients between pairs of soil quality indicators under arable farms in Osun State (n = 20)

	Act. C	Agt. Stab	Av. P	B.S.	B.D.	CEC	PMN	Porosity	Total C	Total N	WHC	pH
Act. C												
Agt. Stab.	0.60*											
Av. P	0.94*	0.95*										
Base Saturation	0.37	0.59	0.26									
Bulk Density	0.45	0.87*	0.13	0.69*								
ECEC	0.28	0.67*	0.27	0.92*	0.04							
PMN	0.89*	0.83*	0.01	0.29	0.11	0.26						
Porosity	0.63*	0.50	0.26	0.89*	0.92*	0.02	0.71*					
Total Carbon	0.92*	0.66*	0.43	0.89*	0.79*	0.26	0.69*	0.57				
Total Nitrogen	0.59	0.97*	0.02	0.28	0.87*	0.26	0.97*	0.76*	0.54			
WHC	0.64*	0.85*	0.08	0.49	0.95*	0.15	0.96*	0.78*	0.84*	0.91*		
pH	0.94*	0.26	0.51	0.68*	0.65*	0.62*	0.67*	0.42	0.28	0.45	0.79*	

*Note: Act. C – Active Carbon, Agt. Stab. – Aggregate Stability, Av.p. – Available Phosphorus, CEC – Cation Exchange Capacity, PMN – Potentially Mineralizable Nitrogen, WHC – Water Holding Capacity, * = Significant at 0.05 level of probability*

Table 6. Product-moment correlation coefficients between pairs of soil quality indicators under arable farms in Ekiti State (n = 20)

	Act. C	Agt. Stab	Av. P	B.S.	B.D.	CEC	PMN	Porosity	Total C	Total N	WHC	pH
Act. C												
Agt. Stab.	0.12											
Av. P	0.99*	0.15										
Base Saturation	0.37	0.68*	0.37									
Bulk Density	0.01	0.90*	0.04	0.34								
ECEC	0.28	0.57	0.24	0.27	0.28							
PMN	0.92*	0.12	0.07	0.12	0.06	0.19						
Porosity	0.96*	0.71*	0.02	0.51	0.94*	0.22	0.83*					
Total Carbon	0.99*	0.85*	0.07	0.28	0.99*	0.19	0.96*	0.95*				
Total Nitrogen	0.99*	0.19	0.04	0.37	0.98*	0.19	0.92*	0.98*	0.99*			
WHC	0.94*	0.68*	0.03	0.42	0.93*	0.13	0.87*	0.98*	0.95*	0.98*		
pH	0.63*	0.08	0.40	0.27	0.67*	0.78*	0.74*	0.39	0.62*	0.53	0.62*	

*Note: Act. C – Active Carbon, Agt. Stab. – Aggregate Stability, Av.p. – Available Phosphorus, CEC – Cation Exchange Capacity, PMN – Potentially Mineralizable Nitrogen, WHC – Water Holding Capacity, * = Significant at 0.05 level of probability*

Table 7. Scores of indicators included as MDS in soil quality assessment for tree crop production

Indicators	S	U	M	I	R	A
Active Carbon	5	4	5	4	4	88%
PMN	5	4	4	4	4	84%
pH	4	4	5	5	4	88%
ECEC	4	5	4	4	4	84%
Effective soil depth	5	4	5	4	3	84%
Aggregate stability	5	3	4	4	4	80%
Bulk density	4	4	5	3	4	84%

Note: A = Acceptance score, S = sensitivity of indicator to degradation and remediation, U = ease of understanding of indicator value, M = ease and/or cost effectiveness of measurement of soil indicator, I = predictable influence of properties on soil, plant and animal health and productivity and R = relationship to ecosystem processes

Table 8. Scores of indicators included as MDS in soil quality assessment for arable crop

Indicators	S	U	M	I	R	A
Active carbon	5	4	5	4	4	88%
Potentially mineralizeable Nitrogen	5	4	4	4	4	84%
ECEC	4	5	4	4	4	84%
Aggregate stability	5	3	4	4	4	80%
Bulk density	4	4	5	3	4	80%
pH	4	4	5	5	4	88%
Available Phosphorus	4	4	3	4	4	76%

Note: A = Acceptance score, S = sensitivity of indicator to degradation and remediation, U = ease of understanding of indicator value, M = ease and/or cost effectiveness of measurement of soil indicator, I = predictable influence of properties on soil, plant and animal health and productivity and R = relationship to ecosystem processes

Table 9. Soil quality indices of conventional indicators and MDS under tree and arable crops for the three states

	Tree crops		Arable crops	
	Conventional	**MDS**	**Conventional**	**MDS**
	85	85	60	66
	87	86	61	64
Oyo	73	78	61	67
State	67	76	65	65
	84	82	68	70
	64	66	72	71
Osun	63	62	68	69
State	65	61	63	63
	75	76	63	61
	80	79	70	71
Ekiti	71	69	65	64
State	75	62	64	66
	r = 0.82		r = 0.74	

4. DISCUSSION

The whole essence of this study is to provide minimum set of soil quality indicators which are less costly to assess and at the same time possess the criteria of good indicators for the assessment of soil quality. Soil quality indicators are many, with some being major and others minor. The more the indicators involved in the assessment the more reliable the assessment, but the higher the cost too. Hence the need for selection of the most relevant indicators as minimum data set. The useful indicators are those that are related to major soil processes that impact on crop yield. Seven different soil quality indicators (Active carbon, Potentially Mineralizable Nitrogen (PMN), pH, cation exchange capacity, aggregate stability, bulk density and effective soil depth) qualified as MDS for the tree crops and seven indicators (Active carbon, Potentially Mineralizable Nitrogen (PMN), pH, cation exchange capacity, aggregate stability, bulk density and available phosphorus) qualified as MDS for arable crops. The selection was based on their high acceptance scores, other specific criteria and their relevance to use and management.

Active carbon is an indicator of the fraction of soil organic matter that is readily available as carbon and energy source for the soil microbial community. It is included as MDS for soil quality assessment because it is a good ‘leading indicator’ of soil health response to changes in soil management. It has a very high acceptance value (88%) and readily responds to change sooner than total organic matter, thus, monitoring the changes in active carbon can be particularly useful to farmers who are changing practices to try to build organic matter. Research has shown that active carbon is highly and positively correlated with percent organic matter, aggregate stability and measures of biological activity [16].

In addition, the measurement of active carbon is very simple, less costly and less labour-intensive than total organic matter. Potentially minieralizable nitrogen had a very high acceptance value (84%) and is thus included as in the MDS for soil quality assessment for crop production. The high acceptance value is a confirmation of its international support as an indicator of soil quality [18,19]. Nitrogen is a macronutrient essential to the growth and yield of plant, but, it is the most limiting nutrient in most agricultural situations [16]. This may be due to the fact that almost all the nitrogen stored in crop residues, soil organic matter, manures and composts, is in the form of complex organic molecules that are not readily available to plants. Microbial species help in converting this organic nitrogen into the ammonium and nitrate forms that plant can utilize. Potentially mineralizable nitrogen is an indicator of the capacity of the soil microbial community to convert (mineralize) nitrogen tied up in complex organic residues into the plant available form of ammonium. It has been discovered that soils with high PMN also have high active carbon, high organic matter and high aggregate stability [16]. The advantages of including PMN as an indicator in the MDS are its ability to indicate arable cropping fertility and potential leaching of nitrate from soils, and as a surrogate for biological activity [15].

pH which is a measurement of soil reaction had a very high acceptance score (88%) and is therefore included in the MDS for soil quality assessment and this seems reasonable. Indeed, there are few, if any, scientific papers or monitoring schemes looking at the physical, chemical and biological status of soils that do not measure pH either in water or in potassium chloride. Reasons may include the significant influence that pH has upon many soil processes like nutrient availability, biogeochemical cycling, contaminant sorption, structural stability and biological activity. Soil pH is an estimate of the hydrogen ions in the soil solution. It is also an indicator of plant available nutrients. High H^+ activity in soil is not desireable and the soil may require liming with base cations in order to bring the solution back to normal. Furthermore, soil acidity has a significant influence on drainage water quality/composition and subsequently on local surface and lake water quality [20].

Cation Exchange Capacity (CEC), the capacity of the exchange sites to perform the function of ion exchange, was rated 84% and is thus included as indicator in MDS for soil quality assessment for crop production function. It was also rated high as an indicator in nutrient retention process for crop production. CEC is very important in ion exchange which is very crucial in nutrient retention and release. Ability to retain and release nutrient at appropriate time is paramount to crop growth and productivity.

Available Phosphorus scored 76% and was included in the MDS for soil quality assessment for crop production function especially arable crops. Phosphorus is a macronutrient which is essential for crop growth. It is involved in energy transfer reactions and plays a role in plant photosynthesis, respiration, cell enlargement and division. Indeed, almost every significant metabolic reaction proceeds via a phosphate derivative. Phosphorus also promotes early root formation and growth, and as plants mature, most phosphorus moves into seeds and/or fruiting; hence the quality of grain, fruit and vegetable crops is greatly improved with an adequate supply of phosphorus [21]. Phosphorus, along with water and nitrogen, tends to be the dominant yield-limiting factor for agricultural crop [15]. In agricultural systems, too little available phosphorus results in stunted crops and reduced yield, therefore, it is broadly accepted that in intensive agricultural systems there is a significant requirement, for most soil types, to apply appreciable amounts of P fertilizer or in manurial form [22]. However, as important as available P is in the soil for plant growth, excessive P is known to alter plant successional dynamics and for semi-natural, nutrient-poor habitats this can reduce diversity [23].

Aggregate stability scored 80% which is a very high acceptance score and is thus included as MDS for soil quality assessment for crop production. It is a measurement of the extent to which soil aggregates resist breaking-up when wetted and under the impact of rain drops. This indicator tests the soil's physical quality with regard to its capacity to sustain its structure during most impactful conditions such as a heavy rain storm. Soils with low aggregate stability tend to form surface crusts which can reduce both water infiltration and air exchange because of blockage of both macro and micropores in the soil. Poor aggregation also makes the soil more difficult to manage, and reduces its ability to dry-up quickly. In heavy soils, enhanced friability and crumbliness from good aggregation makes the soil seem lighter [16].

Effective Soil Depth (ESD), the optimal soil depth which the plant root requires to function, scored

84% and was also included as indicator in the MDS it is a very important soil quality indicator especially for tree crops which are deep rooted. [5] discovered variation in soil depth under different land use systems and thereby submitted that soil depth is one of the important soil quality indicators in determining the response of soil to intensive land use. There is a minimum depth below which the soil cannot growth effectively no matter how great the other soil quality indices are.

Soil bulk density is a very useful soil physical parameter. It is a direct measurement of soil compaction (or loosening) and is essential for estimating the total available pore space within a soil, that is, total porosity [24]. Bulk density is an excellent measure of a most important contemporary form of soil degradation [25]. Bulk density is a useful indicator of change for other soil parameters. For example, an increase in bulk density might indicate a decrease in soil aggregate stability and aggregate size, particularly due to breakdown of soil macroaggregate [26]. Bulk density also has mutual links with chemical and biological soil parameters. [27], found that for all soil groups in England and Wales, increased soil organic carbon levels improved soil structure by decreasing bulk density, improving aggregate stability, pore size and air-filled pore space. Similarly, [28] found that soil texture and soil organic matter were primary factors affecting topsoil bulk density for a range of cultivated soils. In terms of biological indicators, any decline in soil structure is also frequently associated with decreases in microbial biomass and activity [29,30].

To further support the use of MDS in soil quality assessment, the relationship between soil quality indices obtained from assessment with conventional indicators and that of MDS shows high positive correlation for both tree and arable crops. The high r values (0.82 and 0.74) are indicating that both sets of indicators can be used for soil quality assessment. With this fact well established, the concept of minimum data sets should be adopted as suitable and sustainable for soil quality assessment. This will reduce the cost of soil quality assessment and the time spent on the assessment.

5. CONCLUSION

A soil quality assessment study under tree and arable land use was carried out in three states (Oyo, Osun and Ekiti) in southwestern Nigeria to examine the concept of MDS to soil quality assessment for crop production. The indicators included in the MDS were selected for both arable and tree crops by conducting correlation between pairs of the indicators contained in the land requirements for each crop. Seven (7) indicators each qualified as MDS for soil quality assessment of tree and arable crops. High positive correlations exist between soil quality indices from conventional indicators and that of the identified MDS. With the concept of MDS in place, soil quality assessment will be less costly, less time-consuming and therefore more affordable for farmers.

ACKNOWLEDGEMENT

I wish to acknowledge the inputs of Professor Ayoade Ogunkunle of University of Ibadan, Nigeria who supervised this work and helped to review this write up before submission for publication.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Doran JW, Parkin TB. Defining and assessing soil quality for a sustainable environment. Soil Science Society of America Special publication 1994;35:1–21.
2. Arshad MA, Martin S. Identifying critical limits for soil quality indicators in agroecosystems. Agriculture, Ecosystems and Environment. 2002;88:153–160.
3. Doran JW, Sarrantonio M, Liebig M. Soil health and sustainability. In: Sparks, D.L. (ed.). Advances in Agronomy. Academic Press, San Diego. 1996;56:1–54.
4. Larson WE, Pierce FJ. The dynamics of soil quality as a measure of sustainable management. In: Doran JW, Coleman DC, Bezdicek DF, Stewart BA. (eds.). Defining soil quality for a sustainable environment. Soil Science Society of America Special Publication, Madison, WI, USA. 1994;35: 37–51.
5. Murage EW, Karanja NK, Smithson PC, Woomer PL. Diagnostic indicators of soil quality in productive and non-productive smallholders fields of Kenya's Central

highlands. Agriculture, Ecosystems and Environment. 2000;79:1–8.
6. Barrios E, Delve RJ, Bekunda M, Mowo J, Agunda J, Ramisch J, Trejo MT Thomas JJ. Indicators of soil quality: A South-South development of a methodological guide for linking local and technical knowledge. Geoderma. 2006;135:248–259.
7. Kang GS, Beri V, Sidhu BS, Rupela OP. A new index to assess soil quality and sustainability of wheat-based cropping systems. Biology and Fertility of Soils. 2005;41:389–398.
8. Andrews SS, Carroll CR. Designing a soil quality assessment tool for sustainable agroecosystem management: Soil quality assessment of a poultry litter management case study. Ecological. Applications. 2001; 11(6):1573-1585.
9. Brejda JJ, Moorman TB, Karlen DL, Dao TH. Identification of regional soil quality factors and indicators: I. Central and southern high plains. Soil Science Society of America Journal. 2000;64:2115–2124.
10. Andrews SS, Karlen DL, Mitchell JP. A comparison of soil quality indexing methods for vegetable production systems in Northern California. Agriculture, Ecosystems and Environment. 2001;1760: 1-21.
11. Ayoade JO. Introduction to climatology for the tropics. John Willey and Son. Chicherter, UK. 2002;210.
12. Nigerian Meteorological Agency (NIMET). 2007 seasonal rainfall prediction; 2007.
13. Smyth AJ, Montgomery RF. Soil and land use in Central Western Nigeria. Government Printer, Ibadan, Nigeria. 1962; 265.
14. Cameron K, Beare MH, McLaren RP Di H. Selecting physical, chemical and biological indicators of soil quality for degraded or polluted soils. Proceedings of 16th World Congress of Soil Science. Montpellier, France, Symposium. 1998;37:45–56.
15. Merrington G, Fishwick S, Barraclough D, Morris J, Preedy N, Boucard T, Reeve M, Smith P, Fang C. The development and use of soil quality indicators for assessing the role of soil in environmental interactions. Environmental Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol. 2006;241.
16. Gugino BK, Idowu OJ, Schindelbeck RR, Van Es HM, Wolf DW, Thies JE, Abawi GS. Cornel soil health assessment training manual. Edition 1.2. Cornel University, Geneva, NY. 2007;51.
17. Sys C, Van Ranst E, Debaveye J. Land evaluation part II: Methods in land evaluation. General Administration for Development Cooperation, Brussels. Agricultural Publication. 1991;7:247.
18. Doran JW, Safley M. Defining and assessing soil health and sustainable productivity. In: Pankhust C, Doube BM, Gupta VSR. (eds.). Biological indicators of soil health. Wallingford, UK: CAB International. 1997;1–28.
19. Loveland P, Thompson T. Identification and development of a set of national indicators for soil quality. Environment Agency R&D Technical report. 2001;5-53.
20. Seybold CA, Grossman RB, Pierce FJ. On-site assessment of use-dependent soil properties in Michigan. Communication in Soil Science and Plant Analysis. 2003;34: 765–780.
21. Tisdale SL, Nelson WL, Beaton JD, Halvin JL. Soil fertility and fertilizers, 5th edn. Pretence Hall, New Jersey, USA; 1993.
22. MAFF. Towards sustainable agriculture: A pilot set of indicators. In: Fertilizer Recommendations for Agricultural and Horticultural Crops (RB209) 7th Edition. HMSO, London. 2000;73–98.
23. Roem WJ, Klees H, Berendse F. Effects of nutrient addition and acidification on plant species diversity and seed germination in heathland. Journal of Applied Ecology. 2002;39:937–948.
24. Hernanz JL, Peixoto H, Cerisola C, Sanchez-Giron V. An empirical model to predict soil bulk density profiles in field conditions using penetration resistance, moisture content and soil depth. Journal Terramechanics. 2000;37:167–184.
25. Hall DGM, Reeve MJ, Thomasson AJ, Wright VF. Water retention, porosity and density of field soils. A.R.C. Soil Survey Technical Monograph. 1977; 9.
26. Amezketa E. Soil aggregate stability: A review. Journal of Sustainable Agriculture. 1999;14:83–151.
27. Loveland P, Webb J. Is there a critical level of organic matter in the agricultural soils of temperate regions: A review. Soil and Tillage Research. 2003;70:1–18.
28. Chen ZS. Selecting indicators to evaluate soil quality. In food and fertilizer technology center public. 1999;13:1–13.
29. Sparling GP, Sheperd TG, Schipper LA. Topsoil characteristics of three contrasting

New Zealand soils under four long-term landuses. New Zealand Journal of Agricultural Research. 2000;43:569–583.
30. Neves CS, Feller VJ, Guimaraes C, Medina MF, Tavares J, Fortier M. Soil bulk density and porosity of homogenous morphological units identified by the cropping profile method in clayey oxisol in Brazil. Soil and Tillage Research. 2003; 71:109–119.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/18061