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Trends in Land Evaluation Assessment: A Review

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Abstract
Assessment of relative ability of land for sustainable use is as old as farming practices although many of the earlier methods used by farmers may not be scientifically justifiable. Different methods of assessing potentials of land exist, including land capability/suitability evaluation and the current soil security concept and they have their similarities and differences as well as merits and demerits. Assessment of natural (inherent) capacity of land for sustainable use is land evaluation while soil quality is the assessment of dynamic capacity of land. Soil quality assessment became popular and was used as advisory tools for farmers in the USA because it encompasses three major issues of concern with respect to soil function (productivity, environmental quality, and human/animal health). Soil quality assessment and land capability classification are broad in approaches and thus one can be used in place of the other. This is not the case with land suitability evaluation which is crop specific and uses variables that are slow to change and valid for a long-time period. However, soil quality assessment can complement suitability evaluation since it can be more easily carried out on a periodic basis. The most recent concept that brings biophysical and socio-economic perspective together in soil assessment is soil security. Soil security is concerned with maintaining and improving the world's soil resource to produce food, fibre and freshwater, maintain biodiversity and ecosystem services and contribute to human health. There are five dimensions to soil security framework and they are capability, condition, capital, connectivity and codification. However, a lot of work is still needed to bring this concept into fully developed risk-based soil security assessment and policy framework.

Keywords: Dimensions, Land Evaluation, Soil Quality, Soil Security, Trends

Introduction
For long in Nigeria, land use was based on trial-and-error approach which has led to waste of money, efforts, abuse or misuse. Many large-scale farms in Nigeria fold up after 2 or 3 years of cropping due to lack of adequate information on the potentials of the soil for the particular land utilization type (LUT). This has also led to land degradation which although may be slow and gradual, is very costly and difficult to correct; while some are even rapid and catastrophic. For instance, loss of organic matter through topsoil removal by bulldozing can take several decades to remedy.

Evaluation of the relative abilities of soil to support crops is as old as farming practice. Assessment of the natural (inherent) capacity of soil for sustainable use and to avoid degradation is land evaluation. Several systems of land evaluation exist and the most popular are: Land Capability Classification (LCC) (Klingebiel and Montgomery, 1961), Land Suitability Evaluation (FAO, 1976), Fertility Capability Classification (Buol *et al.,* 1975) and Parametric Systems (e.g. Storie, 1933; Sys *et al*., 1991). Although these have been most helpful, the soils' capacity to support crops under use and management is more crucial to continuous crop production. This underscores the importance of the assessment of dynamic capacity of soils. For instance, land suitability evaluation is based on the inherent land characteristics and climatic variables that are slow to change, and are therefore, valid for long time period. However, degradation, particularly of the upper centimeters of the soil could set in with use and management.

Assessment of the dynamic capacity of soil is a more recent development and it assesses the capacity of the soil to function under use, management or cropping systems in addition to the inherent capacity of the soil to function. This dynamic capacity of soils is called soil quality.

High rates of soil erosion, losses of organic matter, reduction in fertility and productivity, chemical and heavy metal contamination and degradation of air and water quality have sparked interest in the concept of soil quality and its assessment (Doran and Parkin, 1994; NRC, 1993). Although, it has received a variety of definitions by various workers, soil quality / health is more simply defined as the state or condition of soil properties and processes at a certain time under use (Karlen *et al*., 1997). The term is being used to describe the soil ability to produce food and fibre and to function as an important interface with the environment. Land evaluation differs from soil quality assessment not only because it evaluate the inherent quality but also because the biological properties of the soil are not usually emphasized in land evaluation. In addition, land evaluation refers not only to soil, but also to the combined resources of soil, climate and crop/management.

The emphasis on soil function in may be a way to compensate for the lack of information on profile characteristics resulting from the five factors of soil formation (Jenny, 1941). Soil quality uses taxonomy as a foundation (Karlen *et al*., 2003). The specific definition of soil quality for a particular soil is dependent on its inherent capabilities, the intended land use and the management goals. The use-dependence of the soil quality concept can be illustrated simply thus: the functions, properties and processes necessary to hold up a physical structure are not the same as those needed to grow a crop. Soil quality assessment provides a basic means to evaluate both the short-term and long-term effects of land uses on the soils (Pierce and Larson, 1993). Assessment methods from land evaluation to soil quality have been primarily developed to measure the inherent and manageable properties of soil, which are taken as indicators of the soil's ability to function or provide a service using soil science dimensions (Robinson *et al*., 2012). However, these assessments are relative, being affected by decisions that are value driven and contextual (Bouma, 2012) such as land management, economic, social and political/regulatory dimensions. This would require a multi-dimensional and multi-disciplinary approach involving many stakeholders. A lot of work is required to bring the soil quality concept into fully developed risk-based soil security and assessment and policy framework.

The most recent concept that brings biophysical and socio-economic perspective together in soil assessment is soil security. Soil security is concerned with maintaining and improving the world's soil resource to produce food, fire and freshwater, maintain the biodiversity and ecosystem services and contribute to human health. There are five dimensions to soil security framework and they are capability, condition, capital, connectivity and codification (McBratney *et al*., 2014). This work is a review of trends of efforts in land evaluation assessment from inception till the recent time.

Land Evaluation

Land evaluation is the process of assessing the possible uses of land for agriculture, engineering, forestry, recreation, industry and conservation. In the agricultural context, it is the assessment of land for a specific kind of land utilization, e.g. grazing, rain-fed farming, irrigation agriculture (FAO, 1976). Land evaluation methods aim at assessing land quality or suitability for specific land use, as conditioned by biophysical parameters (Smith *et al*., 1984).

Many systems of land evaluation exist, all of which originated from the advanced countries of the world. Examples of these are the Land Capability Classification (LCC) of the USDA (Klingebiel and Montgomery, 1961), the FAO Land Suitability Evaluation (LSE) (FAO, 1976) and the Fertility Capability Classification (FCC) by Buol *et al.* (1975). Sys (1985) developed the parametric system for tropical soils.

Land Capability Classification (LCC)

Land capability classification represents one of the earliest systems of land quality assessment (Helms, 1992). The purpose of this evaluation system was to provide farmers and government agencies with tools to determine land that is capable of supporting agriculture, particularly with respect to soil conservation. The system consists of eight categories ranging from class I land with little or no limitations to their use for crop production, to class VIII land that cannot be profitably used for commercial crop production. Later, LCC was extended to other land use types such as engineering (road, housing, airport etc), rangeland and gulf courts.

Land Suitability Evaluation (LSE)

LSE has been defined as the assessment of the fitness of a tract of land for a specified kind of land use (FAO, 1976). Van Ranst *et al.* (1996) suggested that derivation of physical land suitability is a prime requisite for land use planning and development, since it guides decisions on land utilization type (LUT) for optimal use of the land resources.

There are several approaches to land suitability evaluation for which Van Lanen *et al.* (1992) identified three general types. The first one is qualitative evaluation based mainly on expert judgment, where physical suitability is obtained by qualitative procedure. This approach gives useful result that generalizes the constraint of an area for specified kind of land use. The FAO (1976) is an example. The approach is presented in discretely ranked classes e.g. S1 (Highly Suitable), S2 (Moderately Suitable), S3 (Marginally Suitable), N1 (Temporaily/Currently Not Suitable) and N2 (Permanently Not Suitable). The FAO concept is most commonly applied, and, although it is a qualitative approach, it can be completed and enhanced by more quantitative methods (Yizengaw and Verheye, 1995).

The second method includes qualitative evaluation based on parametric methods that assess the suitability of land on a continuous scale, instead of discreet classes. The essentials of these methods are a mathematical model which is either multiplicative (e.g. P = AxBxCxn) or additive (e.g. P = A+B+C+n) where P is the land performance, A, B, C and n are ratings of land characteristics. In these approaches, the best land receives the maximum score, while the poorest receives the lowest score. An example of this approach is the Storie Index Rating (SIR), which is a multiplicative procedure (Storie, 1933). The most limiting factor is used to determine land suitability so that the most limiting land quality dictates the overall suitability (Sys *et al.,* 1991; Van Diepen *et al.*, 1991).

The third method is based on process-oriented simulation models where land performance is related to individual land characteristics with their net effect assessed using a model of land function. This quantified methods usually involve huge data input, which make it more expensive. Each of the different approaches to land suitability evaluation differs from the other in their data needs and qualities of prediction. There are no rules that indicate when any given approach is adequate, or when there is the need to proceed to a more complex level of analysis (Burrough, 1996).

Land characteristics and land qualities

Land Characteristics (LC) are simple attributes of the land that can be directly measured or estimated in routine surveys, including remote sensing as well as resource survey (Rossiter, 1996; FAO, 1976). Land qualities (LQ) are the complex attributes of land that act in a manner distinct from the actions of other land qualities in their influence on the suitability of land for a specified kind of use (FAO, 1983). It is the ability of the land to fulfill specific requirements for a Land Utilization Type (LUT) (Rossiter, 1996). Usually, they cannot be measured directly. Instead, several measurable diagnostic land characteristics that directly influence the chosen land qualities are used. Land quality indices are derived from a set of standardized continuous LC value, which are then combined with weighting factors to arrive at the land quality rating. Examples of land qualities are climate, moisture availability, nutrient availability, nutrient retention, oxygen availability to the root zone, land workability and others. While LC includes rainfall, temperature, organic carbon, CEC, texture, structure, available water etc.

Fertility Capability Classification (FCC)

This system was developed as an attempt to bridge the gap between soil classification and soil fertility (Buol *et al*., 1975). Thus it is aimed at removing the difficulty of direct interpretation of natural systems of soil classification for specific use. It groups soils according to their fertility constraints in a quantitative manner with emphasis on the top soil. Although, the original system (Buol *et al.,* 1975), emphasized only fertility management related modifiers, Sanchez *et al*. (1982), include some physical management limitations (e.g. slope and gravel contents) as modifiers. There is even room for more additional modifiers (Buol and Denton, 1984). This system has been tested in many South American countries (Brazil, Peru, etc.) and found to be a useful tool for interpreting soil maps especially at small scale (Sanchez *et al.,* 1982). In spite of its attractiveness, fertility capability classification has some limitations which may affect its adoption. The interpretation is not use-specific (e.g. crop combination or LUT). As pointed out by Ogunkunle and Babalola (1986), the capability unit designation cannot be easily interpreted at a glance (i.e. high, low, suitable or not suitable). However, Sanchez *et al.* (1982) pointed out that FCC is not sufficient to predict yield because factors not related to fertility also affect yield and yield response.

Trends in Land Evaluation Systems in Nigeria

Land resources survey started majorly in Nigeria in the early 60s with the survey of the soils of the cacao growing area of Central Western Region (Smyth and Montgomery, 1962). Since then, almost all other parts of the country have been covered by land resource surveys. Most of the soil surveys and classifications done in Nigeria are general purpose type. For example, Smyth and Montgomery (1962), in Central Southwestern Nigeria; Moss (1957) for the sedimentary soils of Nigeria; Mudorch *et al.* (1976) for soils of the savannah areas of South-Western Nigeria. However, only in few of these do we have information on the potential of the soils for the most common crops (Oluwatosin and Ogunkunle, 1991 and 1998). Several efforts were made to apply land evaluation systems in Nigeria, some of them are:

- Montgomery and Nwokoye (1961) evaluated the capability of the soils of Central Nigeria for Cacao. They grouped the soils into good, fairly good, poor, and not good. Their work was mainly a resource survey of the forest zone of central Western Nigeria. Similar studies were initiated in the Northern Nigeria by Higgins (1959) and Hope (1957) to interprete and make available soil survey information in prospecting for soils suitable for sugarcane industries at Bacita and Wushishi areas.
- Bramao and Riquier (1965) appraised the capabilities of some Nigerian soils by assigning numerical values to major soil characteristics and qualities that affect productivity. Nine soil characteristics or qualities (soil moisture content, drainage, effective soil depth, texture and structure, base status, soluble salt content, organic matter, mineral exchange capacity, reserves or alterable minerals) were given index values. Ashaye and Jaiyeola (1973) grouped soils of Iyansan N.W. Okitipupa into four classes for sugarcane cultivation. These are A (suitable with good management), B (suitable land), C (unsuitable land) and D (highly limited land). Fagbami and Fayemi (1975), using USDA capability systems grouped soils of lower Ofiki River into classes II, III, IV and V with II, III and IV as arable classes; and V as non-arable class.
- Ashaye *et al.* (1975) carried out some detailed soil investigations in Ogere, Owode and Iyansan areas of Ogun State in connection with sugar cane cultivation. They established land capability ratings with respect to sugarcane cultivation bearing in mind soil characteristics, landscape forms, climatic conditions and other economic factors. They discovered that the soils encountered in most of the areas appeared capable of supporting sugar cane on an industrial scale, but for profitable sugarcane production, the soils would require effective management, maintenance of good drainage, supplementary irrigation and adequate fertilizer application.
- Bennette *et al.* (1979) defined and listed the limitations of the land systems

map in Benue State. They grouped the land systems that can be used for arable cultivation into eight classes on the basis of how many crops they can support without severe limitation. The crops used for the rating are maize, millet, sorghum, groundnut, yam and rice. The land system that would support all these six crops have the highest capability and so are presumably in Class I. Federal Department of Agriclture and Land Resources FDALR (1985) also produced a suitability classification of Benue soils from the reconnaissance soil survey they conducted.

- Fagbami and Babalola (1980) grouped soils of N'gell, near Jos into classes II, III, IV, V and VI. Using four land evaluation systems, Ogunkunle and Babalola (1986), evaluated soils of lowland of Benue River and grouped them into classes for rainfed and irrigated arable crop production.
- Ojanuga and Isirimah (1986) carried out studies on quantitative land evaluation using soil productivity model to assess the current and potential productivity of some soils on the Coastal Plain Sands in parts of Rivers and Imo States. The model they used was based on soil productivity index relating such soil parameters that influence crop growth as acidity, drainage, nutrient levels and organic matter content. They discovered the productivity index values of the soils of the area of study to be very low suggesting a very low productivity in their present state. However, the potential productivity is medium to high if managed carefully by deep ploughing, lime application and fertilizer application to correct the identified soil deficiencies.
- Fagbami and Akamigbo (1986) carried out series of studies on the soils of Benue State and their capabilities. They classified the soils as highly to moderately suitable for most agricultural landuses qualitatively. They reported that more effort is needed in the area of soil test criteria and farm record keeping.
- Oluwatosin and Ogunkunle (1991), assessed the suitability of some soils of the savanna zone of Southwestern Nigeria for rain-fed maize. Ten (10) pedons from 3 locations in the savanna zone of Southwestern Nigeria were rated based on 14 land characteristics covering topography, climate, wetness, some physical properties, nutrient availability and nutrient retention. The pedons were rated for each characteristic with reference to the requirement for optimal rain-fed maize performance and the overall rating for each pedon was computed by a parametric method following the law of minimum. The results showed that the soils ranged between moderately suitable (S2) and presently not-suitable (NS) for actual suitability and between highly suitable (S1) and marginally suitable (S3) for potential suitability. This approach gives a comprehensive assessment of the fitness of a location for maize production and can be adapted for other crops and environments. They however suggested that its efficiency should be tested practically on the field by actual maize grain yield.
- In 1995, Oluwatosin and Ogunkunle examined the correlation among four

internationally recognized land evaluation systems (LCC, FCC, FAO-LSE and IC) being used in Nigeria at that time. The systems were tested for their practical relevance in terms of yield accuracy prediction on 10 major soil series at 3 sites in the savanna zone of south western Nigeria. From the results, there was virtually no difference between them in terms of physical evaluation ($r = 0.89 – 0.96$; $p = 0.01$).

- Ogunkunle (1993) evaluated the suitability of the NIFOR land for oil palm cultivation. He discovered that the NIFOR environment is only marginally suitable for oil palm cultivation in spite of its near-optimal climate. He identified the major constraints to oil palm production as soil texture and chemical fertility (K and CEC). He pointed out that emphasis should be placed on management techniques that will enhance the nutrient and moisture holding capacity of the soil. Ogunkunle (1998), made an appraisal of the capacity of Nigerian soils to sustain food self-sufficiency. The work pointed out the marginal capacity of Nigerian soils, their susceptibility to degradation and hence the need for careful management for continuous crop production. Among the strategies suggested is the need for detailed information on our soils and their suitability for various crops to be made easily available to farmers and other land users. He further suggested that a critical analysis of our crop production system vis-à-vis the capacity of our soils is also necessary to decide which crops to produce within the country and which are better imported. The enforcement of strict regulation against misuse of land through annual bush burning and indiscriminate quarrying and deforestation was also advocated.
- Oluwatosin and Obatolu (2005) evaluated suitability of the land of the cacao growing area of Nigeria for cocoa cultivation by the FAO system using 15 pedons representing 15 locations within the cocoa belt. They found out that the major limitations to suitability vary from climatic (length of dry season > 3 month) in the West to soil fertility (nutrient retention and availability) in the Midwest and the East. Thus, lands in the eastern sector are more suitable for cacao cultivation than the land from the west. In these and similar environment, good soil water conservation, irrigation application and/or soil managements in cacao cultivation can be achieved.
- Oluwatosin (2005) assessed the suitability of soils on continental grits in northwestern part of Nigeria for selected land use types (LUTs) using qualitative physical land evaluation method. It was discovered from the results that the landscape will only be suitable for cereals and grain legumes with high fertility management practices. Also, comprehensive quantitative evaluation methods using computer models to simulate soil-water flow and crop growth was suggested.

Soil Quality Assessment

For about three decades, ability to assess soil quality and to measure the impacts of management practices aimed at improving it have been the topic of considerable discussion in agricultural circles (Larson and Pierce, 1991; Doran and Parkin, 1994; Mitcheli *et al*., 2000; Andrews *et al*., 2004).

Clearly, what is considered good soil quality in one farming context may not be so good in another, and this makes quantitative assessment complex. Although it is well known that soil varies in quality and the quality changes in response to use and management, ability to assess soil quality and identify key soil properties that serve as indicators of soil functions is complicated by the multiplicity of physical, chemical, and biological factors that control biogeochemical processes and their variation in time, space and intensity. Practical assessment of soil quality requires consideration of these functions and their variations in time and space (Larson and Pierce, 1991). Soil quality assessment, however, is necessary for determining the sustainability of land management systems in the near and distant future.

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 (Larson and Pierce, 1991). Because soils perform many simultaneous functions, the goal of relating indicator properties to specific functions or processes has been very difficult; some would even say impossible. Over the years, researchers and farmers alike have tried to establish what is now widely called 'minimum data set' (MDS) of physical, chemical and biological properties that can be used as quantitative indicators in soil quality assessment (Doran and Parkin, 1994).

Soil quality assessment estimates or measures the functional status of ecological processes. The assessment must start with an understanding of the standard to be used for comparison. The timing of assessments also depends on seasonal cycles. Some properties are highly variable on a daily, seasonal, or yearly basis in response to changes in both temperature and moisture. Careful site selection helps to ensure that the assessment sites are truly representative of the area of interest. Offsite features, such as roads, homesteads, and other areas of recent or historic disturbances can have significant impacts and should be noted.

Relevance of Soil Quality Assessment

Soil, water and air are three basic natural resources upon which life depends (Bezdicek *et al.,* 1996). The soil provides nutrients for plant growth that are essential for animal and human nutrition. It provides the medium for recycling and detoxification of organic material and for the recycling of many nutrients and global gases. A healthy soil provides a link between plant, animal and human health (Bezdicek *et al.,* 1996). History has repeatedly shown that mismanagement of the soil resource-base can lead to poverty, malnutrition and economic disasters. Hunger in Africa has been linked to unhealthy people and unhealthy soils (Sanchez and Swaminathan, 2005). Currently, the concept of soil quality is in the process of evolution and progressively moving from a concept focused on yield potential and nutrient levels to one of environmental quality, food safety and human health (Karlen *et al*., 1997). Different people have different objectives for assessing soil quality. Some people may be seeking assistance to improve overall soil quality because they recognize the direct impact of this on the ecosystem. Some may have recognized soil quality degradation in specific fields and want improvement only in those fields.

Global climate change is dramatically increasing the variability of weather conditions worldwide and soil is a critical buffer medium for hydrologic and biogeochemical processes and therefore can mitigate the effects of extreme weather conditions and uncertainties in the availability of water resources (Larson and Pierce, 1994). The present threats of global climate change and ozone depletion through elevated levels of certain atmospheric gases and altered hydrological cycles necessitate a better understanding of the influence of land management on soil quality (Doran and Safley, 1997). Management systems need to be further fine-tuned in order to balance the need and priorities for food production with those for a safe and clean environment.

Soil quality assessment provides information about how particular land uses are affecting soils in the long-term. Some land uses and land management may affect properties and reduce soil quality such as loss of organic matter which can take many decades to remedy. This can mean that future landowners are unable to grow crops of the same quality or need to use greater amounts of fertilizer to achieve the same result as previously. Soil quality assessment can serve as a basis for comparing the options for utilizing soil functions and measuring the risk of that particular utilization to soil degradation processes. Soil quality assessment is also one of the main criteria for planning and practicing sustainable soil use.

Direct effects of soil quality on water quality are attributed to inherent soil characteristics, e.g. parent material, texture, and structure. Water quality is important to human and animal health and it has been a major global concern in developed and developing countries (Lal and Stewart, 1994). Land use and management also affect water quality through the effects of soil quality on water quality. Important management practices that affect water quality include tillage, fertilizer application, pesticides and soil amendments, drainage and farming system. Information on soil quality is useful to researchers and policy makers in setting research priorities with reference to policy decisions and for measuring changes in the soil resource-base. For example, considerable resources have been committed nationally to the development of no-till technology. Many of the soil quality tests currently used indicate that no-till enhances quality attributes (Doran, 1980; Dorman and Lindwall, 1989; Lal, 1994; Oluwatosin *et al*., 2008).

Similarly, information on soil quality could also improve economic assessment of agriculture through assigning values to practices on agricultural land based on environmental considerations (e.g. erosion, water and air pollution, or presence of contaminants) and resource-use efficiency in addition to proven yield (Bezdicek*et al.*, 1996).

Agencies can use evaluation to monitor the long-term soil resource-base. Although, not the sole basis of decision-making, soil quality can have an important input to various policy development considerations. Soil quality assessment forms part of the factors that measure soil resilience and soil capacity to restore itself. Soil resilience is directly related to soil quality and factors affecting it (Lal, 1993).

The Trend: From Land Capability/Suitability to Soil Quality

Land capability/suitability evaluation and soil quality assessment are two major ways by which the potentials of land for a particular kind of use can be known (Oluwatosin *et al.*, 2006). Soil quality assessment is a more recently developed phenomenon while land evaluation has been in use since 1933. Land evaluation forges a link between the basic survey of land resources and decision making on land use planning and management. It puts at the disposal of land users relevant information about land resources that are necessary for planning development and taking management decisions (FAO, 1976). Although, several attempts were made to apply the concept of land evaluation to Nigeria situation with positive results as stated above. This notwithstanding, soil quality assessment became popular and was used as advisory tools for farmers in the USA (USDA, 2001). 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. Hence, the definition of soil quality as 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 characteristics 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, Oluwatosin *et.al.* (2006) made an attempt to find relationship between soil quality and land capability and it showed a significant positive correlation ($r = 0.71$ $p < 0.001$). Similarly, Adeyolanu (2015) made a comparison between land suitability evaluation and soil quality assessment by comparing the suitability and soil quality indices under four different land use types (cacao, cashew, cassava and maize) in three Southwestern States of Nigeria using regression analysis. The results obtained showed linear positive relationship between soil quality and suitability with R values ranging from 0.495 to 0.707. This indicates 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. Thus, with soil quality assessment in place, land suitability can be accurately predicted (Oluwatosin *et. al.*, 2003). However, R^2 values were not very high, indicating that other factors (e.g. land form and climatic variables) exogenous to soil quality may account for land to function and avoid degradation while soil quality is the dynamic capacity of soil to function.

Also, land suitability is crop specific and involves other characteristics other than that of soil (land and climatic variables which are slow to change) while soil quality is assessed based on soil functions which are more sensitive to management (Oluwatosin *et. al.*, 2003). Soil quality assessment and land capability classification were found to have high positive linear relationship (Oluwatosin *et. al.*, 2006). The authors further submitted that the two concepts (soil quality and land capability) are broad in their approaches and thus one can be used in place of the other. This is not the case with land suitability which is crop specific and uses variables that are slow to change and valid for a long-time period. Soil quality assessment can therefore compliment suitability evaluation since it can be more easily carried out on a periodic basis.

Methods of soil quality assessment

There are two major soil quality assessment approaches - qualitative and quantitative. Qualitative approach makes use of descriptive properties to assess soil quality for sustainable crop production and this has been in practice since time immemorial. In southwestern Nigeria for instance, farmers recognized the importance of some mount of clay in the soil for cocoa production. Similarly, farmers have also used soil colour as a measure of organic matter level in the soil. The darker the soil colour, the higher the organic matter content for crop production. However, this approach is highly subjective (Romig *et al*. 1996), as the amount of clay or organic matter is not specific. In addition, it requires several years of experience for accuracy, although it is relatively cheap and less time-consuming. Qualitative approaches are still very relevant to land users who are not literate and non-soil scientist.

Over the years, with the advent of soil and crop sciences and the advancement in analytical procedures, there has been a progressive shift from descriptive to analytical properties for soil quality assessment. This approach is quantitative; more specific and accurate, though more expensive and time-consuming. However, descriptive soil quality information plays some roles in the development and application of technical and non-technical tools for assessing and monitoring soil quality for user groups of diverse background and interests (Aikore, 2002). On-farm assessment of soil quality is recommended to assist farmers evaluate the effects of their management decisions on soil productivity (Andrew and Carroll, 2011). Adeyolanu *et al.* (2018) found out a positive correlation between on-farm assessment by farmers and that by data analysis. Adeyolanu and Ogunkunle, (2016) compared the two approaches and established the relationship between them. From their results, significant positive relationships ($r = 0.64 – 0.93$) exist between qualitative and quantitative approaches. This is an indication that the two methods can be used interchangeably for soil quality assessment but where fund is limiting as with peasant farmers, the qualitative approach is preferable.

Soil Quality Functions, Indicators and Indices

To assess soil quality, there is the need for integration of different indicators and soil function into an index; and numerous attempts have been made to estimate soil index for major soils across the world (Doran and Parkin 1994; Smith et al, 1994, Karlen and Stott, 1994, Doran *et al.,* 1996; Andrews *et al.,* 2004). Larson and Pierce (1991) suggest a concept for quantifying soil quality by expressing soil quality (Q) as a function of measurable soil attributes referred to as soil qualities (q); Q – fq, 0), with the magnitude of Q being a function of the collective contribution of all q values. Smith *et al.* (1994) developed an approach called Multiple Variable Indicators, measured spatially, into an overall soil quality index. Doran and Parkin (1994) presented a framework for the evaluation of soil quality based on the function of soil with respect to (1) sustainable production, (2) environmental quality, and (3) human and animal health. Andrews *et al.* (2004) developed a framework for quantifying Soil Management Assessment Framework (SMAF). They defined critical soil functions and potential chemical, physical and biological indicators of those functions. For each indicator, a scoring function and realistic baseline and threshold values are established. All indicators affecting a particular soil function are grouped together and assigned a relative weight based on importance. After scoring each indicator, the value is multiplied by the appropriate weight, and an overall soil quality index is calculated by summing the weighted score for each soil function.

Pham *et al.* (2015) proposed a more recent method of quantifying soil quality known as Relative Soil Quality Index (RSQI) which is integrated from individual indices into a simple formula for overall assessment of soil quality. RSQI is different because the individual indices and weighing factors are calculated from the laboratory and environmental data and not self-regulated as in earlier methods. These methods have their merits and demerits, and there is no one standard method established, hence a strong need exists for continuous evaluation and comparison of the different methods to arrive at developing a credible method for soil quality assessment. Adeyolanu *et al.* (2018) compared SMAF and MVIT in quantifying soil quality and concluded that SMAF is preferred to MVIT if all relevant data are available. Similarly, Adeyolanu, *et al.* (2018) compared SMAF and RSQI which have their similarities and differences. The two methods have high positive correlation indicating that both methods can be used to assess soil quality. However, for RSQI, the individual indicators scorings and relative weights were calculated from the laboratory data. This makes the method to be less subjective than SMAF which depends on experts' opinions for assigning scores and weights.

Soil Security

There has been a long history of soil assessment framework developed from land evaluation in soil quality assessments (McBratney *et al.,* 2012). These assessment methods have been primarily developed to measure the inherent and manageable properties of the soil, which are taken as indicators of the soil's ability to function or provide a service using soil science dimensions (Robinson *et al.,* 2012). However, these assessments are relative, being effected by decisions that are value driven ad contextual (Bouma, 2012) such as land management, economic, social and political/regulatory dimensions. This would require a multi-dimensional and multi-disciplinary approach recognizing all stakeholders. The most recent concept that brings biophysical and socio-economic perspective together in soil assessment is soil security. Soil security is concerned with maintaining and improving the world resource to produce food, fibre and freshwater, maintain the biodiversity and ecosystem services and contribute to human health. There are five dimensions to soil security framework and they are capability, condition, capital, connectivity and codification (McBratney *et al.,* 2014). For each dimension, there is the common question of how they contribute to the measurement, analysis, and /or management (i.e solution) to the six global challenges of food, water and energy security, maintaining biodiversity, human health and adapting to or mitigating climate change.

Capability: The capability of a given soil refers to its potential functionality and addresses the question of the functions that the soil is expected to perform, and in doing so what it can produce. Thus, it is important to understand the soil's capability in the context of its own reference state. This needs to be linked to the functions that soil performs and contribute to other frameworks such as land suitability. It is strongly influenced by a long history of work by soil scientists on land evaluation and it recognizes the intrinsic difference between different kinds of soil (FAO, 1976). A series of guidelines were produced by the FAO for land evaluation in dryland agriculture, forestry, irrigated agriculture, grazing and steepland (FAO, 1983, 1984, 1985, 1991; Siderius, 1986).

Condition: condition of the soil is concerned with its current state and can be compared to the reference state to determine if it is maximizing its capability. The soil condition is particularly useful to those who want to know about (i) the impact of changes in management practices, and (ii) justification for investment to maintain or improve the soil resources (Schipperand Sparling, 2000; Wilson *et al.,* 2008). Condition is assessed using a collection of indicators that describe soil functions and has similarities with the concept of soil quality.

Capital: The dimension of soil capital is underpinned by the motion that placing a monetary value on an asset enables a society to value or secure the asset and make meaningful comparisons of soil with different capabilities and conditions. Since soil provides functions for service delivery, placing a value on the soil stocks will contribute to an account of its capital (McBratney *et al.,* 2014). According to Robinson *et al.* (2009), placing a value on things that contribute to human well-being avoids the neglect or omission of resource or its contribution to the system in any decision-making process.

Connectivity: This brings in the social dimension around soil and in part is concerned with whether a person who is responsible for the soil or given piece of land has the right knowledge and resources to manage the soil condition and use soil according to its capability. It raises the question regarding the need for a soil ethic and in doing so whether soil should only be valued for the well-being of humans (Thompson, 2011).

Codification: No matter how secure soil may be through management for ideal condition and capability, valuing it through its capital and being highly connected to the society, there still remains the need for public policy and regulation. This will serve as a safety net and to synergize and positively feed back into the other aspects (dimensions) of soil security. An example here is policies around recognition and payment for public goods such as ecosystem services provided by soil to land owners by government on behalf of society. Another one is regulations guiding appropriate soil use and protection of conservation areas.

To assess soil security, the following steps are followed:

- Break down the concept into assessable parts i.e. the five dimensions. This varies over use, space, time and between regions and government.
- Map the variability of each dimension on land use basis.
- Combine the dimensions back into soil security map.

However, a lot of work is still needed to develop this concept into fully developed risk-based soil security assessment and policy framework. There are lots of burning questions for each one of those dimensions. An assessment framework for soil security should recognize and utilize the uncertainties in the assessment of each of the dimensions and their combination.

Summary and Conclusion

Different methods of land assessment exist starting from land capability/suitability evaluation to the current soil security and they have their similarities and differences. Soil quality assessment has positive relationship with land capability and land suitability. Soil quality assessment and land capability classification are broad in their approaches and thus one can be used in place of the other. This is not the case with land suitability which is crop specific and uses variables that are slow to change and valid for a long-time period. However, soil quality assessment can complement suitability evaluation since it can be more easily carried out on a periodic basis for the sustainability of suitability for specific use. The most recent concept that brings biophysical and socio-economic perspective together in soil assessment is soil security.

Although, suitability evaluation is undermined by socio-economics, soil security is concerned with maintaining and improving the world's soil resource to produce food, fire and freshwater, maintain the biodiversity and ecosystem services and contribute to human health. There are five dimensions to soil security framework and they are capability, condition, capital, connectivity and codification. For each dimension, there is the common question of how they contribute to the measurement, analysis, and/or management (i.e. solution) of the six global challenges of food, water and energy security, maintaining biodiversity and human health and adapting to or mitigating climate change. However, a lot of work is still needed to develop this concept into fully developed risk-based soil security assessment and policy framework.

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