# ASSESSING QUALITY OF RICE PRODUCING SOILS USING TWO METHODS OF QUANTIFICATION

**Adeyolanu, O.D., Are, K.S., Adelana, A.O., Denton, A.O., Oluwatosin, G.A., Ande, O.T., Ojo, A.O. and Adediran, J.A.**
Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan
Corresponding Author: olatejuadeoyolanu@gmail.com

**ABSTRACT:** *Many estimates of soil quality index (SQI) assumed to be similar in their measurement have been suggested across the world. This assumption needs to be proved through comparison of various methods. This study therefore aimed at comparing two quantitative SQIs determined by Soil Management Assessment Framework (SMAF) and Relative Soil Quality Index (RSQI), in two rice - intensive cultivation local government areas (Katcha and Gassol) in Nigeria. A semi-detailed soil survey was conducted and seven modal profile pits dug. Soil samples were collected for laboratory analysis of selected indicators. Data were subjected to quantification using SMAF and RSQI procedures, and results subjected to correlation analysis. Based on SMAF, SQI are 66.75 – 84.3 % in Gassol and 55.9 – 77.65 % in Katcha. With RSQI, 68.06 - 73.03 % in Gassol and 66.14 – 81.84 % in Katcha. Positive correlation occurs between them (r = 0.68 in Gassol and 0.74 in Katcha) indicating that both methods are similar in assessing soil quality. However, in computation RSQI is less subjective because the values for scoring and relative weights were calculated rather than experts' opinions used in SMAF. Therefore, RSQI is consistent even with different researchers, thus is more reliable.*

**KEYWORDS:** soil quality index, quantification, SMAF, RSQI, rice intensive

## INTRODUCTION

Soil quality is the capacity of soil to function within ecosystem boundaries; sustaining crop productivity, maintaining environmental quality and promoting plant and animal health. The interest in soil quality assessment have been sparked by high rates of erosion, organic matter losses, reduction in fertility and productivity, chemical and heavy metal contamination and degradation of air and water quality (Doran and Parkin, 1994, NRC, 1993). Also, the quality of soil has a profound effect on the health and productivity of a given ecosystem just as it is with air and water. Furthermore, soil quality assessment and direction of change with time is the primary indicator of sustainable land management (Adeyolanu and Ogunkunle, 2016). Therefore, to know if a land use is sustainable, soil quality assessment is employed as some land use types have been known to degrade the soil.

However, soil, unlike air and water, is a highly complex and buffered system for which there is no single or "easy" measure of its quality or health. 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 quality 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 ~ f(q, 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 Indicator Transform (MVIT) that integrates an unlimited number of soil quality 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 quality using multi-objective analysis principles of systems engineering known as 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 their 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 new 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 weighting 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 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. (2013) compared SMAF and MVIT in quantifying soil quality and concluded that SMAF is preferred to MVIT if all relevant data is available.

The objectives of this study therefore are: (i) to assess soil quality of rice intensive cultivation areas of Nigeria for enhanced sustainable production using SMAF and RSQI methods; and (ii) to compare SMAF and RSQI methods of quantifying soil quality.

## MATERIALS AND METHODS

### Study sites

The study was carried out in two local government areas (Katcha and Gassol) where rice is intensively cultivated in Nigeria. Katcha is a local government area in Niger State (Fig. 1) having its headquarters at Katcha town ($8^0$ 037`N, $6^0$ 4'E and $9^0$ 29`N,$6^0$28 ʿE). It has an area of 1,681 $km^2$ and a population of over 122,176 (Federal Republic of Nigeria, 2007). Katcha local government area has a tropical climate characterized by seasonal rainfall, high temperature, high wind speed and humidity. The environment is noted for two distinct seasons of rainy and dry periods in a year. Climatic variation in Katcha local government contains a significant portion of Sudan-Sahel ecological zone of West Africa. Climatic anomalies in the form of recurrent drought, frightening

dust storms and rampaging floods have overprinted their rhythms, creating short duration climatic oscillations as against the normal cycles of larger amplitudes.
The area is essentially agrarian; hence, highly influenced by the pattern of rainfall. Annual rainfall is 1095 ± 32 mm with the onset and cessation by 30th April (± 3 days) and 1st November (± 4 days), respectively. The length of the growing season is about 186 (±15) days. There are two distinct seasons: wet and dry. April to October is the wet season with the highest mean monthly rainfall in September and dry season during the months of November and March, which is completely devoid of rain.

The temperature of the area like most tropical environment is generally high and characterized by minimum fluctuations. The maximum temperature (33 °C) is recorded in the month of March, while the minimum is usually in December (25.6 °C). The pattern of evapotranspiration is directly related to temperature; that is, the higher the temperature, the higher the evapotranspiration rate. The evapotranspiration ranges between 38 mm in September to 95 mm in March. There is usually a direct correlation between rainfall / temperature status and relative humidity of an area. The mean monthly relative humidity ranges between 38.6 % in December to 83 % in September.The area is predominantly underlain by the pre-Cambrian Basement complex rocks. The local lithological units in the study are granite, gneiss and schist. The granite is the most widely spread rock unit and are porphyritic, medium-coarse-grained in texture. The granite mostly occurs as intrusive, low-lying outcrops into gneisses. They are severely jointed and fairly incised by quartz veins.

The groundwater water table characteristics in the lowlands show a depth of between 0 – 50cm across the study areas. Water table recedes during the dry season while the fields are flooded during wet season except in the upland areas. Water sources for agricultural production in the study areas are from rainfall and rivers. Farmers largely depend on rainfall for their farming activities. During the rainy season, cultivation is extensive in the upland with crops such as groundnut, sorghum, melon and cassava being cropped. However, with the use of bunds and basin constructions, water is conserved for the cultivation of paddy in the dry season farming although activities are limited majorly to the lowland floodplains where flood water is the major source of agricultural water demand.

Natural vegetation, which consists of thick forest with trees and oil palms growing in the wild could still be seen bounding the farms in the distance, but has been replaced around the communities and farming areas. Areas around the communities which can be said to be in fallow are covered with bush regrowth, grasses, sedges, a few broad leaves and shrubs. Fields to be cultivated soon with rice are covered with wire grass, giant star grass, guinea grass and sedges, independence grass, *Mimosa pudica, Impomea involucrate* and *Imperata cylindrical*.

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Gassol Local Government in Taraba State (Fig. 2) is located between latitude 7° 32` to 8° 40`N and longitude 10° 25` to 11° 15` E. The local government has a landmass of 5,982 $km^2$ and a population of 244,749 according to the National Population Census (2006) and is one of the most populous local government areas in the State. It is 75 km away from Jalingo, the State capital. About 80 % of the population is crop farmers, while others are cattle breeders and fishermen. Gassol local government has tropical continental type of climate characterized by well-marked wet and dry season. The rainy season usually starts around May and ends in October, while the dry season begins in November and ends in April. The annual rainfall is 859 ± 25 mm with onset and cessation on 2nd May (± 3 days) and 4th November (± 4 days), of every year respectively. The length of the growing season is 187 (± 15 days). There is direct correlation between rainfall and relative humidity; hence, the relative humidity during the wet season ranges between 60 and 70 %, while the relative humidity during the dry season ranges between 35 and 45 %.

In general, the temperature is high throughout the year; hence it is favorable for cultivation of crops in the area. The average monthly temperature ranges between 26 and 32 °C. The highest evapotranspiration was recorded in the months of March and April, while the lowest was recorded in the months of December and January. This shows that there is a strong correlation between evapotranspiration and temperature in Gassol Local Government Area.Gassol is located within the northern Guinea Savanna zone of Nigeria characterized by grasses interspersed with tall trees and shrubs; some of the trees include locust beans (*Parkia biglobosa*), shea butter (*Vitellaria paradoxa*), baobab (*Adansonia digitata*) and silk cotton (*Ceiba pentandra*) trees.

The area is underlain by the undifferentiated Basement Complex rocks which consist of migmatites, gneisses and older granites. Tertiary to recent basalt also occurs in the area. The rock unit constitutes principally the undifferentiated igneous and metamorphic rocks of Pre-Cambrian age.

The area is within the Upper Benue Basin with River Benue as the principal drainage system. The northern border of Gassol watershed is the Benue River while Taraba river flows north through the Gassol to its confluence with the Benue River. River Taraba is the major drainage of Gassol watershed with other rivers discharging into it.

The floodplains of the Taraba River constitute the major agricultural land in Gassol. The areas are irrigable low-lying floodplains characterized by low slope (0 – 3%). The flat nature of the topography contributes to the challenge of flooding often face by farmers in the area. The plains are currently being cultivated; however, the level of irrigation practices is still low. The water management in the watershed entails use of surface water conservation practices including basin and construction of bunds as water conservation strategy. This is very effective and should be encouraged. Water lifting from the rivers is also being practiced using small petrol pumps.

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As regards vegetation, Gassol is located within the northern guinea savanna zone characterized by grasses interspersed with tall trees and shrubs. Some of the trees include locust bean, sheabutter, eucalyptus, baobab and silk cotton tree. Fields to be cultivated soon with rice are covered with wire grass, giant star grass, guinea grass, independence grass, *Mimosa pudica*, *Impomea involucrate* and *Imperata cylindrical*.

**Soil survey and morphological characteristics**

The base maps for the study areas were produced with the aid of satellite imageries from Nigeria Sat-1 with 30 m resolution. The soil survey was carried out at a scale of 1:50,000 on the floodplains across the major rivers and their tributaries, which serve as the base lines in each local government. The soils were examined from auger holes and mini-pits, using flexible grid survey along transects at 100 to 250 m intervals, depending on the homogeneity of the mapping units. Global Positioning System (GPS) was used to determine the coordinates and slopes of the terrain. The morphological characteristics of the soils were examined and recorded appropriately from the soil surface to a depth of 120 cm along transects, footpaths and nomad tracks. Boundaries were established using floodplain geomorphology and morphological differences. Changes in physiography, soil surface form and stoniness, micro-relief, wetness and soil colour were also recorded and used as clues to arrive at changes in soil types and establishment of soil boundaries.

Modal soil profile pits were dug at points that are the most representative of each of the identified soil types. In each of the locations, seven modal soil profile pits (2mx1m) were dug, described and sampled, with the depth depending on the peculiarity of the soil types (e.g. water table and lithology barriers). All necessary environmental information relating to the site characteristics and soil morphology were also recorded according to the FAO guideline (FAO, 2006). Three replicated, undisturbed soil cores were also taken from each horizon of the soil profiles for the determination of bulk density, total porosity and saturated hydraulic conductivity ($K_{sat}$).

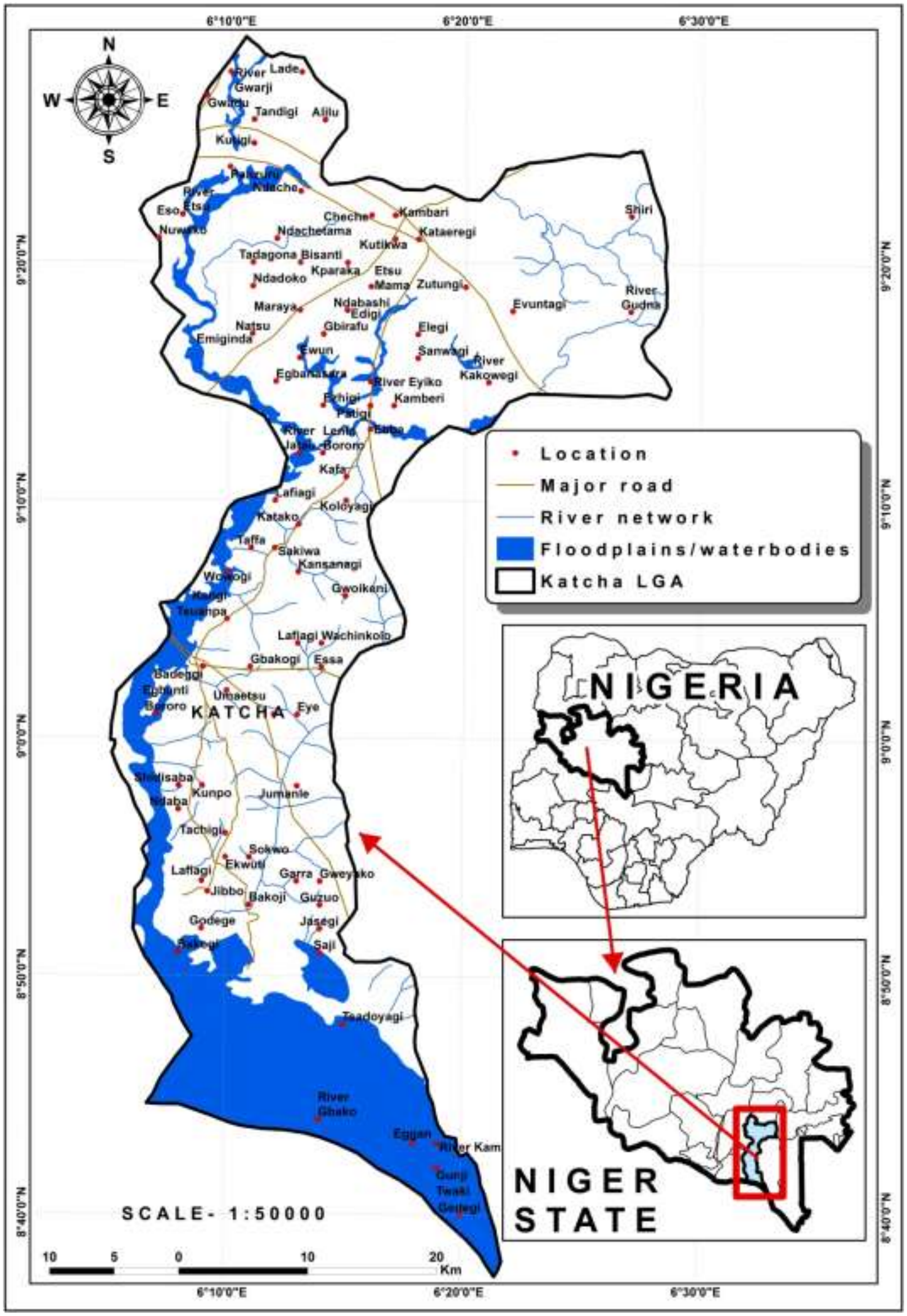


Fig. 1: Administrative map of Katcha local government, Niger State

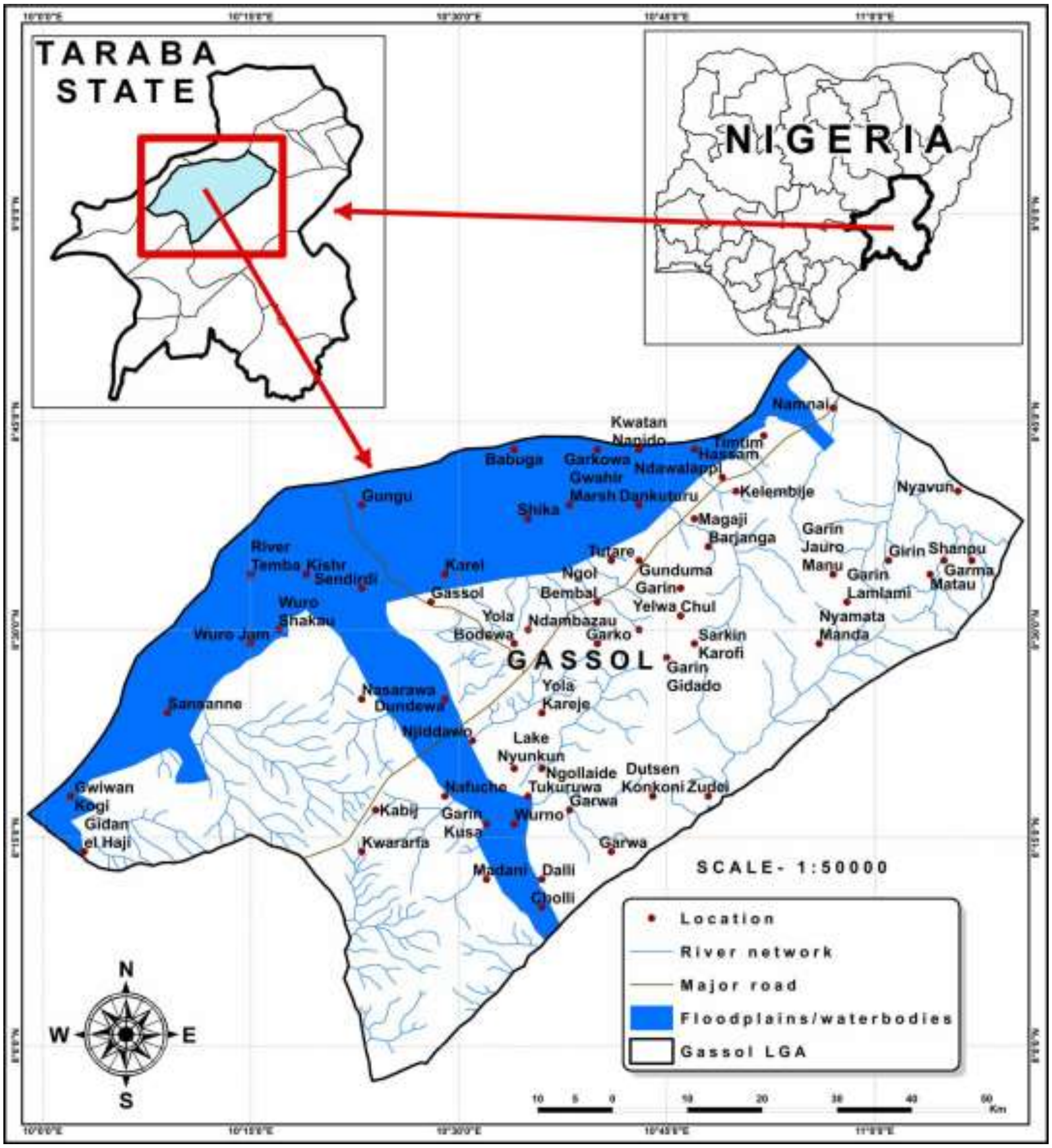


Fig. 2: Administrative map of Gassol local government area, Taraba State

## Laboratory analyses

The soil samples were air-dried and crushed to pass through a 2.00 mm mesh sieve. Gravel content (> 2.00 mm diameter) was weighed and the ratio of gravel to fine earth calculated as a percentage of total air-dried soil. Particles size distribution was determined by a modified Bouyoucos hydrometer method as described by Gee and Or (2002). The soil cores were soaked into water overnight to saturate the soil and thereafter weighed at saturation. Total porosity was estimated as the difference between saturated mass and dry mass of the soil in the core divided by the soil sample volume, using the relationship described by Flint and Flint (2002).

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Bulk density was determined by dividing the oven-dry mass of the soil by the volume of the soil as described by Grossman and Reinsch (2002). Saturated hydraulic conductivity (Ksat) was determined using a constant head permeameter method (Reynolds and Elrick, 2002). Soil pH was determined in 1:1 soil:water ratio, and in KCI using a glass electrode pH meter with calomel electrode (Bates, 1964). Organic carbon was estimated by the dichromate wet oxidation method as described by Nelson and Sommers (1982). Total nitrogen was determined by the micro-Kjeldahl method of Jackson (1962). Available phosphorus was evaluated by Bray 1 method of Bray and Kurtz (1945); while exchangeable cations (Ca, Mg, K and Na) were extracted by neutral NH4OAC. Calcium, K, and Na were measured through a flame photometer, while Mg was determined by atomic absorption spectrophotometer AAS (Rhoades, 1982). Exchangeable acidity was determined by 1 N KC1 extraction and thereafter titrated with 0.05 N NaOH solution (Peech, 1965). Effective cation exchange capacity (ECEC) was calculated by the summation of the values of exchangeable cations and exchangeable acidity. The micronutrients (Fe, Mn, Zn and Cu) were determined in 0.1 N HC1 and evaluated using the atomic absorption spectrophotometer (Jackson, 1962).

**Determination of Soil Quality Index**

Soil quality Index was determined using two different methods:

1. Soil Management Assessment Framework (SMAF)

This technique uses the principle that soil quality can only be assessed by a combination of different properties or indicators (i.e. no single indicator can represent the condition of the soil). The combination was based on the critical values of the indicators in relation to soil processes that are relevant to crop productivity (Nearing *et al.,* 1990). In this case, four soil processes crucial to crop productivity were identified and relative weights were assigned to them based on the perceived level of importance. Soil quality indicators relating to each process were identified and given weights as well (Table 1). All weights within each level sums up to 1.0 and 100% equivalent. To combine the different processes and indicators, Standard Scoring Functions (SSF) approach was used. These were developed for systems engineering problems (Wymore, 1993). It enables the user to convert numerical or subjective ratings to unitless values on a scale of 0 – 1. All indicators affecting a particular process were grouped together, given scores and relative weights based on relative importance. After scoring each indicator, the value was multiplied by the appropriate weight producing an equation that was summed to provide the soil quality rating for crop productivity as follows:

$Q=\sum_{i=1}^{n} \text{q. na x wt.} + \text{q. nr. x wt.} + \text{q. we x wt.} + \text{q. tl x wt}$ …. ………………….1

Where,

Q = Overall soil quality index for crop productivity

q.na = soil quality rating for nutrient availability process

q. nr = soil quality rating for nutrient retention process

q.we = soil quality rating for water entry process

q.tl = soil quality rating for toxicity level process

wt = relative weight.

2. Relative Soil Quality Index (RSQI).

This approach is based on the integration of individual index $q_i$ of $n$ surveyed parameters to form a formula which simplifies the SQ assessment at each monitoring point. RSQI is calculated by the following formula:

$$\text{RSQI} = 100\left(1 - \frac{Pk}{Pn}\right) \quad (2)$$

Where,

$$P_k = \sum_{i-1}^{k} W\ (qi - 1) \quad (3)$$

$$P_m = \sum_{i=1}^{m} Wqi + \sum_{i-1}^{m} W(1 - qi) \quad (4)$$

$$P_n = P_m + P_k \quad (5)$$

This method clearly shows that RSQI depends on the relative ratio $P_k/P_n$. The higher the value of the ratio , the smaller the value of RSQI . Thus, the SQ is poorer.

To calculate RSQI in formula (2), we first need to calculate individual soil quality index ($q_i$) and weighting factors (both temporary (W*) and permanent/final (W) weighting factors) as follows:

$q_i = C/C^*$

Where C = Actual indicator value and C* is the critical value of the indicator.

To calculate the temporary weighting factors W* and the final weighting factor W. W* accounts for the importance which presents the relationship between each parameter *i*; and *j* is the number of parameters of each examination group. The final weighting factor is determined through the temporary weighting factor W*.

There are four groups of soil processes being considered in this assessment (Fertility, Nutrient retention, Water movement and Toxicity level) with their indicators as seen in table 1.

The formula to calculate W of parameter 1 for each group is as given below:

$$W^* = \frac{\sum_{i=1}^{j}(C*1----C*n)}{n \times C*1}, \quad (6)$$

where C*1 is the critical value of indicator 1 in the group, C*n is the critical value of the nth indicator in the group and n is the number of indicators of each group.

For example, there are 2 indicators (Organic carbon and CEC) in nutrient retention group ($n$ = 2)

$$W^*1(\text{O.C}) = \frac{1+4.5}{2\times1} = 2.71$$

$$W^*2(\text{CEC}) = \frac{1+4.5}{2\times4.5} = 0.611$$

The final weighting factor of each indicator for each group is calculated by the following formula:

$$W = \frac{W*}{\sum_1^n W*} \quad (7)$$

For the above example, final weights for the two indicators is calculated thus:

$$W^*1\ (\text{O.C}) = \frac{2.75}{2.75+0.611} = 0.82$$

$$W^*2\ (\text{CEC}) = \frac{0.611}{2.75+0.611} = 0.18$$

To calculate Pk $\{P_k = \sum_{i-1}^{k} W\ (qi - 1)\}$for a particular soil type, the permanent weight (W) for each indicator is multiplied by (qi – 1) then the results are summed up for all the indicators.

To calculate Pm $\{P_m = \sum_{i=1}^{m} Wqi + \sum_{i-1}^{m} W(1 - qi)\}$for a particular soil type, the product of qi and W are summed for all the indicators and added with the sum of W and (1 – qi) for all indicators.

**Table 1: Group of Soil Processes and Indicators for Crop Production**

| Soil Processes | Soil quality indicators |
|---|---|
| Fertility | Total Nitrogen |
| | Available Phosphorus |
| | Exchangeable K |
| | pH |
| Nutrient Retention | Organic Carbon |
| | Cation Exchange Capacity |
| Water Movement | Bulk Density |
| | Ksat |
| Toxicity Level | Sodium Adsorption Ratio |
| | Available Fe |

## RESULTS

The values of soil quality indicators assessed in Gassol and Katcha LGAs are shown on Tables 2 and 3 respectively. The soils of both LGAs are strongly to moderately acidic (pH 3.02 – 5.27 in Gassol and 2.96 – 5.54 in Katcha). Tables 4 and 5 show the percentage values of soil processes for each soil type in Gassol and Katcha local government areas respectively. In Gassol LGA, the values of all the processes ranged from low to high. Illiah Series have high values (80 – 86 %) for all the soil processes with lowest value under water entry process. Across all the soil types, water entry capacity has the lowest value except Tsantsaga 1 and 3 series with lowest values in nutrient retention. This is an indication that in the study area, Gassol LGA is experiencing water entry or drainage problem. In Katcha LGA, four out of the seven soil types have low values in water entry capacity process. There are two extremes in nutrient retention where four soil types have very low values and three soil types have very high values. The values of Pk, Pm and Pn for the two local government areas are shown on Table 6.

Using the two methods, the percentage aggregate soil quality indices for all the soil types in the two LGAs are shown on Figures 1 and 2. Using SMAF, the soils have moderate to high quality with SQI value ranging from 66.75 – 84.3 % in Gassol LGA and 55.9 – 77.65 % in Katcha LGA. Using RSQI, similar values were obtained with SQI values ranging from 68.06 – 73.03 % in Gassol LGA and 66.14 – 81.84 % in Katcha LGA. High positive correlation occurs between the two methods in the two LGAs (r = 0.68 in Gassol and r = 0.74 in Katcha). This is an indication that both methods can be used to assess soil quality.

## DISCUSSION

Humankind is dependent on good quality soil resource for survival; therefore, it should be an important part of the national policy to protect this natural resource. Soil quality assessment can help to identify areas where problems occur, or need special attention, or a different management system. There are different methods of computing soil quality index with their merits and demerits In soil quality assessment program, the result is meaningless if not computed in an index value which can be categorized as low, moderate or high. The essence of this study is the identification of an appropriate soil quality index. To achieve this, soil quality of rice intensive cultivation areas was assessed by two different methods to present a credible method of soil quality indexing. The soil quality of the studied areas in is moderate to high. This is as a result of the impact of the individual indicators and processes. Although low values were obtained for water entry process for most soil types leading to surface ponding, this cannot be a disadvantage because of the type of crop (low land rice) being cultivated.

The index values of the methods (SMAF and RSQI) were compared through Pearson correlation coefficient. There was a high and significant correlation between the values of the two methods of quantification in the two LGAs ($r = 0.68$ in Gassol and $r = 0.74$ in Katcha $p < 0.05$) indicating a significant positive relationship between both methods. Hence, the two methods are related in the assessment of soil quality for crop production. Since both methods are significantly correlated, it is difficult to conclude which is the best approach; however, it depends greatly on factors such as number of indicators and the level of information required. Andrews et al., (2002) submitted that a recommendation of one technique over the other must be carefully considered and this varies with site and use.

These two methods (SMAF and RSQI) have some similarities and differences. One of the similarities is that both methods made use of more than a single indicator for assessment. It is an already established fact that overall soil quality is determined only by combination of different physical, chemical and biological indicators; and that no single indicator can adequately determine the quality of a soil (Doran and Parkin, 1994, Andrews, et al., 2004, Adeyolanu, et al., 2013, Adeyolanu, 2017). Another similarity is that both methods made use of indicators with three component goals which are: crop productivity, environmental quality, human/animal health. Doran and Parkin (1994) submitted that the goal of soil quality assessment is to increase crop productivity, improve environmental quality and promote plant and animal health. Similarly, Andrews et al. (2002), Mukherjee and Lal (2014) stated that an appropriate soil quality index must have three component goals: environmental quality, agronomic sustainability, and socio-economic viability. Also, both methods made use of relative weights and scores for the different indicators and group/process.

A major difference between SMAF and RSQI has to do with their method of computation. SMAF made use of relative weight and scoring functions which are subjective to the judgement of the assessor (i.e. they are self-regulated). RSQI on the other hand made use of values that are calculated from the analytical laboratory data. This is an important component of RSQI which makes it different and gives it an edge over SMAF and other methods of quantifying soil quality. This method is less subjective, has a scientific basis and relative accuracy (Pham, et al., 2015). However, calculating the relative weights for individual indicators and group (or process) may be a complex exercise which is time-consuming. Compared to RSQI, SMAF is easier but is more subjective therefore may have lower level of accuracy/reliability. On the contrary, the RSQI, with carefully selected indicators, can accurately assess soil quality and provide useful information for decision making. Another advantage of using RSQI is that it has the ability to calculate soil quality index from fewer number of indicators thereby minimizing the cost of soil analysis. Adeyolanu,

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(2017) supported the adoption of the use of fewer indicators as minimum data set with reason that with the concept of minimum data set in place, soil quality assessment will be less costly, less time-consuming and therefore more user friendly.

**Table 2: Values of selected soil quality indicators in Gassol LGA**

| Soil type | BD ($g/cm^3$) | $K_{sat}$ (cm/hr) | pH | ECEC (cmol/kg) | OC (%) | TN (%) | Exch K(cmol/kg) | Av. P (mg/kg) | SAR (cmol/kg) | Fe (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| Tsantsaga Series 1 | 1.55 | 3.39 | 3.68 | 4.60 | 1.36 | 0.24 | 0.23 | 19.1 | 0.11 | 187.0 |
| Tsantsaga Series2 | 1.08 | 11.65 | 3.11 | 11.12 | 4.41 | 0.54 | 0.21 | 59.0 | 0.20 | 471.0 |
| Edozhigi Series 1 | 1.01 | 9.78 | 3.02 | 12.03 | 2.21 | 0.32 | 0.22 | 22.4 | 0.13 | 375 |
| Edozhigi Series 2 | 1.02 | 14.26 | 3.11 | 12.16 | 3.32 | 0.43 | 1.49 | 26.8 | 0.16 | 542.0 |
| Tsantsaga Series3 | 1.57 | 4.38 | 4.39 | 2.74 | 0.74 | 0.17 | 0.08 | 5.5 | 0.32 | 144.0 |
| Agaie Series | 1.59 | 21.36 | 3.27 | 2.70 | 1.67 | 0.27 | 0.16 | 5.7 | 0.20 | 67.9 |
| Illiah Series | 1.48 | 3.56 | 5.27 | 9.74 | 2.05 | 0.31 | 0.26 | 12.8 | 0.12 | 276.0 |

**Table 3: Values of selected soil quality indicators in Katcha LGA**

| Soil type | BD ($g/cm^3$) | $K_{sat}$ (cm/hr) | pH | ECEC (cmol/kg) | OC (g/kg) | TN (g/kg) | Exch K(cmol/kg) | Av. P (mg/kg) | SAR (cmol/kg) | Fe (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| Badeggi Series | 1.53 | 0.014 | 3.12 | 1.78 | 3.24 | 0.64 | 1.41 | 11.8 | 0.13 | 462.0 |
| Oji Series | 1.77 | 1.81 | 4.14 | 2.07 | 0.40 | 0.34 | 0.06 | 5.2 | 0.18 | 49.2 |
| Adepele Series | 1.98 | 0.009 | 5.06 | 2.42 | 0.44 | 0.32 | 0.07 | 4.6 | 0.19 | 153.0 |
| Agaie Series 1 | 1.64 | 0.105 | 5.54 | 1.89 | 0.32 | 0.33 | 0.09 | 4.4 | 0.36 | 88.6 |
| Suwazuru Series | 1.60 | 2.83 | 3.48 | 2.28 | 0.76 | 0.28 | 0.09 | 7.3 | 0.15 | 75.6 |
| Sepeti Series | 1.11 | 2.95 | 2.96 | 16.8 | 2.47 | 0.82 | 0.27 | 0.8 | 0.13 | 491 |
| Agaie Series 2 | 1.78 | 0.009 | 3.2 | 15.02 | 2.49 | 0.99 | 0.27 | 6.0 | 0.15 | 92.2 |

**Table 4: Percentage Values of Soil Processes using SMAF in Gassol LGA**

| | Soil Processes | | | |
|---|---|---|---|---|
| Soil Type | Nutrient Availabilty (%) | Nutrient Retention (%) | Water Entry (%) | Degradation/Toxicity Level (%) |
| Tsantsaga Series 1 | 80 | 64 | 72.5 | 90 |
| Tsantsaga Series2 | 82 | 81 | 65 | 75 |
| Edozhigi Series 1 | 78 | 80 | 65 | 77.5 |
| Edozhigi Series 2 | 71.5 | 83 | 62.5 | 70 |
| Tsantsaga Series3 | 69.5 | 48 | 67.5 | 90 |
| Agaie Series | 70.5 | 70 | 47.5 | 90 |
| Illiah Series | 85 | 86 | 80 | 85 |

**Table 5: Percentage Values of Soil Processes using SMAF in Katcha LGA**

| | Soil Processes | | | |
|---|---|---|---|---|
| SOIL TYPE | Nutrient Availabilty (%) | Nutrient Retention (%) | Water Entry (%) | Degradation/Toxicity Level (%) |
| Badeggi Series | 67.5 | 93 | 65 | 70 |
| Oji Series | 63 | 40 | 45 | 80 |
| Adepele Series | 70.5 | 40 | 35 | 80 |
| Agaie Series 1 | 69 | 30 | 50 | 80 |
| Suwazwu Series | 64.5 | 91 | 85 | 70 |
| Sepeti Series | 53 | 40 | 75 | 80 |
| Agaie Series 2 | 71.5 | 93 | 45 | 80 |

**Table 6: Values of Pk, Pm and Pn for the two LGAs**

| Gassol LGA | | | | Katcha LGA | | | |
|---|---|---|---|---|---|---|---|
| Soil type | $P_k$ | $P_m$ | $P_n$ | Soil type | $P_k$ | $P_m$ | $P_n$ |
| Tsantsaga series 1 | 2.47 | 6.6881 | 9.1581 | Badeggi series | 8.581 | 17.79675 | 26.37875 |
| Tsantsaga series 2 | 8.627 | 18.3849 | 27.0119 | Oji series | 3.72 | 7.59377 | 11.31377 |
| Edozhigi series 1 | 4.974 | 11.1119 | 16.0859 | Adepele series | 3.771 | 7.619335 | 11.390335 |
| Edozhigi series 2 | 7.771 | 17.0511 | 24.8221 | Agaie series 1 | 3.83 | 7.47998 | 11.30998 |
| Tsantsaga series 3 | 2.045 | 5.15455 | 7.19955 | Suwazwu series | 2.844 | 10.565042 | 13.409042 |
| Agaie series | 4.536 | 10.6722 | 15.2082 | Sepeti series | 8.24 | 17.888512 | 26.128512 |
| Illiah series | 3.708 | 9.22924 | 12.93724 | Agaie series 2 | 3.097 | 13.9564675 | 17.0534675 |

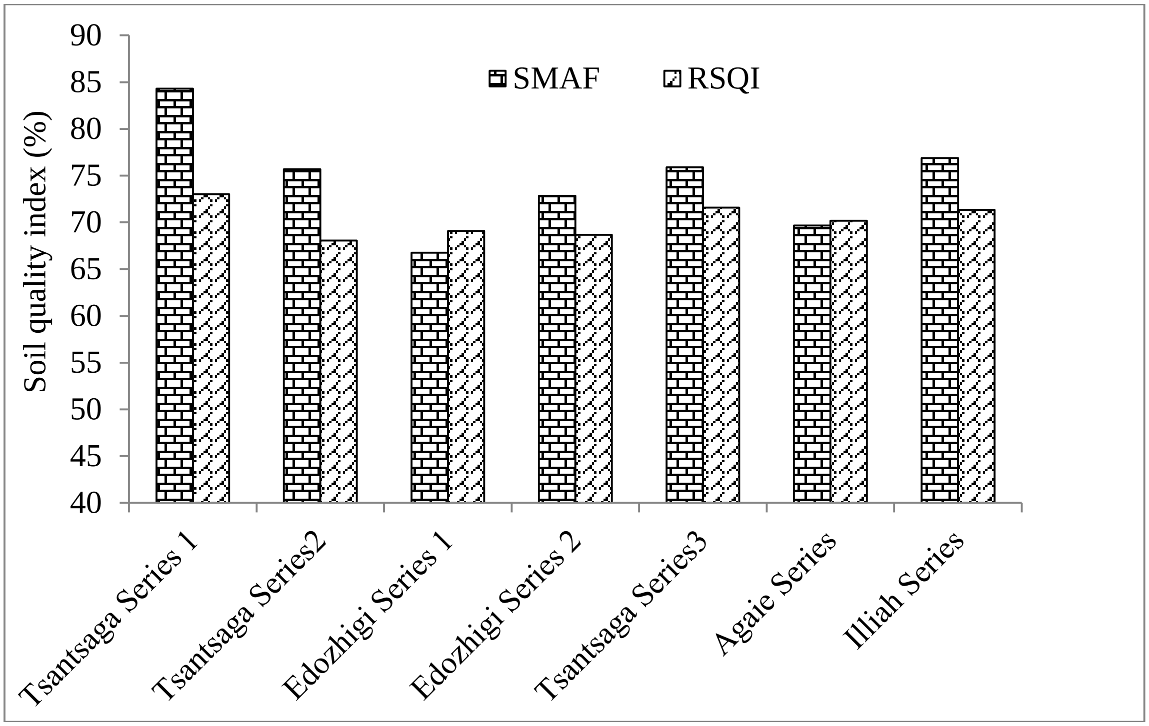


Fig. 1: Aggregate soil quality indices of Gassol Local Government using SMAF and RSQI
SMAF – Soil Management Assessment Framework RSQI = 100 (1 – $P_k/P_n$) – Relative Soil Quality Index

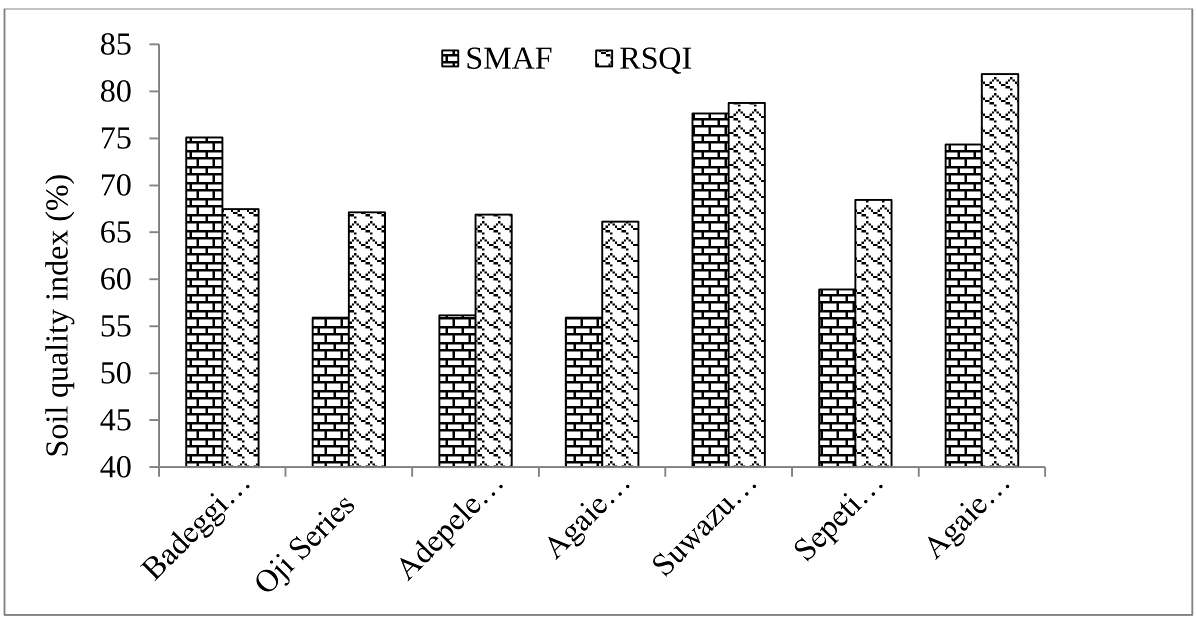


Fig. 2: Aggregate soil quality indices of Katcha Local Government using SMAF and RSQI
SMAF – Soil Management Assessment Framework RSQI = 100 (1 – $P_k/P_n$) – Relative Soil Quality Index

## CONCLUSION

The two quantitative methods (SMAF and RSQI) of assessing soil quality examined have similarities and differences. They 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 depend on experts' opinions for assigning scores and weights.

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