Nigerian Journal of Ecology (2023) 19(1): 51-61

ISSN: 1116-753X (Print); E-ISSN: 2955-084X (Online)

# Spatial Variability of Selected Soil Properties of Organic and Conventional Management Systems in Citrus Orchards in Ibadan, Southwestern Nigeria

**Julius R. Orimoloye[1]*, Avwarosuoghene Kpomah[1], and Bernard N. Okafor[2]**

[1]Department of Soil Resources Management, University of Ibadan, Ibadan, Nigeria
[2]National Institute of Horticultural Research (NIHORT), Ibadan, Nigeria

*Corresponding Author's Email: juliusorimoloye@gmail.com

(Accepted 18 April, 2023)

## ABSTRACT

Spatial variability of soil properties may reflect the effects of management practices adopted in an area, and understanding this is prerequisite for devising location specific nutrient management for a better farm economy and increased sustainability in crop production. This study assessed the influence of conventional and organic management practices on spatial variability of the soil properties at the National Horticultural Research Institute (NIHORT), Ibadan. Soil samples were collected from conventionally and organically management citrus orchards at 14 m x 21 m grids and at depths of 0 – 15, 15 – 30 and 30 – 60 cm. Soil samples were also collected from an adjacent undisturbed forest as Control. Variance analysis, semivariogram models and relative variance were used to analyse the results of selected soil chemical and physical properties. It was observed that management systems had significant effects on soil properties. The control had the highest organic carbon, potassium, sodium content and bulk density values. The organically managed citrus orchard was closer to the control in terms of nutrient content than the conventionally managed orchard. pH, bulk density and coarse sand were the least variable parameters (CV < 15%) at all depths in both management systems and the control. Total nitrogen, available P, calcium, magnesium, clay and fine sand were highly variable (CV > 35%) at all depths, while organic carbon, potassium, sodium and silt varied irregularly from highly, moderately to least variable at various depths in both orchards. However, in control samples, available P and total nitrogen were the highly variable (CV > 35%) properties at all depths. Silt, organic carbon and calcium were moderately variable (CV 15 – 35%) at all depths. The undisturbed forest had fewer variations in soil properties than both orchards. Nevertheless, the organically managed orchard showed more similarities in soil properties with the control. Therefore, the organic management system caused less spatial variability in soil properties compared with the conventionally managed system, thus it could be more sustainable and less cumbersome to manage.

**Key words**: Soil properties, Spatial variability, Management systems, Citrus orchard.

## INTRODUCTION

The soil is an essential part of any terrestrial ecosystem. One may look at the soil on a piece of land and see one homogenous mass, but this is unlikely as soil usually differ in physical, chemical and biological properties. The cause of this difference may be due to morphological factors, type of crop grown, or management practices adopted. According to Maniyunda *et al*. (2013) the soil is inherently heterogeneous in nature, as a result of the many factors that contribute to its formation and the complex interactions of these factors. Ferreira *et al*. (2015) reported soil physical and chemical properties to vary with land use, cultural practices and local conditions like complex topographic landscape and soil type

Management practices have a great effect on the direction and degree of changes in soil properties. They have been known to affect the soil either positively or negatively, but their impact on the soil properties from point to point on a piece of land may have been overlooked. Conventional farm management in a bid to increase food production to meet the ever increasing human demands employ intensive use of land resources, irrigation, fertilizers, pesticides and modern farm machineries. Conventional management fully depends on external inputs like chemical fertilizer for productivity and synthetic pesticides for pest management. According to Rattanasuteerakul and Thapa (2012), these chemicals pollute the environment and cause various kinds of health problems among consumers. Organic farm management on the other hand is a holistic approach consisting of a set of conservation activities such as green manures, composting, cultural practices, bio-fertilizer and biologically nitrogen fixation for environmentally friendly production (Leifeld, 2012). It is rapidly expanding through the world due to the growing demand for a more sustainable agriculture (Mzoughi, 2011). Organic farming relies on biological processes and thus aims at reducing the utilization of external inputs (Schader *et al*., 2013).

Soil variability is the degree of variation in physical and chemical properties of soil from one point to another (Akinbola *et al*., 2010) which could be due to varying influence of the soil forming factors in a natural setting or could be induced by the varying landuse or land management practices. Variability in soil properties could result in some part of a cultivated field receiving insufficient inputs with the other part receiving excess of it (Effiom *et al*., 2010). Mulla and McBratney (2001) also note that variability in soil properties causes uneven crop growth, confounds treatment effects in field experiments and decreases the effectiveness of uniformly applied fertilizer on a field scale. While induced variability in soil properties is unavoidable, high degree of soil variability could make mapping and accurate prediction of management and productive potentials difficult (Ogunkunle, 2003). Excessive induced variability may also be an indication that such management practices may not be sustainable with time (Tugrul, 2019). Understanding the magnitude and pattern of soil spatial variability is necessary for improved management of soil and research design for field trials in agricultural production (Khan *et al*., 2014).

Citrus (*Citrus sinensis*) is the most widely cultivated fruit-tree in Nigeria. As at 2017, Nigeria ranked 9th in world citrus production with 4.09 million tonnes (FAOSTAT, 2018). Citrus serves as a raw material for fruit juice and confectionery industry. Citrus and citrus products are rich in vitamins, minerals and dietary fibre which are essential for normal growth and development and overall nutritional wellbeing (Etebu and Nwauzomam, 2014). Citrus trees are grown on a wide range of soil types. (Shah *et al*., 2012) reported that citrus orchards are generally not uniform in soil fertility due to variability in soil properties. Therefore, blanket fertilizer application may not be economical in circumstances where fertility gradient across the site is not uniform.

Understanding spatial variability of soil properties is prerequisite for devising location specific nutrient management with the aim of obtaining better farm economy and increased sustainability in crop production (Behera and Shukla, 2015). This study was conducted to assess the spatial variability of the soil of citrus orchards and the influence of management practices on soil properties.

## MATERIALS AND METHODS

### Location

The study was conducted at the National Horticultural Research Institute (NIHORT), Ibadan. The study area lies within latitude 07$^o$ 24.484′ N - 07$^o$ 24.410′ N and longitude 3$^o$ 50.672′ E - 03$^o$ 50.719′ E with a mean altitude of 165.5 m. The area has a humid climate with an average rainfall range of 1100 – 1400 mm/annum (NIMET, 2018). It experiences a bimodal rainfall distribution pattern with peaks in June/July and September. Maximum and minimum temperatures are 30$^o$C and 21$^o$C with relative humidity of over 70%. The area is underlain by basement complex parent rocks which have thick foundation of ancient and old metamorphic and igneous rocks.

### Field survey and Soil sampling

Reconnaissance visit was made to the study area in order to have an idea of the terrain and make prior arrangements before embarking on the main field work. The coordinates of the sampling points were taken using the Global Positioning System (GPS) devise. Soil samples were collected from organically managed citrus orchard and conventionally managed citrus orchard using soil auger. These samples were collected at 14 m x 21 m grids and at the depth of 0-15, 15-30, and 30-60 cm. These gave a total of 48 samples for each orchard. Undisturbed soil samples were collected from the study area using a metal core sampler (of known height and diameter) for the determination of bulk density. Samples were also collected from an undisturbed forest to serve as control.

### Laboratory analysis

Soil Samples collected were air-dried and passed through a 2 mm sieve and 0.5 mm sieve to analyse for physical and chemical (routine) properties. The soils were analysed using standard procedures described by Udo *et al*., 2009. Parameters determined include; pH 1:1 $H_2O$, exchangeable bases (Na, K, Ca, Mg), available phosphorus, organic carbon, total nitrogen and bulk density.

### Statistical analysis

The data set of soil properties was analysed statistically. The mean, standard deviation and coefficient of variation for each area studied were assessed. coefficient of variation (CV) was calculated as the percentage the standard deviation to the mean. Two-way ANOVA was done to test the effect of management systems and depths on soil properties using Genstat 4th edition. Means were separated using LSD at $P<0.05$. Geostatistical technique of semivariogram analysis was used to determine spatial structure of some chemical properties of the soil. Soil test values were interpolated using geostatistical technique of kriging to generate nutrient distribution maps. Relative variance which is the ratio of variance withing units to total variance was used to test the heterogeneity of soil properties within each study unit.

## RESULTS

### Selected descriptive statistics of some soil properties of the study area

Table 1 shows selected descriptive statistics of some properties of surface layer (0 - 15 cm) and sub soil (15 - 30 and 30 - 60 cm soil depth) from the conventionally managed citrus orchard. The pH varied with depth with mean pH decreasing from 6.78 in the surface layer to 6.54 at subsurface layer. The values of CV for soil pH in all the soil depths revealed their low variability (CV < 15). The organic carbon content in the surface soil layer varied from 10.50 g/kg to 31.92 g/kg across the conventionally managed citrus orchard. The mean organic carbon content decreased with increasing soil depth. Highest variation was observed in available P. The variability of available P in surface layer (CV = 191 %) was higher than in lower horizons (CV = 100 %). Coefficient of variation (CV) of total N in the surface soils was higher (139.8 %) than at subsurface horizons (129.9 %). With, the value of CV for total N, classified as highly variable

The mean K content in the top soil was 0.3 cmol/kg which decreased to 0.1 cmol/kg at the sub soil. The spatial variation in K content was classed as ‘moderate’ (CV = 24.4 to 26.5%), at the surface layer and sub-surface layer (30 - 60 cm) respectively. For the exchangeable bases, Ca and Mg content in all the soil layers was highly variable except for Mg content in the sub layer (30 - 60 cm) which was moderately variable. Ca reduced with depth. Na was moderately variable at all depths, with CV ranging from 18.9 % to 30.4 %.

Particle size distribution revealed that sand was the dominant soil texture component in the area with surface layer having mean value of 838.3 g/kg, followed by silt with 129 g/kg and clay 27 g/kg. As indicated by the values of the coefficient of variation (CV), it was observed that the variability of the clay component across all depths of the field was high (CV > 35) while that of coarse sand was the least (CV < 15). Bulk density had CV < 15 % at all depths: thus classed as least variable.

Table 1: Descriptive statistics of selected properties of the conventionally managed citrus orchard

| | 0 – 15 cm soil depth | | | | 15 – 30 cm soil depth | | | | 30 – 60 cm soil depth | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil properties | Range | X | SD | CV | Range | X | SD | CV | Range | X | SD | CV |
| pH | 6.7 - 8.0 | 6.78 | 0.54 | 8.0 | 6.1 - 7.4 | 6.69 | 0.38 | 5.7 | 5.8 - 7.5 | 6.54 | 0.59 | 9.0 |
| OC (g/kg) | 10.50 - 31.92 | 18.72 | 6.03 | 32.2 | 3.78 - 21.00 | 9.37 | 5.02 | 53.6 | 0.42 - 25.62 | 8.21 | 6.52 | 79.4 |
| Total N (g/kg) | 0.14 - 12.60 | 2.64 | 3.69 | 139.8 | 0.14 - 11.62 | 2.91 | 3.38 | 116.2 | 0.14 - 9.80 | 1.94 | 2.52 | 129.9 |
| Avail. P (mg/kg) | 1 – 86 | 11.00 | 21.00 | 191.0 | 1 – 64 | 12.00 | 18.00 | 150.0 | 1 – 11 | 3.00 | 3.00 | 100.0 |
| K (cmol/kg) | 0.12 - 0.49 | 0.26 | 0.08 | 31.8 | 0.08 - 0.25 | 0.14 | 0.06 | 40.9 | 0.07 - 1.74 | 0.13 | 0.04 | 28.3 |
| Mg (cmol/kg) | 0.62 - 2.53 | 1.45 | 0.60 | 41.6 | 0.65 - 2.49 | 1.47 | 0.60 | 40.5 | 0.85 - 2.22 | 1.38 | 0.46 | 33.1 |
| Ca (cmol/kg) | 0.88 - 7.86 | 3.23 | 2.26 | 69.9 | 0.22 - 4.03 | 2.30 | 1.56 | 67.9 | 0.21 - 4.67 | 1.32 | 1.33 | 100.8 |
| Na (cmol/kg) | 0.48 - 1.17 | 0.79 | 0.19 | 24.0 | 0.39 - 1.52 | 0.80 | 0.24 | 30.4 | 0.57 - 1.13 | 0.77 | 0.15 | 18.9 |
| Clay (g/kg) | 0.00 - 4.00 | 2.70 | 1.40 | 51.9 | 0.00 - 6.00 | 2.58 | 1.54 | 59.7 | 0.00 - 6.00 | 2.49 | 1.99 | 79.9 |
| Silt (g/kg) | 3.40 - 35.40 | 12.90 | 5.12 | 39.7 | 5.40 - 17.40 | 10.15 | 3.31 | 32.6 | 5.40 - 15.40 | 9.25 | 3.08 | 33.3 |
| Fine sand (g/kg) | 0.04 - 17.94 | 10.88 | 5.68 | 52.2 | 1.88 - 41.02 | 18.91 | 9.78 | 51.7 | 3.94 - 28.38 | 14.58 | 6.52 | 44.7 |
| Coarse sand (g/kg) | 57.80 - 80.46 | 73.73 | 5.39 | 7.31 | 48.78 - 80.88 | 68.50 | 8.25 | 12.0 | 61.42 - 80.67 | 73.19 | 5.71 | 7.8 |
| BD ($g/cm^3$) | 1.39 - 1.42 | 1.41 | 0.01 | 0.7 | 1.39 - 1.42 | 1.41 | 0.02 | 1.4 | 1.39 - 1.44 | 1.41 | 0.02 | 1.4 |

OC - Organic carbon, Avail p - Available Phosphorous, Ca - Calcium, Mg - Magnesium, N - Nitrogen, Na - Sodium, K - Potassium, BD – Bulk density, CV - Coefficient of variation, SD - Standard deviation, X - Mean

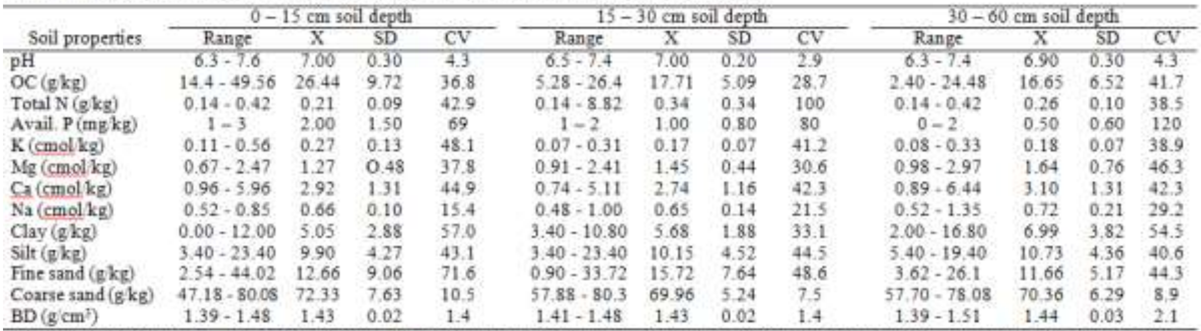
Table 2 shows some descriptive statistics of some soil properties of the organically managed citrus orchard. The surface profile (0 - 15 cm) showed pH varying from 6.3 to 7.6 with mean value of 7.0, which was in close range with the sublayers, indicating that the soils were neutral at all depths. The values of CV for soil pH in all the soil layers showed the low variability and these values were less compared to CV values of other measured soil chemical properties. The organic carbon content in the surface layers varied from 14.4 to 49.56 g/kg and had CV value that was highly variable (36.8 %). The mean organic carbon content decreased with depth. Available P had the highest spatial variation compared to other measured soil properties. The variability of available P (CV=69 %) at the surface was less than was observed at the lowest depth (CV = 120 %). Coefficient of variation (CV) of total N at 15 -30 cm depth was highest compared with the other depths. The, total N content was also highest at this depth. All the CVs of total N in the soil were classified as high variability.

Mean K content in the top layers was 0.27 cmol/kg and then decreased to 0.17 cmol/kg at the sub soil layer. The CV for K content in all the studied soil profiles decreased with depth. and was classified as highly (CV=38.9 to 48.1 %). Ca and Mg content in all the soil horizons were highly variable except for Mg. content in the 15 - 30 cm depth that was moderate. Sodium content was in the moderate variability class at all depths.

For the particle size distribution, mean clay fractions ranged from 5.05 to 6.99 %, silt (9.90 to 10.73 %), while that of coarse sand was (69.96 to 72.33 %) across all depths. Clay and silt fractions increased with increasing depth, and had CV values classified as highly variable. Coarse sand fractions were least variable at all depths (CV < 15 %). Bulk density had mean values that increased with depth and CV values that were low at all depths.

Descriptive statistics of some soil properties of the undisturbed forest are shown in Table 3. The pH varied from 6.1 to 8.0 across depths. There was slight variation in the pH with depth, mean pH increased from 7.0 at the 0-15 and 15-30 cm depths to 7.2 at 30 - 60 cm depth. The values of CV (5.7, 4.2 and 9.7 %) for soil pH in all soil depths revealed their low variability. The mean organic carbon content decreased with depth. The organic carbon at the 0-15cm depth varied from 29.4 g/kg to 48.72 g/kg across the study area. The mean value of the total nitrogen was classified as low and it reduced from 0-15 to 15-30 cm depth. The total nitrogen at the surface ranged from 0.14 g/kg to 0.56 g/kg. The CV at 0 - 15 cm was highest compared to other depths, although all the CV were classified as highly variable. The mean values of available phosphorus reduced with increasing depth. 0-15 cm depth (CV = 38 %) was higher than the 15 – 30cm (CV = 36 %) and lower than the 30-60 cm depth (CV = 60 %). The spatial variation in K content was moderate at the surface and low at sub layers. Ca, Mg and Na ranged from high to moderate across depths. For the particle size distribution, mean clay values increased while that of silt and coarse sand content reduced with increasing depth. Coarse sand was the least variable at all depths. Silt was classed as moderately variable (CV 18 % - 25.3 %). Clay content had low variability at 30 - 60 cm depth, while bulk density had low CV values.

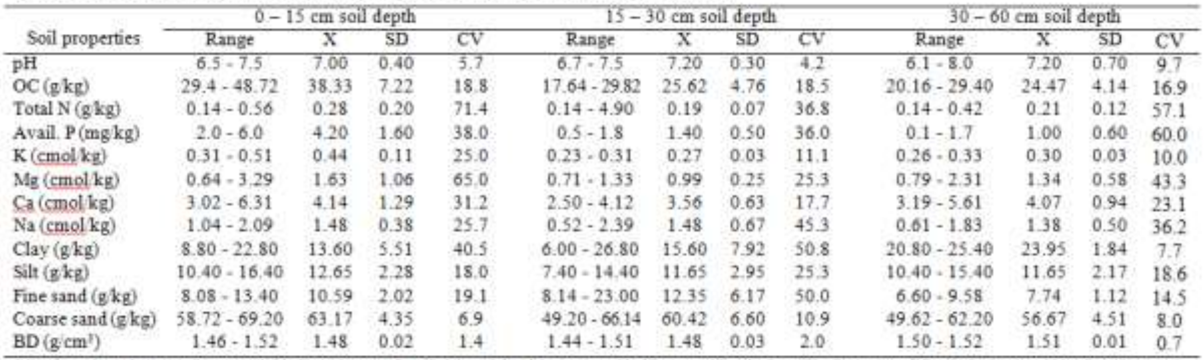
Table 2: Descriptive statistics of selected properties of the organically managed citrus orchard



| Soil properties | 0 – 15 cm soil depth | | | | 15 – 30 cm soil depth | | | | 30 – 60 cm soil depth | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Range | X | SD | CV | Range | X | SD | CV | Range | X | SD | CV |
| pH | 6.3 - 7.6 | 7.00 | 0.30 | 4.3 | 6.5 - 7.4 | 7.00 | 0.20 | 2.9 | 6.3 - 7.4 | 6.90 | 0.30 | 4.3 |
| OC (g/kg) | 14.4 - 49.56 | 26.44 | 9.72 | 36.8 | 5.28 - 26.4 | 17.71 | 5.09 | 28.7 | 2.40 - 24.48 | 16.65 | 6.52 | 41.7 |
| Total N (g/kg) | 0.14 - 0.42 | 0.21 | 0.09 | 42.9 | 0.14 - 8.82 | 0.34 | 0.34 | 100 | 0.14 - 0.42 | 0.26 | 0.10 | 38.5 |
| Avail. P (mg/kg) | 1 – 3 | 2.00 | 1.50 | 69 | 1 – 2 | 1.00 | 0.80 | 80 | 0 – 2 | 0.50 | 0.60 | 120 |
| K (cmol/kg) | 0.11 - 0.56 | 0.27 | 0.13 | 48.1 | 0.07 - 0.31 | 0.17 | 0.07 | 41.2 | 0.08 - 0.33 | 0.18 | 0.07 | 38.9 |
| Mg (cmol/kg) | 0.67 - 2.47 | 1.27 | 0.48 | 37.8 | 0.91 - 2.41 | 1.45 | 0.44 | 30.6 | 0.98 - 2.97 | 1.64 | 0.76 | 46.3 |
| Ca (cmol/kg) | 0.96 - 5.96 | 2.92 | 1.31 | 44.9 | 0.74 - 5.11 | 2.74 | 1.16 | 42.3 | 0.89 - 6.44 | 3.10 | 1.31 | 42.3 |
| Na (cmol/kg) | 0.52 - 0.85 | 0.66 | 0.10 | 15.4 | 0.48 - 1.00 | 0.65 | 0.14 | 21.5 | 0.52 - 1.35 | 0.72 | 0.21 | 29.2 |
| Clay (g/kg) | 0.00 - 12.00 | 5.05 | 2.88 | 57.0 | 3.40 - 10.80 | 5.68 | 1.88 | 33.1 | 2.00 - 16.80 | 6.99 | 3.82 | 54.5 |
| Silt (g/kg) | 3.40 - 23.40 | 9.90 | 4.27 | 43.1 | 3.40 - 23.40 | 10.15 | 4.52 | 44.5 | 5.40 - 19.40 | 10.73 | 4.36 | 40.6 |
| Fine sand (g/kg) | 2.54 - 44.02 | 12.66 | 9.06 | 71.6 | 0.90 - 33.72 | 15.72 | 7.64 | 48.6 | 3.62 - 26.1 | 11.66 | 5.17 | 44.3 |
| Coarse sand (g/kg) | 47.18 - 80.08 | 72.33 | 7.63 | 10.5 | 57.88 - 80.3 | 69.96 | 5.24 | 7.5 | 57.70 - 78.08 | 70.36 | 6.29 | 8.9 |
| BD (g/cm$^3$) | 1.39 - 1.48 | 1.43 | 0.02 | 1.4 | 1.41 - 1.48 | 1.43 | 0.02 | 1.4 | 1.39 - 1.51 | 1.44 | 0.03 | 2.1 |

OC - Organic carbon, Avail p - Available Phosphorous, Ca - Calcium, Mg - Magnesium, N - Nitrogen, Na - Sodium, K - Potassium, BD – Bulk density, CV - Coefficient of

Table 3: Selected descriptive statistics of some properties of the Natural Forest (control)



| Soil properties | 0 – 15 cm soil depth | | | | 15 – 30 cm soil depth | | | | 30 – 60 cm soil depth | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Range | X | SD | CV | Range | X | SD | CV | Range | X | SD | CV |
| pH | 6.5 - 7.5 | 7.00 | 0.40 | 5.7 | 6.7 - 7.5 | 7.20 | 0.30 | 4.2 | 6.1 - 8.0 | 7.20 | 0.70 | 9.7 |
| OC (g/kg) | 29.4 - 48.72 | 38.33 | 7.22 | 18.8 | 17.64 - 29.82 | 25.62 | 4.76 | 18.5 | 20.16 - 29.40 | 24.47 | 4.14 | 16.9 |
| Total N (g/kg) | 0.14 - 0.56 | 0.28 | 0.20 | 71.4 | 0.14 - 4.90 | 0.19 | 0.07 | 36.8 | 0.14 - 0.42 | 0.21 | 0.12 | 57.1 |
| Avail. P (mg/kg) | 2.0 - 6.0 | 4.20 | 1.60 | 38.0 | 0.5 - 1.8 | 1.40 | 0.50 | 36.0 | 0.1 - 1.7 | 1.00 | 0.60 | 60.0 |
| K (cmol/kg) | 0.31 - 0.51 | 0.44 | 0.11 | 25.0 | 0.23 - 0.31 | 0.27 | 0.03 | 11.1 | 0.26 - 0.33 | 0.30 | 0.03 | 10.0 |
| Mg (cmol/kg) | 0.64 - 3.29 | 1.63 | 1.06 | 65.0 | 0.71 - 1.33 | 0.99 | 0.25 | 25.3 | 0.79 - 2.31 | 1.34 | 0.58 | 43.3 |
| Ca (cmol/kg) | 3.02 - 6.31 | 4.14 | 1.29 | 31.2 | 2.50 - 4.12 | 3.56 | 0.63 | 17.7 | 3.19 - 5.61 | 4.07 | 0.94 | 23.1 |
| Na (cmol/kg) | 1.04 - 2.09 | 1.48 | 0.38 | 25.7 | 0.52 - 2.39 | 1.48 | 0.67 | 45.3 | 0.61 - 1.83 | 1.38 | 0.50 | 36.2 |
| Clay (g/kg) | 8.80 - 22.80 | 13.60 | 5.51 | 40.5 | 6.00 - 26.80 | 15.60 | 7.92 | 50.8 | 20.80 - 25.40 | 23.95 | 1.84 | 7.7 |
| Silt (g/kg) | 10.40 - 16.40 | 12.65 | 2.28 | 18.0 | 7.40 - 14.40 | 11.65 | 2.95 | 25.3 | 10.40 - 15.40 | 11.65 | 2.17 | 18.6 |
| Fine sand (g/kg) | 8.08 - 13.40 | 10.59 | 2.02 | 19.1 | 8.14 - 23.00 | 12.35 | 6.17 | 50.0 | 6.60 - 9.58 | 7.74 | 1.12 | 14.5 |
| Coarse sand (g/kg) | 58.72 - 69.20 | 63.17 | 4.35 | 6.9 | 49.20 - 66.14 | 60.42 | 6.60 | 10.9 | 49.62 - 62.20 | 56.67 | 4.51 | 8.0 |
| BD (g/cm$^3$) | 1.46 - 1.52 | 1.48 | 0.02 | 1.4 | 1.44 - 1.51 | 1.48 | 0.03 | 2.0 | 1.50 - 1.52 | 1.51 | 0.01 | 0.7 |

OC - Organic carbon, Avail p - Available Phosphorous, Ca - Calcium, Mg - Magnesium, N - Nitrogen, Na - Sodium, K - Potassium, BD – bulk density, CV – Coefficient of variation, SD - Standard deviation, X - Mean

## Relative variance

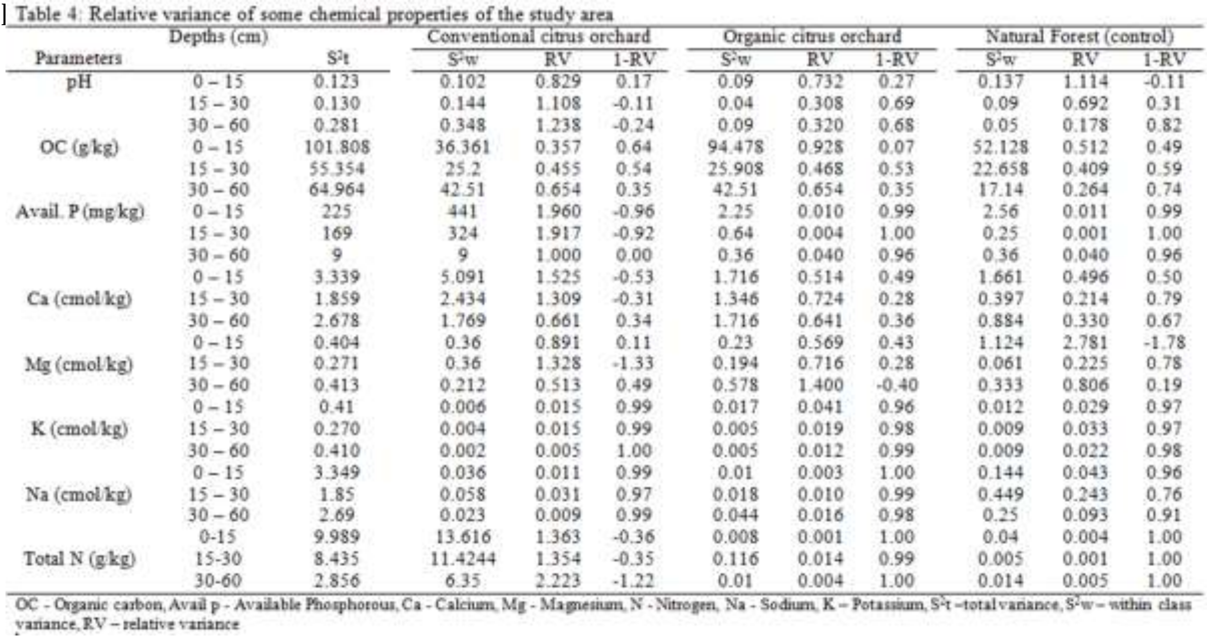
Relative variance was used to measure the degree of homogeneity in each management system (Tables 4 and 5). The K, Na and clay were homogenous in both management systems at all depths, having 1-RV values ranging from 0.5 – 1, while available P and total nitrogen were homogenous in the organically managed orchard, at all depths.

## Two-way analysis of variance on selected soil properties of the study area

From Table 6, organic carbon, available P, potassium, sodium and bulk density were significantly influenced by management systems, while organic carbon and potassium were significantly affected by soil depths. There were no significant differences in the interaction between depths and management systems for all soil properties analysed. The control had the highest organic carbon, potassium, sodium and bulk density. The organically managed citrus orchard was closer to the control in terms of nutrient content than the conventionally managed orchard. Total nitrogen and available phosphorous were more in the conventionally managed orchard, although the total nitrogen was not significantly different from that of the other management systems.

Semivariogram model parameters of some chemical properties of the citrus orchards and the control are shown in Table 7. The nuggets, sill, ranges and nugget/sill ratio of some chemical soil properties of both citrus orchards and the control reveals the s

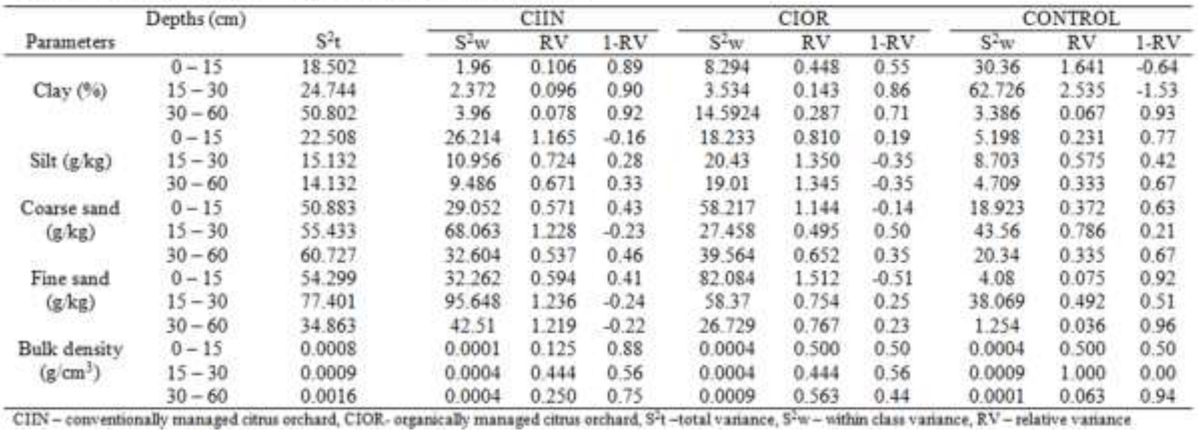
Table 4: Relative variance of some chemical properties of the study area



| Parameters | Depths (cm) | $S^2t$ | Conventional citrus orchard $S^2w$ | Conventional citrus orchard RV | Conventional citrus orchard 1-RV | Organic citrus orchard $S^2w$ | Organic citrus orchard RV | Organic citrus orchard 1-RV | Natural Forest (control) $S^2w$ | Natural Forest (control) RV | Natural Forest (control) 1-RV |
|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 0 – 15 | 0.123 | 0.102 | 0.829 | 0.17 | 0.09 | 0.732 | 0.27 | 0.137 | 1.114 | -0.11 |
| | 15 – 30 | 0.130 | 0.144 | 1.108 | -0.11 | 0.04 | 0.308 | 0.69 | 0.09 | 0.692 | 0.31 |
| | 30 – 60 | 0.281 | 0.348 | 1.238 | -0.24 | 0.09 | 0.320 | 0.68 | 0.05 | 0.178 | 0.82 |
| OC (g/kg) | 0 – 15 | 101.808 | 36.361 | 0.357 | 0.64 | 94.478 | 0.928 | 0.07 | 52.128 | 0.512 | 0.49 |
| | 15 – 30 | 55.354 | 25.2 | 0.455 | 0.54 | 25.908 | 0.468 | 0.53 | 22.658 | 0.409 | 0.59 |
| | 30 – 60 | 64.964 | 42.51 | 0.654 | 0.35 | 42.51 | 0.654 | 0.35 | 17.14 | 0.264 | 0.74 |
| Avail. P (mg/kg) | 0 – 15 | 225 | 441 | 1.960 | -0.96 | 2.25 | 0.010 | 0.99 | 2.56 | 0.011 | 0.99 |
| | 15 – 30 | 169 | 324 | 1.917 | -0.92 | 0.64 | 0.004 | 1.00 | 0.25 | 0.001 | 1.00 |
| | 30 – 60 | 9 | 9 | 1.000 | 0.00 | 0.36 | 0.040 | 0.96 | 0.36 | 0.040 | 0.96 |
| Ca (cmol/kg) | 0 – 15 | 3.339 | 5.091 | 1.525 | -0.53 | 1.716 | 0.514 | 0.49 | 1.661 | 0.496 | 0.50 |
| | 15 – 30 | 1.859 | 2.434 | 1.309 | -0.31 | 1.346 | 0.724 | 0.28 | 0.397 | 0.214 | 0.79 |
| | 30 – 60 | 2.678 | 1.769 | 0.661 | 0.34 | 1.716 | 0.641 | 0.36 | 0.884 | 0.330 | 0.67 |
| Mg (cmol/kg) | 0 – 15 | 0.404 | 0.36 | 0.891 | 0.11 | 0.23 | 0.569 | 0.43 | 1.124 | 2.781 | -1.78 |
| | 15 – 30 | 0.271 | 0.36 | 1.328 | -1.33 | 0.194 | 0.716 | 0.28 | 0.061 | 0.225 | 0.78 |
| | 30 – 60 | 0.413 | 0.212 | 0.513 | 0.49 | 0.578 | 1.400 | -0.40 | 0.333 | 0.806 | 0.19 |
| K (cmol/kg) | 0 – 15 | 0.41 | 0.006 | 0.015 | 0.99 | 0.017 | 0.041 | 0.96 | 0.012 | 0.029 | 0.97 |
| | 15 – 30 | 0.270 | 0.004 | 0.015 | 0.99 | 0.005 | 0.019 | 0.98 | 0.009 | 0.033 | 0.97 |
| | 30 – 60 | 0.410 | 0.002 | 0.005 | 1.00 | 0.005 | 0.012 | 0.99 | 0.009 | 0.022 | 0.98 |
| Na (cmol/kg) | 0 – 15 | 3.349 | 0.036 | 0.011 | 0.99 | 0.01 | 0.003 | 1.00 | 0.144 | 0.043 | 0.96 |
| | 15 – 30 | 1.85 | 0.058 | 0.031 | 0.97 | 0.018 | 0.010 | 0.99 | 0.449 | 0.243 | 0.76 |
| | 30 – 60 | 2.69 | 0.023 | 0.009 | 0.99 | 0.044 | 0.016 | 0.98 | 0.25 | 0.093 | 0.91 |
| Total N (g/kg) | 0-15 | 9.989 | 13.616 | 1.363 | -0.36 | 0.008 | 0.001 | 1.00 | 0.04 | 0.004 | 1.00 |
| | 15-30 | 8.435 | 11.4244 | 1.354 | -0.35 | 0.116 | 0.014 | 0.99 | 0.005 | 0.001 | 1.00 |
| | 30-60 | 2.856 | 6.35 | 2.223 | -1.22 | 0.01 | 0.004 | 1.00 | 0.014 | 0.005 | 1.00 |

OC - Organic carbon, Avail p - Available Phosphorous, Ca - Calcium, Mg - Magnesium, N - Nitrogen, Na - Sodium, K – Potassium, $S^2t$ –total variance, $S^2w$ – within class variance, RV – relative variance

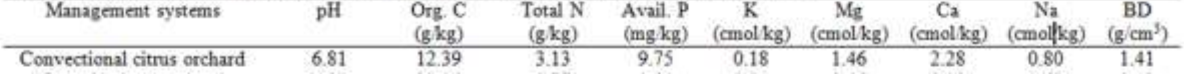
Table 5: Relative variance of some physical properties of the study area



| Parameters | Depths (cm) | $S^2t$ | CIIN $S^2w$ | CIIN RV | CIIN 1-RV | CIOR $S^2w$ | CIOR RV | CIOR 1-RV | CONTROL $S^2w$ | CONTROL RV | CONTROL 1-RV |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Clay (%) | 0 – 15 | 18.502 | 1.96 | 0.106 | 0.89 | 8.294 | 0.448 | 0.55 | 30.36 | 1.641 | -0.64 |
| | 15 – 30 | 24.744 | 2.372 | 0.096 | 0.90 | 3.534 | 0.143 | 0.86 | 62.726 | 2.535 | -1.53 |
| | 30 – 60 | 50.802 | 3.96 | 0.078 | 0.92 | 14.5924 | 0.287 | 0.71 | 3.386 | 0.067 | 0.93 |
| Silt (g/kg) | 0 – 15 | 22.508 | 26.214 | 1.165 | -0.16 | 18.233 | 0.810 | 0.19 | 5.198 | 0.231 | 0.77 |
| | 15 – 30 | 15.132 | 10.956 | 0.724 | 0.28 | 20.43 | 1.350 | -0.35 | 8.703 | 0.575 | 0.42 |
| | 30 – 60 | 14.132 | 9.486 | 0.671 | 0.33 | 19.01 | 1.345 | -0.35 | 4.709 | 0.333 | 0.67 |
| Coarse sand (g/kg) | 0 – 15 | 50.883 | 29.052 | 0.571 | 0.43 | 58.217 | 1.144 | -0.14 | 18.923 | 0.372 | 0.63 |
| | 15 – 30 | 55.433 | 68.063 | 1.228 | -0.23 | 27.458 | 0.495 | 0.50 | 43.56 | 0.786 | 0.21 |
| | 30 – 60 | 60.727 | 32.604 | 0.537 | 0.46 | 39.564 | 0.652 | 0.35 | 20.34 | 0.335 | 0.67 |
| Fine sand (g/kg) | 0 – 15 | 54.299 | 32.262 | 0.594 | 0.41 | 82.084 | 1.512 | -0.51 | 4.08 | 0.075 | 0.92 |
| | 15 – 30 | 77.401 | 95.648 | 1.236 | -0.24 | 58.37 | 0.754 | 0.25 | 38.069 | 0.492 | 0.51 |
| | 30 – 60 | 34.863 | 42.51 | 1.219 | -0.22 | 26.729 | 0.767 | 0.23 | 1.254 | 0.036 | 0.96 |
| Bulk density ($g/cm^3$) | 0 – 15 | 0.0008 | 0.0001 | 0.125 | 0.88 | 0.0004 | 0.500 | 0.50 | 0.0004 | 0.500 | 0.50 |
| | 15 – 30 | 0.0009 | 0.0004 | 0.444 | 0.56 | 0.0004 | 0.444 | 0.56 | 0.0009 | 1.000 | 0.00 |
| | 30 – 60 | 0.0016 | 0.0004 | 0.250 | 0.75 | 0.0009 | 0.563 | 0.44 | 0.0001 | 0.063 | 0.94 |

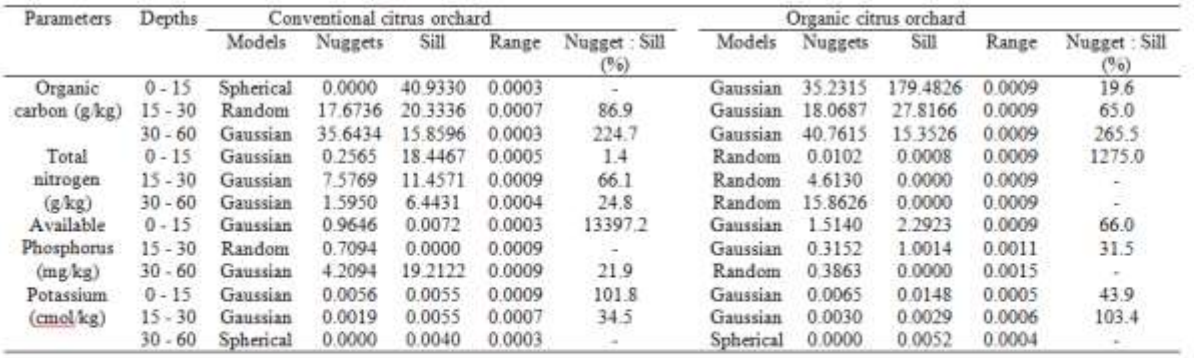
CIIN – conventionally managed citrus orchard, CIOR- organically managed citrus orchard, $S^2t$ –total variance, $S^2w$ – within class variance, RV – relative variance

Table 6: Effect of management systems and soil depths on selected soil properties of the study area



| Management systems | pH | Org. C (g/kg) | Total N (g/kg) | Avail. P (mg/kg) | K (cmol/kg) | Mg (cmol/kg) | Ca (cmol/kg) | Na (cmol/kg) | BD ($g/cm^3$) |
|---|---|---|---|---|---|---|---|---|---|
| Convectional citrus orchard | 6.81 | 12.39 | 3.13 | 9.75 | 0.18 | 1.46 | 2.28 | 0.80 | 1.41 |

Table 7 Semivariograms model parameters of some chemical properties of the study area



| Parameters | Depths | Conventional citrus orchard | | | | | Organic citrus orchard | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Models | Nuggets | Sill | Range | Nugget : Sill (%) | Models | Nuggets | Sill | Range | Nugget : Sill (%) |
| Organic carbon (g/kg) | 0 - 15 | Spherical | 0.0000 | 40.9330 | 0.0003 | - | Gaussian | 35.2315 | 179.4826 | 0.0009 | 19.6 |
| | 15 - 30 | Random | 17.6736 | 20.3336 | 0.0007 | 86.9 | Gaussian | 18.0687 | 27.8166 | 0.0009 | 65.0 |
| | 30 - 60 | Gaussian | 35.6434 | 15.8596 | 0.0003 | 224.7 | Gaussian | 40.7615 | 15.3526 | 0.0009 | 265.5 |
| Total nitrogen (g/kg) | 0 - 15 | Gaussian | 0.2565 | 18.4467 | 0.0005 | 1.4 | Random | 0.0102 | 0.0008 | 0.0009 | 1275.0 |
| | 15 - 30 | Gaussian | 7.5769 | 11.4571 | 0.0009 | 66.1 | Random | 4.6130 | 0.0000 | 0.0009 | - |
| | 30 - 60 | Gaussian | 1.5950 | 6.4431 | 0.0004 | 24.8 | Random | 15.8626 | 0.0000 | 0.0009 | - |
| Available Phosphorus (mg/kg) | 0 - 15 | Gaussian | 0.9646 | 0.0072 | 0.0003 | 13397.2 | Gaussian | 1.5140 | 2.2923 | 0.0009 | 66.0 |
| | 15 - 30 | Random | 0.7094 | 0.0000 | 0.0009 | - | Gaussian | 0.3152 | 1.0014 | 0.0011 | 31.5 |
| | 30 - 60 | Gaussian | 4.2094 | 19.2122 | 0.0009 | 21.9 | Random | 0.3863 | 0.0000 | 0.0015 | - |
| Potassium (cmol/kg) | 0 - 15 | Gaussian | 0.0056 | 0.0055 | 0.0009 | 101.8 | Gaussian | 0.0065 | 0.0148 | 0.0005 | 43.9 |
| | 15 - 30 | Gaussian | 0.0019 | 0.0055 | 0.0007 | 34.5 | Gaussian | 0.0030 | 0.0029 | 0.0006 | 103.4 |
| | 30 - 60 | Spherical | 0.0000 | 0.0040 | 0.0003 | - | Spherical | 0.0000 | 0.0052 | 0.0004 | - |

## DISCUSSION

The summary statistics of soil properties suggested that all the soil properties exhibited considerable variability across the study region. The soils were generally high in sand in the surface layer and subsoil levels same as observed by Ogeh and Osiomwan (2012). On the surface, the textural class for the organically and conventionally managed orchard was mainly loamy sand, that of the control was sandy loam, at the sub soil, the organic was loamy sand, the conventional was sand and the control went from sandy loam to sandy clay loam. The control had the highest clay content while that of the organically managed orchard was more than the conventionally managed. There was high variation in clay content in all areas at all depths except for of the organic at 15 - 30 cm and control at 30 - 60 cm which were moderately and least variable, respectively. The bulk density of the organically managed orchard was higher than the conventionally managed, and this is due to the higher clay content, compared with that of the conventionally managed orchard. According to Wolf and Snyder, (2003) the variation in bulk densities is the result of differences in soil texture, organic matter contents and management practices. The bulk density of the control was higher than that of the orchards.

The conventionally managed citrus orchard had mean pH values that indicated that the soils were neutral to slightly acidic with depth, this may be as a result of the application of synthetic fertilizers. Schrama *et al*., 2018 also recorded lower pH in conventional management system. The mean pH of the organically managed citrus orchard indicated that the soils were neutral at all depths. According to Si *et al*. (2016), organic manure significantly increased soil pH, this may be the reason for the higher pH value observed in the organically managed orchard. The pH was also neutral across all depths of the control. The values of CV for soil pH in all sampled areas and at all soil depths revealed their low variability (CV < 15). These values were less compared to CV values of other measured soil chemical properties this may be because pH is considered to be a stable soil parameter (Yan *et al*., 2019). Houlong *et al.* (2014) also observed lowest CV in case of soil pH as compared to other soil 1properties recorded in tobacco plantations of southern china, same as experienced by (Kilic *et al*., 2012) on their work assessment of spatial variability of soil properties in areas under different land use.

There was reduction in the amount of organic carbon in both orchards and in the control, with increasing soil depth. The organic carbon content in the organically managed orchard was higher than that observed in the conventional. This may have been due to the accumulation of organic matter over the years on the surface layer. This observation corroborates with observations made by Ogunkunle and Eghaghara (1992) and

Ogeh and Ogwurike (2006). Soil carbon levels increased under organic farming, mostly as a result of substantial additions of organic matter (Gattinger *et al*., 2012). The control had the highest organic carbon and this may be due to the land being left fallow. Organic carbon varied moderately in the control at all depths, but the variation increased with depth in the conventionally managed orchard and was higher than that of the organically managed. Total nitrogen varied greatly in the entire study area though the variation in the conventionally managed orchard was highest, this may be due to uneven application of inorganic fertilizer or leaching of the nitrogen at some points since the soil is sandy.

The available P was highly variable in all areas of the study sites and within depths, same as observed by Ogeh and Osiomwan (2012). That of the conventional management system had a wider range compared to the organic, also the variability of available P was highest in the lowest depth for the organically managed orchard but for the conventional the highest variability was on the surface. The lower available P at certain point could have been due to some loses through plant uptake or leaching of plant nutrient, the findings were similar to Karaman *et al*. (2001), who recorded that among soil properties, available P was more variable compared to others.

The potassium in the control varied moderately in the 0-15 cm depth and reduced with depth. Compared with other nutrients consider, potassium varied highly in the organically managed orchard than the conventionally managed. The potassium content was similar for both orchards, as K ranged from low to very low in both organically and conventionally managed orchard.

The relative variance showed that the control and the organically managed citrus orchard had more of the homogenous soil chemical properties at all depths when compared to the conventionally managed citrus orchard. The reason for the more homogenous soil chemical properties recorded in the control and organically managed orchard in comparison to the conventionally managed orchard may be due to litter falls which tend to cover the soil surface and the addition of organic materials applied to the soil in the organically managed orchard which helps to stabilize and reduce leaching of nutrients from the soil. This is in agreement with the findings of Schrama *et al*. (2018) who noted that reduction in organic matter in convectional farming increases spatial stability in soil properties.

From the two-way analysis of variance on some soil properties, it was observed that the management systems had significant effect on soil properties. This agrees with the findings of Hondebrink *et al*. (2016) who noted that agricultural management has important influence on different soil properties. Total nitrogen and available phosphorous were more in the conventionally managed system. Thomsen *et al.* (2018) reported that in conventional agriculture, nitrogen is typically applied in its most soluble form--urea or ammonium sulphate ranging from 30-40% available nitrogen. In comparison, organic fertilizers usually contain 1-15% total nitrogen with an even lower percentage of that nitrogen immediately available for crop growth. Available P increases with cultivation due to fertilizer application (Dick, 1982) this may be the reason why the available P content is higher in the conventionally managed citrus orchard, than the organically managed orchard and the control. Also, maintaining sufficient soil phosphorus levels for non-limiting crop growth is challenging in organic systems since off-farm inputs of P are restricted (Cooper *et al*., 2018). Bulk density, potassium, calcium and organic carbon were highest in the control and they were higher in the organically managed orchard than the conventional.

According to Li and Reynolds (1995), the nugget to sill ratio is used to determine the strength of spatial dependence. When a variable has a nugget to sill ratio of less than 25 % it is said to have a strong spatial dependence, moderate spatial dependence if the nugget to sill ratio ranges between 25% and 75%, and weak if it is greater than 75% (Cambardella *et al*., 1994). Using a similar approach, strong spatial dependence in organic carbon at 0 - 15 cm, total nitrogen at 0 - 15 and 30 - 60 cm, available P at 15 - 30 and 30 - 60 cm and potassium at 30 - 60 cm in the conventionally managed orchard and organic carbon at 0 - 15 cm, total nitrogen at 15 - 30 and 30 - 60 cm, available P at 30 - 60 cm and potassium at 30 - 60 cm in the organically managed orchard. while weak spatial dependence was observed in organic carbon at 15 - 30 and 30 - 60 cm, available P and potassium at 0 - 15 cm in the conventionally managed orchard and organic carbon at 30 - 60 cm, total nitrogen at 0 - 15 cm and potassium at 15 - 30 cm in the organically managed orchard. Soil properties with strong spatial dependence are heterogeneous, while weak spatial dependence are uniformly distributed.

## CONCLUSIONS

Citrus management systems significantly influenced the variability in soil properties. The conventionally managed citrus orchard showed more variation in nutrient elements of total nitrogen and available Phosphorus than the organically managed orchards and higher heterogeneity in most other soil properties. Organically managed citrus orchard had similarities in soil properties with the undisturbed natural forest (control) indicating that the organic citrus management system causes less spatial variability of soil properties thus may be more stable and a more sustainable citrus production system.

## REFERENCES

Akinbola, G. E., Ojo, U. A. and Adigun, M. O. (2010). Variability of properties of some pedons on basement complex of South Western Nigeria. *Proceedings of the 34th Annual Conference of the Soil Science Society of Nigeria*, Ibadan, Nigeria

Behera, S. K. and Shukla, A. K. 2015. Spatial distribution of surface soil acidity, electrical conductivity, soil organic carbon content and exchangeable potassium, calcium and magnesium in some cropped acid soils of India. *Land Degradation Develop*, 26: 71–79.

Cambardella, C. A., Moorman, T. B., Parkin, T. B., Karlen, D. L., Novak, J. M., Turco, R. F. and Konopka, A. E. 1994. Field-scale variability of soil properties in central Iowa soils. *Soil Science Society of America Journal*, 58: 1501–1511.

Cooper, J., Reed, E. Y., Hortenhuber, S., Lindenthal, T., Loes, A., Mader, P., Magid, J., Oberson, A., Kolbe, H. and Mo, K. 2018. Phosphorus availability on many organically managed farms in Europe. *Nutrient Cycling in Agroecosystem*, 110: 227–239.

Dick, W. A., 1982. Organic carbon, nitrogen, and phosphorus concentrations and pH in soil profiles as affected by tillage intensity. *Soil Science Society American Journal*, 47: 102-107.

Effiom, O., Ayuk, E. and Thomas, E. 2010. Variability in soil properties along an Udalf toposequence in the humid zone, Nigeria. *Kasetsart Journal of Natural Science*, 44: 564–573.

Etebu, E. and Nwauzoma, A. B. 2014. A review on sweet orange (Citrus Sinensis Osbeck): health, diseases, and management. *American Journal of Research Communication*, 2(2): 33–70.

FAOSTAT 2018. Statistical databases and data-sets of the Food and Agriculture

Organization of the United Nations. http://faostat.fao.org/default.aspx

Ferreira, V., Panagopoulos, T., Andrade, R., Guerrero, C. and Loures, L. 2015. Spatial variability of soil properties and soil erodibility in the Alqueva reservoir watershed. *Solid Earth,* 6:383– 392.

Gattinger, A., Muller, A., Haeni, M., Skinner, C., Fliessbach, A., Buchman, N. and Niggil, U. 2012. Enhanced top soil carbon stocks under organic farming. Proceedings of National Academic Science. U.S.A. 109(44)18226-18231.

Hondebrink, M. A., Cammeraat, L. H. and Cerdà, A.2016. The impact of agricultural management on selected soil properties in citrus orchards in Eastern Spain: A comparison between conventional and organic citrus orchards with drip and flood irrigation. *Science of the total environment,* 21608: 1-8.

Houlong, J., Hongfeng, W., Li, N., Xu, A., and Yang, C. 2014. Evaluation of spatial variability of soil propertises in a long-term experimental tobacco station in southwest china. *Journal of Agricultural Science Tech,* 4: 723–735.

Karaman, M. R., Ersahin, S. and Durak, A. 2001. Spatial variability of available phosphorus and site specific P fertilizer recommendations in a wheat field. In: Horst WJ, et al. (Eds.), Plant Nutrition-Food Security and Sustainability of Agro-ecosystems. Kluwer Academic Publishers, Netherlands, pp. 876–877.

Khan, M. J., Rashid, M., Ali, S., Khattak, I., Naveed, S. and Hanif, Z. 2014. Mapping of Variability in Major and Micro Nutrients for Site-Specific Nutrient Management, *International Journal of Plant & Soil Science,* 3(3): 303–329.

Kilic, K., Kilic, S. and Kocyigit, R. 2012. Assessment of spatial variability of soil properties in areas under different land use. *Bulgarian Journal of Agricultural Science,* 18: 722–732

Leifeld, J. 2012. How sustainable is organic farming? *Agriculture, Ecosystems and Environment* 150: 121-122.

Li, H. and Reynolds, J. F. 1995. On definition and quantification of heterogeneity. Oikos, pp. 280-284.

Maniyunda, L, M., Raji, B. A. and Gwari, M. G. 2013. Variability of Some Soil Physicochemical Properties on Lithosequence in Funtua, North – Western Nigeria. *International Journal of Science and Research,* India Online ISSN: 2319-7064.

Mulla, D. J. and McBratney, A. B. 2001. Soil spatial variability, pp. 343-374. In A.W. Warrick (ed.). Soil Physics Companion. CRC Press. USA.

Mzoughi, N. 2011. Farmer's adoption of integrated crop protection and organic farming: Do moral and social concerns matter? *Ecological Economics* 70: 1536-1545.

Ogeh, J. S. and Osiomwan, G. E. 2012. Evaluation of the Effect of Oil Palm on Some Physical and Chemical Properties of R. paleudults. *Nigerian Journal of Basic and Applied Science,* 20(1): 78-82.

Ogeh, J.S. and Ogwurike, P.C. 2006. Influence of Agricultural Land Use Types on some Soil Properties in Midwestern Nigeria. *Journal of Agronomy* 5(3): 387-390.

Ogunkunle, A.O. and Eghaghara, O.O. 1992. Influence of land use on soil properties in a Forest region of Southern Nigeria. *Soil Use and Manage,* 8: 121-125.

Ogunkunle, A. O. 2003. Spatial variability of some chemical properties in two Ultisols mapping units in Southern Nigeria. *Soil Survey and Land Evaluation,* 6: 26-32.

Rattanasuteerakul, K. and Thapa, G. B. 2012. Status and financial performance of organic vegetable farming in northeast Thailand. *Land Use Policy* 29: 456-463.

Schader, C., Lampkin, N. and Christie, M. 2013. Evaluation of cost effectiveness of organic farming support as an agrienvironmental measure at Swiss agricultural sector level. *Land Use Policy* 31: 196-208.

Schrama, M., Haanc, J.J., Kroonend, M., Verstegend, H., Van der Puttenb, W.H. 2018. Crop yield gap and stability in organic and conventional farming systems Agriculture, *Ecosystems and Environment* 256: 123–130.

Shah, Z., Shah, M. Z., Tariq, M., Bakht, I. and Rahman, H. 2012. Survey of citrus orchards for micronutrients deficiency in Swat Valley of Khyber Pakhtunkhwa Pakistan. *Pakistan Journal of Botany*, 44(2): 705–710.

Si, H. H., Ji, Y. A., Jaehong, H., Se, B. K. and Byung, B. P. 2016. The effects of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow poplar (Liriodendron tulipifera Lin.) in a nursery system, *Forest Science and Technology* 2016: 1-7.

Thomsen, E. O., Culumber, C. M., Reeve, J. R., Cardon, G., Alston, D., Black, B. L. and Ransom, C. V. 2018. Strategies for Managing Soil Fertility and Health in Organic Orchards. Extension, Utah State University.

Tugrul, K. M. (2019). Soil Management in Sustainable Agriculture. In M. Hasanuzzaman, M. C. M. T. Filho, M. Fujita, & T. A. R. Nogueira (Eds.), Sustainable Crop Production. IntechOpen. https://doi.org/10.5772/intechopen.88319

Udo, E. J., Ibia, J. O., Ogunwale, A. O. and Esu, I. 2009. *Manual of Soil, Plant and Water Analysis*. Sibon Books Ltd. Lagos.

Wolf, B. and Snyder, G. H. 2003. Sustainable soils: The place of organic matter in sustaining soils and their productivity. CRC Press. New York. 380p.

Yan, P., Peng, H., Yan, L., Zhang, S., Chen, A. and Lin, K. 2019. Spatial variability in soil pH and land use as the main influential factor in the red beds of the Nanxiong Basin, China. *Peer Journal* 7: 6342.