Organic Farming: A Practice for Conserving Arthropod Diversity and Soil Health in an Agroecosystem

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Abstract

The sustainability of any agroecosystem depends on agricultural practices, arthropod diversity and soil health. This study assessed the diversity of arthropods and some soil parameters (soil organic matter (SOM), pH and Temperature (^{o}C)) of three organic (ORGF) and conventional (CONF) farmlands at University of Nigeria, Nsukka. Each farm measured 10,000 m^2, 100 m apart was divided into four quadrants with pitfall traps (7.20 × 4.80 cm). Arthropods were collected weekly for three months and were preserved in a vial containing 70 % ethanol before identification. Soil samples were collected with auger at 10 cm depth, analyzed ex-situ for SOM and pH, in-situ for Temperature using standard protocols. A total of 172 arthropods belonging to six orders, 10 families, 19 genera and 15 species were observed with ORGF having higher number (n =113; 65.69%) than CONF (n = 59; 37.31%). *Camponotus perrisii nigeriensis* was the most dominant species (n =37; RA=21.51) while *Anochetus siphneus*, *Gymnopleurus coerulescens* and *Gyna costalis* were the least (n=1; RA=0.58). Hymenoptera were higher in ORGF (n=58) than CONF (n=9). Shannon-Wienner diversity index revealed that ORGF had more species diversity (H=2.21) than CONF (H=1.48) which varied significantly ($p \leq 0.05$). Descriptive statistics showed that SOM was higher in ORGF (1.89 ± 0.34) than CONF (1.26 ± 0.45), pH higher in ORGF (5.44 ± 0.06) than CONF (2.34± 0.28) while Temperature was higher in CONF (27.23± 0.05) than in ORFG (24.09 ± 0.25). Diptera and Hymenoptera showed negative correlation with soil parameters while the rest showed positive. Organic farming had minimal effects on arthropods and soil parameters therefore it should be encouraged.

Keywords: agroecosystem, arthropods, biodiversity, organic farming

Introduction

Agriculture is one of the largest employers of labour in Nigeria and Africa at large, an important sector that provides food for human and raw materials for manufacturing industries (Zahid et al., 2016; FAO 2020; RUFORUM, 2021). It is one of the backbones of many nations economy because it contributes 24 % to the gross domestic product (GDP) and 60 % to export earnings (Zahid et al., 2016; RUFORUM, 2021). Over decades, human population has increased geometrically and in order to meet up food production and raw materials, agricultural activities are been intensified (FAO, 2020).

Agricultural intensification also known as conventional farming is an array of components that involves intense application of herbicides, deep soil tillage and the practice of monoculture (Sutherland 2002; Laura et al. 2010). It increases crop yield but declines biodiversity and soil quality in an agroecosystem (Lavelle, 1997; Foley et al., 2005; Laura et al., 2010; Li et al., 2017), which can be reversed by organic farming that is eco-friendly and total avoidance of agrochemical, hence, conserves arthropods population

(Carlos et al., 2011; Sean et al., 2014).
Arthropods are the most abundant invertebrate fauna in agroecosystem, constitutes about 85 % of soil invertebrates (Suzana et al., 2018; Danjuma and Ibrahim, 2019; Ekpo et al., 2023). They are characterized with rapid adaptive features such as, high fecundity rate and short life cycle which enables them to conquer their habitats (Khaliq et al., 2014). They occupy every possible environment, even the soil. Spiders (Araneae: Salticidae), grasshoppers (Orthoptera: Acrididae), and bees (Hymenoptera: Apidae) lives on the soil upper surface layer. Ants (Hymenoptera: Formicidae) and dung beetles (Coleoptera: Scarabaeidae) lives in the mid-layer of the soil while mole cricket (Orthoptera: Gryllotalpidae) and millipedes (Polydesmida: Eurymerodesmidae) lives underground of the soil (Ekpo et al., 2023). Arthropods are useful bio-indicators in the management of agroecosystems and biocontrol agents that feed on pest that attack agricultural crops (Rieske and Buss, 2001; Rainio and Niemela 2003; Rochfort et al., 2008; Work et al., 2008; Rodrigues et al., 2013; Socarras, 2013; Ng et al., 2017; Reinaldo et al., 2017). They provide ecological services such as, decomposition of organic matter, recycling of nutrients, compartment and maintenance of soil structure and fertility, enhancement of soil porosity and infiltration which reduces soil erosion (Weisser and Siemann, 2004; Suheriyanto et al., 2018).
Soil is the foundation of food security, climate change mitigator, habitat for soil dwelling organisms, holdfast for phyto-organisms, medium through which energy flows across the trophic and ecosystem services provider (FAO, 2017; Peter et al., 2019). It is a component of the earth consisting of mineral particles and organic compounds, provides the basics for human livelihood and well-being such as food and water (Menta and Remeli, 2020; Ekpo et al., 2023). It plays a great role in agricultural production, and varies in space and time due to variations in topography, climate, physical weathering processes, vegetation cover, microbial activities and several other biotic and abiotic variables (FAO, 2017).
Despite the global campaign on the negative impact of conventional farming on agroecosystems, most agrarian communities in Nigeria continually adopt conventional farming and that could be attributed to the short-term benefits to farmers, low level of education of farmers, paucity of research and strong advocacy, public enlightenment and lack of government will in implementing agri-environmental laws on the subject matter. Therefore, this study assessed the diversity of soil arthropods due to organic farming and their relationships between soil pH, temperature and SOM in organic and conventional farmlands at University of Nigeria, Nsukka.

Materials and Methods

Study Area

A total of six study sites situated in University of Nigeria Nsukka on Latitude 6°51’30”N and 6°52’30”N, Longitude 7°23’45”E and 7°24’45”E and 92 m above sea level was used for this study. Three organic farmlands ORGF (non-application of agrochemicals, application of poultry wastes, little tillage of soil, presence of trees mostly *Magnifera indica* L. (Mango tree) and mixtures of shrubs at the margin of the farmlands) and three conventional farmlands CONF (application of herbicides especially glyphosate-based herbicides, deep tillage of soil, the use of synthetic fertilizers and absence of trees and shrubs). To minimize the effects from variation in environmental factors, farmlands were selected within the same geographical location, ORGF were separated from the CONF by a motorable tared road about 100 m distance apart. Farmland locations were identified using Geographical position system (GPS). Each farm was 100 m apart, soil on both farms was loamy in texture which supports maize (*Zea may* L.) production as the most common crop during the study.

Arthropod sampling and identification

Each farmland was divided into four equal quadrants with four modified pitfall traps

(7.20 × 4.80 cm) at the centre on each quadrant set at equal level to the surface of the ground (Agwunobi and Agwumba, 2013). Each trap had 110 mL of water and two pinches of detergents to immobilize trapped arthropods that were collected with forceps into well labeled vials containing 70 % ethanol. Collected arthropods were taken to Entomology Museum, Department of Crop Protection, Ahmadu Bello University, Zaria, Kaduna State, Nigeria for identification to species level through cross matching with reference collection.

Soil sampling and determination of parameters
Soil samples were collected monthly for three months with auger both at the furrow and top of ridges, 10 cm deep, between the hours of 8.00-10.00 am on every last week of the month. Soil was collected from every quadrant into a clean and well labeled polythene bag. Wet samples were air dried under room temperature (20-22°C) at Soil Science laboratory, Department of Soil Sciences, Ahmadu Bello University, Zaria, Kaduna State, Nigeria. A composite mixture of all the samples were obtained according to farm type. Soil temperature and pH were determined using the method of Saleh et al. (2020), while SOM was done by Walkley-Black wet oxidation method.

Statistical analysis
Data were analyzed in excel statistical package (Version, 2016). The total number of arthropods sampled based on farm type and species was calculated by simple summation. Relative abundance of species, families and order was calculated adopting the formula of Braimah and Popoola (2018) as shown in Equation [1]. Species diversity was calculated using Shannon Wiener Diversity Index (H) as shown in Equation [2]. One-way analysis of variance (ANOVA) was used to test the significant difference across order and family abundance of arthropods while student t-test was used to test the significant difference of species diversity based on farm type. Descriptive statistics was used to calculate the mean values of soil parameters while Pearson correlation was used to determine the relationship between arthropod order and soil parameters. All statistical analysis was done at 5 % ($p \leq 0.05$) confidence level.

$$\text{Relative Abundance} = \frac{\text{Number of arthropods of a paticular species}}{\text{Total number arthropods sampled}} \times 100 \qquad \text{Equation [1]}$$

$$\text{Shannon} - \text{Weiner index (H)} = -\sum_{i=1}^{s} Pi \ln Pi \qquad \text{Equation [2]}$$

H= Shannon Wiener diversity index
P = the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N).
ln = natural log
Σ = sum of the calculations
s = number of species

Results

A total of 172 arthropods belonging to Six orders, 10 family, 19 genera and 15 species were sampled throughout the study; 113 (65.69%) arthropods belonging to Six orders, 10 families, 12 genera and 15 species were trapped from organic farmlands (ORGF) while 59 (37.31%) individual belonging to Four orders, Six families, Eight genera and 11 species were trapped from conventional farmlands (CONF) (Table 1). *Camponotus perrisii nigeriensis* had the highest relative abundance (RA=21.50), followed by *Chrysomyia chloropyga* (RA=19.76), *Pheidole megacephala* (RA=15.69), *Sarcophaga*

TABLE 1
Total number of arthropods sampled throughout the study

Farm type	Total number trapped	Order	Families	Genera	Species
ORGF	113	6	10	12	15
CONF	59	4	6	8	11
Total	172	6	10	19	15

*ORGF = Organic farmlands; CONF = Conventional farmlands

TABLE 2
Checklist and relative abundance of arthropods species observed throughout the study

Species	Total number	Relative Abundance
Anochetus siphneus (Brown, 1978)	1	0.58
Blattella germanica (Linnaeus, 1767)	8	4.65
Camponotus maculatus (Fabricius, 1782)	3	1.74
Camponotus perrisii nigeriensis (Santschi, 1914)	37	21.51
Chrysomyia chloropyga (Wiedermann, 1818)	34	19.76
Gryllus bimaculatus (De Geer, 1773)	2	1.16
Gymnogryllus lucens (Walker, 1869)	2	1.16
Gymnopleurus coerulescens (Olivier, 1789)	1	0.58
Gymnopleurus fulgidus (Olivier, 1789)	11	6.39
Gyna costalis (Walker, 1868)	1	0.58
Isomyia evanida (Villeneuve, 1913)	2	1.16
Digitonthophagus gazella (Fabricius, 1787)	8	4.65
Onthophagus obliquus (Olivier, 1789)	11	6.39
Pheidole megacephala (Fabricius, 1793)	27	15.69
Sarcophaga exuberance (Pandelle, 1896)	24	13.95
TOTAL	**172**	

exuberance (RA=13.95), *Gymnopleurus fulgidus* (RA=6.39), *Onthophagus obliquus* (RA= 6.39) while *Anochetus siphneus*, *Isomyia evanida* and *Gyna costalis* had the least (RA = 0.58) relative abundance (Table 2).The abundance of arthropods across family and farm type was significantly different ($p < 0.05$) with Formicidae (n=58) and Scarabaiedae (n=22) higher in ORGF than CONF (n=9) and (n=18), Calliphoridae higher in CONF (n=27) than ORGF (n=8) while Blattodea (n=10), Syrphidae (n=1) and Braconidae (n=1) were only observed in ORGF (Figure 1). Similar observation was recorded across order with Hymenoptera (n=58) and Coleoptera (n=22) higher in ORGF than CONF (n=9) and (n=5), Diptera (n=48) and Orthoptera (n=9) higher in CONF than ORGF (n=8) and (n=1), while Dictyoptera (n=8) and Julida (n=1) were only observed in ORGF (Figure 2). Shannon Wiener diversity index (H) revealed that ORGF had higher species diversity (H=2.21) than CONF (H=1.48) which varied significantly (t-test, t=1.69, df = 33, $p \leq 0.05$) (Figure 3).

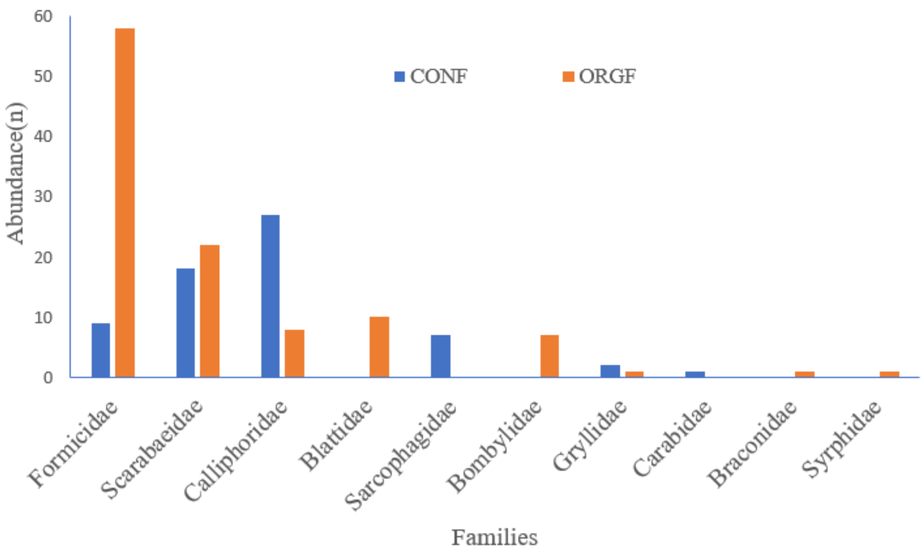

Fig. 1 Arthropod abundance based on Family and farm type: Organic farmlands (ORGF), Conventional farmlands (CONF)

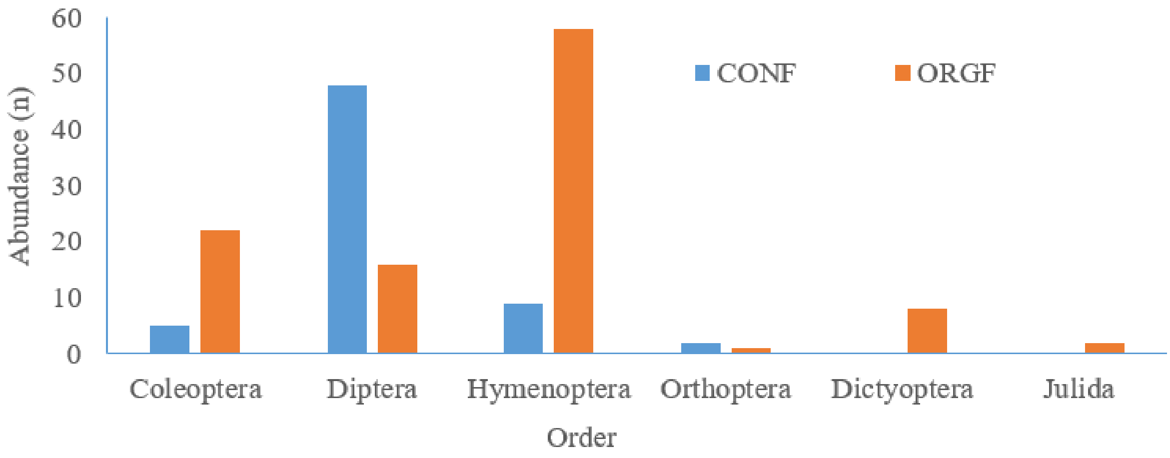

Fig. 2 Arthropod abundance based on Order and farm type: Organic farmlands (ORGF), Conventional farmlands (CONF)

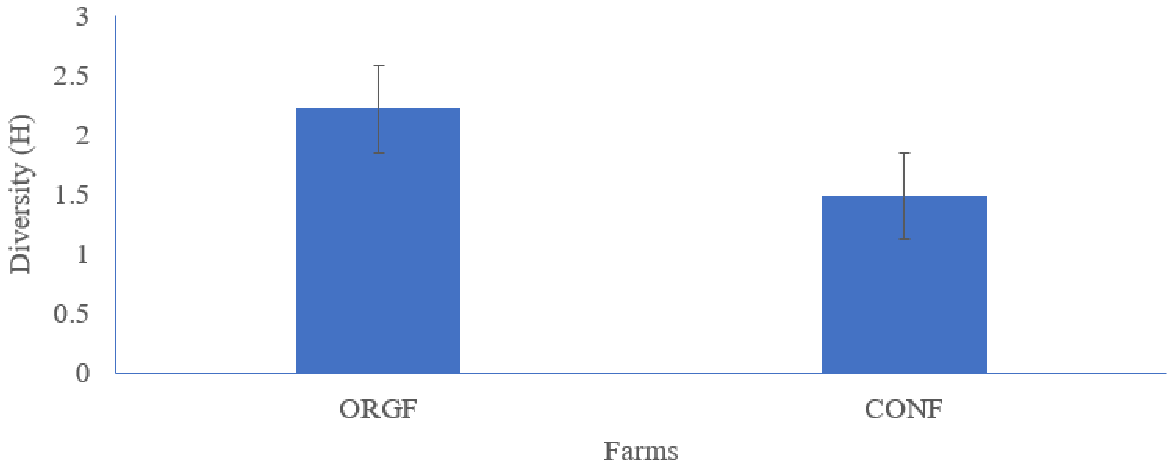

Fig. 3 Arthropod Diversity (H) per farm type: Organic farmlands (ORGF), Conventional farmlands (CONF)

Descriptive statistics showed that Soil organic matter (SOM) was higher in ORGF (1.89 ± 0.34) than CONF (1.26 ± 0.45), Temperature was higher in CONF (27.00 ± 0.05°C) than in ORGF (24.00±0.25°C) while pH was lower in CONF (2.44± 0.28) than ORGF (5.34± 0.06) (Table 3). This variation could be attributed to the farming practices observed between the farm types. Pearson correlation showed that Diptera and Hymenoptera had a negative correlation with SOM, Temperature and pH while Coleoptera, Dictyoptera, Orthoptera

TABLE 3

Mean (±SE) values of soil parameters from the study area

Farm Type	Temperature (°C)	SOM	pH
CONF	27.23 ± 0.05	1.26±0.45	2.34 ± 0.28
ORGF	24.09± 0.25	1.89±0.34	5.44 ± 0.06

*ORGF = Organic farmlands; CONF = Conventional farmlands

TABLE 4
Correlation matrix showing relationship among arthropod order and soil parameters

	SOM	pH	Temp	Dp	Co	Di	Hy	Cr	Ju
SOM	1								
pH	0.80	1							
Temp	0.89	0.85	1						
Dp	-0.59	-0.62	-0.66	1					
Co	0.32	0.68	0.50	-0.39	1				
Di	0.37	0.44	0.49	-0.37	0.20	1			
Hy	-0.14	-0.45	-0.35	-0.29	0.39	-0.44	1		
Or	0.32	0.47	0.29	0.27	0.08	0.57	-0.32	1	
Ju	0.37	0.46	0.19	-0.19	0.16	0.57	-0.22	0.68	1

*SOM = Soil Organic Matter; pH= Hydrogen Ion Concentration; Temp = Temperature; Dp = Diptera; Co = Coleoptera; Di = Dictyoptera; Hy = Hymenoptera; Or = Orthoptera, Ju= Julida

and Julida showed a positive correlation with these parameters (Table 4).

Discussion

The sustainability of any agroecosystem greatly depends on arthropods species abundance, distribution and variability (Ekpo et al., 2023), because of their ecological roles and services they play and provide in agroecosystem (Bagchi et al., 2014; Rana et al., 2019; Torma et al., 2019; Ekpo et al., 2023). This study was designed to compare the population of arthropods and soil parameters between organic and conventional farmlands in University of Nigeria Nsukka. A great number of arthropods observed in this study was collected from organic farmlands (ORGF) which is attributed to the sustainable system of farming practiced and the presence of hedgerows (trees and shrubs) at the margin of the farmlands. Hedgerows serves as habitats, sources of food and shelter for arthropods (Sutherland, 2002; Goncalves and Pereira, 2014).

The high abundance of arthropods observed in ORGF in this study, coincides with the findings of Stephen and Paul (2003) in their work carried out in Co. Cork and Co. Tippery in Southern Ireland where they reported that the abundance, biomass, richness and diversity of dung beetles was higher in organic farms than intensive and rough grazing farms. Fahri et al. (2016) observed similar occurrence in their work and reported that the diversity of longhorn beetles is greatly affected by application of glyphosate-based herbicides that was used to control ground shrubs. Jardel et al. (2018) in their work carried out at UFV Field Experimental Station, Coimbra County, State of Minas Gerais, Brazil reported that more leaf beetle (*Cerotoma arcuate*) was found in control field (organic farm) than treated field (conventional farm). Okrikata et al. (2020) in their work carried out at Federal University Wukari, Taraba state, Nigeria reported that more leaf-feeding beetles *Aulacophora Africana*, *Asbecesta nigripennis* and *Asbecesta transversa* were significantly abundant on unsprayed farms than sprayed farms. Tari et al. (2021) in a review concluded that, the application of herbicides reduces the population of beetles by 28.30 %.

The presence of trees and shrubs at the margin of ORGF greatly contributed to the high abundance of *Camponotus perrisii nigeriensis* (Compact carpenter ant), Formicidae and Hymenoptera observed in this study. Ants serve as a link between the aboreal and terrestrial habitat (Esenowo et al., 2014), therefore, the presence of trees and shrubs which are their preferred habitats may have contributed greatly to their high population. This finding agrees with the observation of Santos et al. (2007) who recorded high abundance of Formicidae in Olive grove ecosystem in Portugal. Esenowo et al. (2014) reported that more numbers of Formicidae are observed in areas with trees than areas without. Adrian (1990) stated that the spatial distribution of arthropods is strongly influenced at a local level by habitat, including vegetation type. Pérez and Romero (2012) reported that high numbers of soil arthropods were captured from field margins in abandoned vineyard compared to intense cultivated farmland. Khaliq et al. (2014) reported that arthropods abundance and diversity were higher on farmlands with extensive vegetation than farmlands with intensive vegetation which is mostly caused by agricultural intensification.

The order Coleoptera was the second abundant order in ORGF in this study, with the largest number of individual dominated by Scarabidae. This could be attributted to the poultry waste that was applied on ORGF and presence of litter. Most species of Coleoptera are decomposers that feed on dung. Viric et al. (2017) reported that the high distribution, abundance and species richness of beetles in an ecosystem is linked to the leaf litter covering the soil and shrubs present in that habitat.

The high amount of soil organic matter observed in ORGF could also be attributed to the application of poultry waste. The decomposition of the poultry waste increases SOM. The variation in soil pH reported in this study could be attributed to the application of herbicides (Ayoola et al., 2023). Both soil samples were acidic but the CONF samples were more highly acidic than those of the ORGF. The high temperatures observed in CONF compared to ORGF in this study could be attributed to the absences of hedgerows thereby exposing the soil to direct heat from the sun. This further explained the low species abundance and diversity of arthropods observed in CONF. This observation coincides with the reports of Popoola and Amusat (2015); and Ekpo et al. (2023) that when temperature is exceedingly high, there is a drop in arthropod abundance, richness and diversity. Mcglynn et al. (2019) supported this observation in their report by concluding that the population of arthropods are reduced in hot climatic condition and that moderate temperature is crucial for better growth and reproduction of soil arthropod species. The positive correlation of SOM with Coleoptera, Dictyoptera, Orthoptera and Julida could be attributed to their mode of feeding because most members of the Coleoptera are decomposers. Zhanguo et al. (2018) reports that the presence of SOM increases the population of ground-dwelling arthropods.

Conclusion

It is evident from this study that organic farming has minimal effects on soil arthropods and quality compared to conventional farming. Though conventional farming increases agricultural outputs marginally in a short term, it threatens biodiversity and ecological services. Organic farming remedies the poor effects of conventional farming and sustains agroecosystem for a long duration.

Authors Contribution

This work was carried out in collaboration among all authors.

Declaration of Competing Interest

Authors have declared that no competing interest exist.

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