

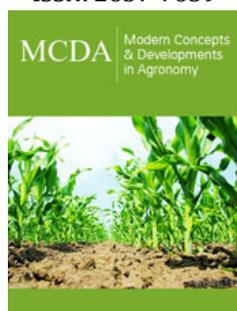
# Organic Farming: An Agricultural Waste Management System for Enhancing Soil Properties and Crop Yield

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## Abstract

Sustainable agricultural production systems are crucial for meeting the food demand of the ever-increasing human population. However, these systems generate large amount of wastes which is a major environmental challenge when not properly managed. The difficulty and cost-related constraints associated with achieving sustainable food production through effective soil and crop management practices has led to a paradigm shift from inorganic farming to organic farming, where agricultural wastes are incorporated into the production systems. Organic farming applies natural principles for improved quality and quantity of crop produce while maintaining and/or improving soil health. This paper explores some ways in which agricultural wastes are used and their impacts on soil properties and crop yield in organic farming systems.

**Keywords:** Organic wastes; Environmental quality; Soil physical properties; Soil organic carbon; Crop yield

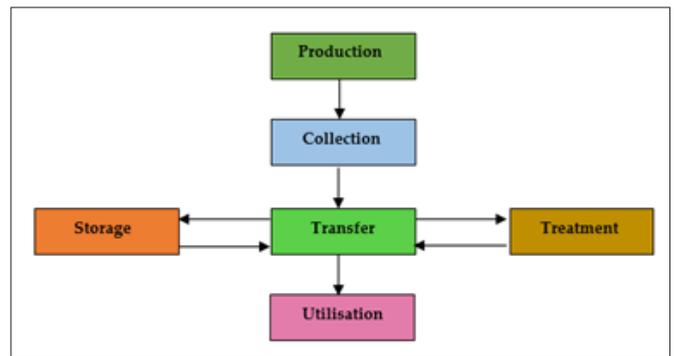
## Introduction

Agriculture is very pivotal to human growth and development. This is due to the production of food and fiber which are needed by humans all over the world. However, agriculture is also associated with the production of large amount of wastes such as crop residues, animal manure, etc. [1]. These wastes are usually difficult to dispose and often reduces environmental aesthetics and quality as they are usually disposed on open fields or burnt in most parts of the world. Those left on the field encounter wetting and dry processes which may sometimes cause anaerobic conditions that lead to bad smell, attraction of flies and insects, and spread of epidemic diseases, while those burnt are usually associated with air pollution and release of obnoxious and greenhouse gases [2]. Aiyelari EA [3] explained that burning of agricultural wastes could be detrimental to human health and the environment owing to the release of greenhouse gases to the atmosphere which could also lead to global warming effects. Some consequences of this phenomenon may result into chaotic weather changes, food insecurity, starvation and malnutrition [4]. In recent years, agricultural production has advanced beyond the focus on great yield production to improved food quality, human nutrition and environmental quality via practices that improve environmental health, sound ecology, while enhancing food security. Rodale [5] advised that instead of focusing on greater yields in production agriculture, which will eventually exhaust soil nutrients, the goal should be an agricultural management system that has the capability to preserve or improve soil quality and the environment. Lokeshwari M [2] noted that most agricultural wastes contain biodegradable hemicellulose and cellulose materials, which on decomposition improve soil properties and supply nutrients to crops. Hence, they can be better managed by reusing and/or recycling them. They may be used as a source of energy, bedding, manure, mulch, compost, organic matter, or plant nutrients which are environmentally friendly practices, or they can be marketable when properly treated [3, 6]. A common practice is to recycle the nutrients in the waste through land application which is an alternative means of supplying nutrients to crops and maintaining soil fertility [6,7]. Hence, their use as a source of plant nutrients for growing vegetable crops could assume increasing importance as they are comparable to chemical fertilizers in crop yield improvement [3,8]. In general, all of these practices have been effectively coordinated under the umbrella of organic farming and have been reported as effective means of managing agricultural wastes for improvement of agricultural land while maintaining environmental quality.

### Organic Farming

This system makes the best use of crop residues, animal manure, green manure and off-farm organic waste in order to maintain soil productivity, supply plants with necessary nutrients, and control insects, weeds and other pests [9]. It is an agricultural waste management system in which all necessary components are installed and managed to control and use by-products of agricultural production in a manner that sustains or enhances the quality of air, water, soil, plant, animal and energy resources [6]. Organic farming, as a waste management system, consists of six basic functions as shown in Figure 1. Production is a function of the amount and nature of agricultural waste generated by an agricultural enterprise [6]. It varies with type, volume, time etc. The collection of these wastes involves capturing and gathering from point of deposition. The major problem with this as it affects environmental quality is that this aspect is given little or no consideration in most developing countries, including Nigeria. An agricultural waste management system should identify methods of collection, location of collection etc. [6]. Also, the transfer which involves the movement and transportation of waste from the collection point to storage, treatment and utilization site is very crucial. The mode and equipment for transfer will depend on

the nature (liquid, semi-solid or solid) of the waste. This will also influence the type of storage facility and the processes required for treatment in order to reduce the pollution potential and/or modify the physical characteristics of the waste prior to utilization. Utilization of agricultural wastes has been reported to improve sanitary conditions, soil quality and crop yield [10]. Some of the soil properties and crop yield shown to be enhanced by use of some agricultural wastes under organic farming, and the forms in which these wastes were used are discussed as follows:



**Figure 1:** Agricultural waste management functions {Adapted from [6]}.

### Effects of organic farming on soil properties

**Table 1:** Response of soil physical properties to organic and other forms of farming.

| Parameter                   | Unit                | Farming System                      |                       | % Difference | Source |
|-----------------------------|---------------------|-------------------------------------|-----------------------|--------------|--------|
|                             |                     | Organic (Type)                      | Others                |              |        |
| Bulk density                | Mg m <sup>-3</sup>  | 1.15 (FYM and compost)              | 1.25 (NPK fertilizer) | 8.7          | [11]   |
| Bulk density                | Mg m <sup>-3</sup>  | 1.28 (Vermicompost)                 | 1.32 (Unamended soil) | 3.1          | [12]   |
| Water holding capacity      | %                   | 51.6 (FYM and compost)              | 46.4 (NPK fertilizer) | 5.2          | [11]   |
| Volumetric moisture content | %                   | 0.68 (Compost and K <sub>2</sub> O) | 0.67 (NPK fertilizer) | 1.5          | [13]   |
| Mean weight diameter        | mm                  | 0.95 (Not stated)                   | 0.73 (Not stated)     | 30.1         | [14]   |
| Total porosity              | %                   | 44.8 (1YACP)                        | 47.7 (2YACP)          | 6.5          | [15]   |
| Hydraulic conductivity      | cm hr <sup>-1</sup> | 59.2 (1YACP)                        | 56.7 (2YACP)          | 4.4          | [15]   |

Values are mean across applications rates, soil depths or aggregate sizes; 1YACP: first year after compost application; 2YACP: second year after compost application.

Management of agricultural wastes via organic farming has been shown to improve several soil properties. This is due to alterations in soil physical properties, especially soil structural characteristics, which regulate soil functions and processes. Table 1 presents some results of responses of soil physical properties to organic farming. Papadopoulos A [11] reported that organic management significantly affects pore structure and enhances biological activities with positive effects on the environment. Comparing the impact of organic farming and conventional systems of coffee farming on soil properties, Velmourougane K [12] reported 8.4% increase in water holding capacity (WHC) under organic farming system of organic manure (5 tonnes farmyard manure and compost) relative to conventional method of N:P:K 40:30:40 (N:P205:K2O kg ha<sup>-1</sup> per

year). Earlier study by [13] reported improved soil WHC following application of residues and farmyard manure, while the application of vermicompost at 1t ha<sup>-1</sup> combined with farmyard manure and its sole application at 2.5t ha<sup>-1</sup> and 5t ha<sup>-1</sup> increased WHC and soil moisture content [14,15].

This could be as a result of the affinity for water by organic matter which enhances the soil capacity to retain water for crop use, hence reducing the incidence of water loss through deep percolation and runoff. Krol A [16], in a 14-year study on organic farming and conventional farming systems, reported higher water infiltration following compost application than conventional farming of mineral fertilizer. They observed that the repellency index was mostly

higher under the conventional farming system. Water repellent soil resists water infiltration and leads to surface runoff and infiltration [17]. Krol A [16] also observed that soil aggregate crushing strength was higher under the organic farming system than the conventional farming system. Nestic Lj [18] demonstrated that organic farming enhanced soil aggregate stability by recording higher mean weight diameter than conventional farming system. With respect to soil bulk density ( $\rho_b$ ), the combination of composted coir pith and

farmyard manure has also been reported to reduce  $\rho_b$  relative to unamended soil [19]. Soil bulk density was also lower under organic farming than conventional farming by  $0.1\text{Mg m}^{-3}$  [12]. The combined effect of the internal aggregate strength and wettability can result to increased soil stability and water infiltration [20]. This could increase soil resistance to compaction and carbon sequestration.

**Table 2:** Soil chemical properties as influenced by organic and inorganic farming systems.

| Parameter                           | Unit                | Farming System                          |                        | % Difference | Source |
|-------------------------------------|---------------------|---|------------------------|--------------|--------|
|                                     |                     | Organic (Type)                          | Others                 |              |        |
| pH                                  | -                   | 4.5 (FYM and compost)                   | 6.1 (NPK fertilizer)   | 35.6         | [11]   |
| pH                                  | -                   | 6.4 (Compost and $\text{K}_2\text{O}$ ) | 5.6 (NPK fertilizer)   | 14.3         | [13]   |
| Organic carbon                      | %                   | 0.9 (Compost and $\text{K}_2\text{O}$ ) | 0.8 (NPK fertilizer)   | 11.1         | [13]   |
| Aggregate associated organic matter | %                   | 3.7 (Not stated)                        | 2.7 (Not stated)       | 37           | [14]   |
| Avail. N                            | $\text{kg ha}^{-1}$ | 346.0 (FYM and compost)                 | 307.5 (NPK fertilizer) | 12.5         | [11]   |
| Avail. P                            | $\text{mg kg}^{-1}$ | 23.5 (Green manure)                     | 21.2 (NPK fertilizer)  | 10.8         | [23]   |
| Avail. K                            | $\text{kg ha}^{-1}$ | 363.5 (FYM and compost)                 | 344.5 (NPK fertilizer) | 5.5          | [11]   |
| Electrical conductivity             | $\text{dS m}^{-1}$  | 0.91 (Green manure)                     | 1.22 (NPK fertilizer)  | 34.1         | [23]   |

Values are means across applications rates, soil depths or aggregate sizes.

**Table 3:** Influence of organic and inorganic farming systems on soil biological properties.

| Parameter                      | Unit   | Farming System         |                       | % Difference | Source |
|--------------------------------|--|------------------------|-----------------------|--------------|--------|
|                                |  | Organic (Type)         | Others                |              |        |
| Fungal count                   | $\times 105\text{cfu g}^{-1}$                          | 0.39 (Compost)         | 0.31 (Unamended soil) | 25.8         | [15]   |
| No. of micro-arthropod         | $\times 102\text{m}^{-2}$                              | 8.8 (Compost)          | 8.7 (Unamended soil)  | 1.1          | [15]   |
| Soil respiration               | $\text{CO}_2\text{mg}/50\text{g}$                      | 23.9 (FYM and compost) | 20.9 (NPK fertilizer) | 14.4         | [11]   |
| Urease                         | $\mu\text{g NH}_4\text{-N}/\text{g}^{-1}\text{h}^{-1}$ | 32.3 (FYM and compost) | 43.6 (NPK fertilizer) | 35           | [11]   |
| Fluorescein diacetate activity | $\mu\text{g}/\text{g}^{-1}$                            | 39.0 (FYM and compost) | 28.2 (NPK fertilizer) | 38.3         | [11]   |

Values are mean across applications rates, soil depths or aggregate sizes.

The decomposition and mineralization of organic wastes usually result to alterations in the chemical constituents of soils. Several studies have demonstrated the effectiveness in the use of organic wastes as amendments in improving soil chemical properties (Table 2). This is largely affected by the type and amount of organic waste used. For instance, Gosling P [21] reported that there was no significant difference between an organically managed farm and conventional managed farm in organic matter content. In another study, however, Velmourougane K [12] reported significant increase in organic carbon under organic system of farm management. Based on a 50-year study, Blanchet G [22] demonstrated that incorporation of crop residues and farmyard manure increased soil organic carbon content by 2.45% and 6.40% compared to mineral fertilizer, respectively. The application of organic amendments such as crop residues and/or farmyard manure significantly increased soil organic carbon [23,24]. In major nutrients including nitrogen, phosphorus and potassium, Velmourougane K [12] reported an increase in nutrient levels under organic farming and conventional

farming. They however noted a more pronounced inclination and availability under the conventional system. This could be due to the slow rate of decomposition of organic amendments. Bhogal A [25] explained that the variation in organic farming effects on soil chemical properties may be due to the rate and amount of organic matter added to the soil. The use of organic manure has been reported to give lower electrical conductivity (EC) when compared to the use of mineral fertilizer [12]. Though lower soil pH was reported for organic farming compared to conventional farming [12], the reverse was the order in Krol A [16]. This suggests that the effect of organic amendments on soil chemical properties depends on the type and amount. In terms of soil biological attributes (Table 3), [12] demonstrated that soil respiration and fluorescein diacetate activity were higher in organic managed farm relative to conventional farm. They also noted that organic system had higher macrofauna (31.4%), microbial population (34%), and microbial diversity indices compared to the conventional system of mineral fertilizer application. Although soil urease activity was

higher under conventional farming system and the dehydrogenase activity showed no significant difference between the two systems, Velmourougane K [12] concluded that soil cultivated with coffee under long-term organic system has better soil properties than conventional farming system.

### Effects of organic farming on crop productivity

The modification of soil properties by organic amendments in organic farming system often results to improved soil productivity and crop yield. Poultry manure and *Terminalia catappa* leaves compost was evaluated for its effect on okra (*Abelmoschus*

*esculentus*) by Aiyelari EA [3] as shown in Table 4. They observed that the application of these organic wastes either as compost or mulch significantly improved okra pod yield. For example, 5t ha<sup>-1</sup> and 10t ha<sup>-1</sup> compost of poultry manure and *Terminalia catappa* leaves gave 72.7% and 87.4% increase in the number of okra pods produced, while the use of *Terminalia catappa* leaves as mulch at 10t ha<sup>-1</sup> resulted to 1.0% increase. Corresponding values for fresh pod weight (g plant<sup>-1</sup>) were 204.4% and 267.0% increase under 5t ha<sup>-1</sup> and 10t ha<sup>-1</sup> compost, while mulching at 5t ha<sup>-1</sup> and 10t ha<sup>-1</sup> gave 48.4% and 52.7% increase compared to unamended soil.

**Table 4:** Response of yield attributes of selected crops under organic farming system.

| Crop   | Yield Attribute    | Unit                  | Farming System  |                        | % Difference | Source |
|--------|--------------------|-----------------------|-----------------|------------------------|--------------|--------|
|        |                    |                       | Organic (Type)  | Others                 |              |        |
| Okra   | No. of fruits      | -                     | 19.0 (Compost)  | 10.6 (Unamended soil)  | 79.2         | [3]    |
| Okra   | Fresh fruit weight | g plant <sup>-1</sup> | 678.9 (Compost) | 537.8 (NPK fertilizer) | 26.2         | [3]    |
| Rice   | Grain yield        | t ha <sup>-1</sup>    | 3.50 (Mulch)    | 1.77 (Unamended soil)  | 97.7         | [29]   |
| Rice   | Straw yield        | t ha <sup>-1</sup>    | 4.83 (Manure)   | 3.17 (Unamended soil)  | 52.4         | [29]   |
| Pepper | Fresh fruit weight | g pot <sup>-1</sup>   | 56.2 (Compost)  | 55.1 (NPK fertilizer)  | 2            | [30]   |
| Pepper | Shoot dry matter   | g pot <sup>-1</sup>   | 2.8 (Compost)   | 2.6 (NPK fertilizer)   | 7.7          | [30]   |

Values are mean across applications rates, soil depths or aggregate sizes.

However, some authors have demonstrated that the use of organic wastes as mulch offer little or no significant effect on crop yield. For instance, Gruber S [26] reported that mulching with wood chips had no effect on crop yield. Johnson JM [27] also reported that potato yields were similar in mulched and unmulched plots, but watermelon yield was higher in plots with straw mulch. Doring TF [28] reported no positive effect of straw mulch on potato yield due to the relatively low amounts of straw applied. Though Dauda BM [29] reported similar length of pepper fruit under grass mulch and unamended soil, they observed higher pepper yield in mulched plots than unmulched soil. Nasir M [30] reported that the average cucumber and bitter melon yield was higher under mulch conditions compared to the control. The application of *Gliricidia* lopping's as mulch was reported to significantly enhance the dry fruit yield of chilli as compared to no mulch treatment [31]. Cocoa husk mulch increased tomato fruits weight per plant compared to the control [32]. In comparison to mineral fertilizers, compost at 5 and 10t ha<sup>-1</sup> gave higher okra fresh pod weight than NPK fertilizer by 12.6 and 27.5%, respectively [3]. In another study on swine manure composted with almond leaves, Ogunsesin A [33] reported that swine manure and almond leaves compost gave higher number of pepper fruits (16.8) than NPK 15-1-5 fertilizer (15.5). They also noted that the organic amendment enhanced the nutritive components of pepper [34-37]. Thus, the impact of organic amendment applied as mulch could depend on the amount, nature and crop response under the prevailing environmental conditions.

### Conclusion

Agriculture is associated with the production of large amount of organic wastes that can adversely affect environmental quality and human health if not properly managed. These wastes are biodegradable and rich in nutrient elements that are essential for enhancing soil fertility and crop growth. Therefore, management functions involving the collection, transfer, storage, treatment and utilization of agricultural wastes in organic farming could enable farmers harness the bio-fertilizer potentials in these wastes for agricultural crop production. Their utilization as compost, green manure and farmyard manure improves soil water holding capacity, saturated hydraulic conductivity, organic matter and total nitrogen content, microbial population and crop yield relative to conventional use of chemical fertilizers which are expensive. Thus, the alteration of agricultural wastes and their use as soil amendments would make them easy to handle and environmentally friendly, hence making organic farming an environmentally sound production system for improving soil properties and crop yield. However, the role of organic farming in managing soil erosion is yet to be fully explored.

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