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Review Article

Effects of Organic Amendments on Soil Fertility and Environmental Quality: A Review

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Abstract: The main objective of this paper is to review the main effects of organic amendments on soil fertility and environmental quality. The review showed that both organic amendment types could improve the physical, chemical and biological characteristics of soil and environmental quality in a dose dependent manner and frequency of application. Application of organic amendments lower soil bulk density values by more than 5% versus sole urea fertilized soil and for each 1% increase inorganic matter, soil water holding capacity increased by up to 3.7%. Organic amendments play a positive role in chemical characteristics of the soil including increase in organic carbon (up to 58% with 120 t ha^{-1} versus unfertilized soil) and organic nitrogen up to 90% depending on the type and the level applied. Repeated application of organic amendments to cropland led to an improvement of microbial biomass by up to 100% and increased enzymatic activity by 30%. Organic amendments also play a positive role in climate change mitigation by soil carbon sequestration although the size of which is dependent on their type, rates and frequency of application. However, organic amendments have more of long-term return rather than short-term positive effect and there is competition of organic materials for the purpose of fodder or fuel. As a result, additional measures such as physical and biological soil conservation measures should get due attention and it is better to use the combination of organic and inorganic fertilizers in order to sustain soil fertility and environmental quality.

Keywords: Organic Amendments, Soil Fertility, Environmental Quality, Compost, Farmyard Manure

1. Introduction

As population pressure increases and fallow cycles shortened, rapid depletion of nutrients in smallholder farms is one of the major problems affecting food production in Africa including Ethiopia [1]. Soil nutrient replenishment is therefore a prerequisite for halting soil fertility decline. Organic sources of plant nutrients as organic amendment could remain the principal sources for the maintenance of soil fertility and environmental quality, and this may also accomplished through the application of mineral and organic fertilizers [2, 3].

Organic materials derived from plants and animals might possess many characteristics that can improve soil fertility, quality of the environment and enhance crop performance. These materials can be particularly useful as amendments to severely degraded soils associated with mining activities [4]. As a result, organic amendments (OAs) can be defined as any materials originated from plants and animals and added/or incorporated into the soil for the improvement and/or replacement of physical, chemical and biological properties of soil and in turn to make the environment suitable for production and productivity [5, 6].

The management of nutrients to maintain productivity and quality in crop production systems is great challenge that must be meet through a combination of organic materials and management of soil organic matter (OM).

The management strategies might include use of leguminous crops, household wastes, crop residues, compost and manures [7]. In long-term soil conservation and/or restoration to sustaining soil fertility and agricultural production, OAs play an important role due to their ability for the improvement of physical, chemical and biological properties of soils. The use of organic materials as soil amendment has received better attention in recent years for agronomic applications as well as soil reclamation projects and viewed as serving as a means to improve physical, chemical and biological soil properties, which in turn promotes improved crop performance and sound environment.

Soil fertility is defined as the quality of a soil that enables it to provide essential chemical elements in quantities and proportions for the growth of plants [8]. Continuous cultivation of lands for several years without adequate replacement of nutrients, removal of harvested crops with their residues, erosions problems, leaching and gas emission degrade soil physical and bio-chemical properties and results in overall decline of soil fertility. However, through application of OAs as manure and compost, soil fertility could maintain in the cropping systems [9].

The OM content in the soils is the result of the inputs by plant, animal and microbial residues and the rate of decomposition through mineralization of both added and existing OM [10]. Several investigations have demonstrated that soil OM is a very reactive and ever-present soil quality indicator that influences the productivity and physical well-being of soils and environmental conditions [11]. As a consequence, agricultural management practices by applying OAs mainly compost and farmyard manure (FYM) that enhance soil OM content are needed for preserving farming output and environmental quality [10].

For any farming operations with livestock that relies on manure and for crop producers who have access to an economical supply of compost, there is a need to knowing and understanding about the effect of OAs on soil fertility and environmental quality. Therefore, the main objective of this paper is to review the major effects of organic amendments (compost and farmyard manure) on soil fertility parameters and other environmental quality.

2. Literature Review

2.1. General Overview of Organic Amendments

A soil amendment is a material that can improve soil physically and/or chemically, making it more suitable for plant growth [6]. According to Davis and Wilson [5], Organic Amendments come from something that was alive and include wood chips, grass clippings, straw, compost, manure, biosolids, sawdust and wood ash. However, this review focuses on compost and farmyard manure.

Compost commonly describes plant and animal material that has been fully rotten in a targeted process initialized and controlled by man [12]. The average nutrient contents of compost are 0.95% N, 0.58% P_2O_5 and 0.95% K_2O although it varies depending on the types of compost (farm and town compost) [13]. Whereas, farmyard manure refers to a more or less decomposed mixture of livestock dung and urine (mostly from cattle) mixed with straw and litter that used as bedding material. It may also contain residues from the fodder fed to the cattle and decomposed household waste. On an average, well-decomposed FYM contains 0.5% N, 0.2% P_2O_5 and 0.5% K_2O [13]. According to FiBL [12], the availability of phosphorus and potassium from FYM is similar to that of chemical fertilizers.

The greatest challenge to organic growers is to harmonize nutrient availability from diverse fertility sources to that of crop demand. This challenge can be reduced through OM management. Nevertheless, it requires an understanding of factors affecting soil OM maintenance and decomposition of the organic materials. The successful use of OAs for the purpose of soil fertility can often produce crop yields and quality equivalent to conventional agriculture [7].

Crop growers use soil OAs like compost and FYM to improve soil fertility and create a healthy habitat for soil life. Many of the nutrients and minerals in the amendments are insoluble and slowly released. However, the gradual release is similar to natural nutrient cycle and leads to healthy crops with little or no nutrient leaching. Loss of OM during land surface disturbance through erosion, improper storage, mixing with underlying sub soil (cultivation) is common and one of the most serious threats facing many arable lands of the world. Thus, OAs aimed at restoring soil OM content that in turn leads to the improvement of physical, chemical and biological properties of the soil and result in a more favorable environment [14].

Compost and FYM had long been documented as soil OAs to preserve and enhance soil OM pools. Nowadays, there is a growing recognition that the safe and appropriate application of organic materials may contribute to fight plant diseases and reduce soil contamination, erosion and desertification. Although, the safe and appropriate application of OAs requires an in-depth scientific knowledge of their nature and impacts on the soil-plant system, as well as on the surrounding environment, scientific studies have to focus on the use of OA in modern agriculture and for the restoration of degraded soils [14].

Generally, many research results revealed that organic materials help nutrients to remain in the agricultural production system. However, the gathering, storage and application of organic materials are usually labor-intensive tasks, requiring the availability of sufficient workers [15]. There is a common misperception that increasing soil OM by additions of soil OAs is always a good practice. It is not a good practice if the amendments create excessive nutrient concentrations in soils and cause pollutions of surface and ground water with nitrate and phosphorus [16].

2.2. Effects of Organic Amendments on Soil Physical Properties

2.2.1. Aggregate Stability and Bulk Density

Concerning the physical soil properties, aggregate stability seems to be the most important parameter of all and contrary to many other parameters, it is easily measured. Many studies have addressed the effects of composts and FYM on aggregate stability. As an example, Zelalem [17] highlighted that organic materials including compost and FYM have a positive effect on improvement of the soil structure and Bouajila and Sanaa [18] showed that the addition of OA was associated with a significant ($p<0.05$) improvement of the structural stability of the soil. Such behavior might be the result of elevated OM content and improved microbial activities.

Aggregate stability is a basic factor in questions of soil physical fertility and could enhance by means of an appropriate management of OAs involving the incorporation of compost and FYM into soils, which can maintain an appropriate soil structure [10]. Bipfubusa *et al.* [19] also concluded that adding fresh and composted organic substrates usually have beneficial effects on soil aggregate stability, humification and microbial activity. Amlinger *et al. [*20] has confirmed the throughout positive effects of compost on soil structure and other soil physical properties (e.g. pore volume, soil density, water capacity, hydraulic conductivity and infiltration rate, etc.).

Through application of compost and FYM in the soil, soil bulk density could be improved and in turn, this may lead to improvement of soil porosity, soil water holding capacity and permeability. For example, the result of Ogunwole *et al.* [21] finding indicates that soil bulk density reduced under crop residue and compost incorporation and soil porosity was improved. This practice also favors increased soil organic carbon sequestration in soil and increasing the fertility status of the soil.

Mohamed *et al. [*22] also pointed out that the applications of soil OA significantly decreased the soil bulk density and the modulus of rupture, in each of the surface and subsurface soils. A decrease in bulk density could be expected when soil is mixed with less dense organic material, but there may also be associated changes in soil structure. According to Eche *et al. [*23], the soil bulk density values obtained from the incorporation of legumes and animal manures were>5% lower (<1.45 g cm^{-3}) as compared to the values of the treatments with sole urea fertilizer (>1.52 g cm^{-3}). In addition, the incorporation of these soil amendments increased total porosity at the surface and subsurface compared to treatments with sole urea fertilizer.

Soils rich in OM are less prone to erosion processes than soils with low OM content, such as those that predominate in arid and semi-arid areas [24]. The reason is that OM improves soil structure and tilth as well as it cements individual soil particles into larger aggregates, which leads to less runoff and erosion. Compost and FYM can increase stability of surface soil aggregation, which has ability to resist movement by wind or water and soil pores created by aggregation promote water infiltration, thereby reducing runoff and the likelihood that soil particles will transported with the water. This also indicates that the soil has less chance to become higher bulk density.

2.2.2. Water Holding Capacity

As soil fertility status is strongly related to water availability; regarding the effect of compost and FYM on physical properties of the soils, it is essential to underline that the effect of amendments on soil water content and water holding capacity (WHC). Addition of compost and FYM to the soil increases the WHC, because adhesive and cohesive forces within the soil hold water and an increase in the pore space will lead to an increase in WHC of the soil [25]. Hudson [26] showed that for each 1% increase in OM, soil WHC increased by 3.7%; consequently, less irrigation water is needed to irrigate the same crop [27]. Moreover, those OAs have been shown to improve the water retention in sandy soils, when the OAs applied at relatively high rates [28], but also to decrease moisture content in clay soils [27].

Concerning water retention, soils with coarse texture are substantially more sensitive to the amount of organic carbon (OC) compared with fine textured soils, thus the effect of changes in OC content on soil water retention depends on the proportion of textural components, but also on the amount of OC in soil. In fact, at low carbon content in soil, an increase in OC leads to an increase in water retention in coarse textured soils and to a decrease in fine textured soils. Whereas, at high carbon content in soil, an increase in OC results in an increase in water retention for all texture types [29].

Different researchers showed that compost addition to a sandy soil resulted in higher retention of rainfall if application levels are sufficiently high [20, 30]. Moreover, they noticed that after addition, physical properties of the amended soil were improved and in most of the cases, the improvements were proportional to the application rates of the compost and they were greater in the loamy soil than in the clay soil [14, 30, 31]. Research results of Bouajila and Sanaa [18] also indicated that the application of 120 t ha^{-1} manure improved water infiltration (596.46 cm) when compared with control (332.16 cm). This result often encountered since water infiltration essentially improved by the presence of OM and microbiological activity. In addition to this, compost and FYM could result in dark colour of the soil, which increases soil temperature and reduced warming up in spring and cooling effect in summer. The highest application rate of compost and manure decreases the temperature fluctuation of the soil [32].

2.3. Effects of Organic Amendments on Soil Chemical Properties

2.3.1. Organic Matter and Soil Reaction (pH)

Organic amendments increase soil OM content depending on the amounts and quality of the materials added. The literature review of McConnell *et al.* [33] shows that compost applied at a rates, varying from 18 to 146 t ha^{-1}, produced a 6 to 163% increase in soil OM content.

Manure amendments add OM to the soil, primarily in the form of OC and the amount of OC present in a soil reflects the long-term balance between additions of OC and losses through different pathways. The addition of manure typically shifts this balance and increases soil OM. Vitosh *et al.* [34] calculated that applying FYM at 67.2 Mg ha^{-1} yr^{-1} increased the OM content of a sandy loam soils by 0.1% each year for over 25 years. The research work of Bouajila and Sanaa [18] showed that the application of 120 t ha^{-1} manure improved an

OC (1.09%) when compared with control (0.69%). This indicates that 120 t ha^{-1} manures results 58% higher carbon content as compared with the control. Wakene *et al.* [3] and Khaliq*et al*. [35] also asserted that application of manures to agricultural fields is a widely used method of increasing soil OM and fertility.

Soil fertility amendments also affect soil pH. There are reports in the literature of long-term compost and manure application both increasing [36] and decreasing [37] the pH of soils, depending on their initial pH and organic residues. This means the response was in direct relationship to the pH of the materials themselves.

Butler and Muir [36] observed that soil pH increased on average by 0.5 units as the dairy manure rate doubled in magnitude from 11.2 to 179.2 t ha^{-1}. Increasing pH is clearly valuable in acid soils in terms of improving microelement availability and reducing the solubility of some toxic elements and it is interesting to consider whether in some circumstances FYM can substitute for lime application, thus making use of locally available resources.

2.3.2. Primary Nutrients (N, P and K)

Organic amendments mainly composts and FYM have great contributions for nutrient availability to plants [38]. There is a common understanding that many microorganisms convert organic N into inorganic N forms by mineralization. Both C and N potentially mine realizable pools and basal respiration were higher in soils treated with OA than in soils treated with mineral fertilizers [39]. A large number of authors confirmed that N mineralization from compost is very limited in the short term. However, there is a significant residual effect from the cumulative applications, which becomes visible later after 4–5 years, resulting in deferred higher N availability [40].

Regular addition of OM to soil for more than 10 years, through compost or manures, enhanced both soil C and N stocks and resulted in build-up of N, indicating a physical protection of this nutrient within macro aggregates [41]. On the review of long-term effects of OA on soil fertility, Diacono and Montemurro [10] asserted that repeated application of composted materials enhances soil organic N content by up to 90%, storing it for mineralization in future cropping seasons, often without inducing nitrate leaching to groundwater. Application of manure and compost resulted in significant ($p<0.05$) increase of total N content, with the compost treatment being the most efficient depending the amount to be applied [18].

As Hue and Silva [38] and Mohamed *et al.* [22] indicated, with continued application of composts and manures, soil P levels become increased. Compost and FYM have been observed to release considerable amounts of organic acids into the soil there by resulting in the hydrolysis of organic P; hence, improving P nutrition for plant and microorganisms [42]. This could be the reason for the higher P levels obtained in the OA treatments compared to sole urea fertilizer treatment.

In addition to phosphorus, the experimental result of Bulluck *et al.* [43] shown that potassium concentrations in soils amended with OAs (compost and FYM) increased by a factor of three, and were higher at the end of the second year in soils with alternative amendments whereas potassium concentrations decreased over time in soils with synthetic fertilizers. Similarly, Kabirinejad and Hoodaji [44] indicated that the application of compost (50 t ha^{-1}) increased significantly ($p<0.01$) the potassium level in soil.

2.3.3. Other Elements and Cation Exchange Capacity

Organic amendments provide advantages beyond the benefits of increasing OM and primary elements since nutrients that seldom applied by farmers (e.g. manganese, zinc, and sulfur) are added as insurance against potential yield limitations. Furthermore, nutrients that normally applied in liming sources (i.e. calcium, magnesium) supplemented in OA and permitted to mount up in the soil [43]. One of the perceived benefits of the use of composts and manures over fertilizers is their ability to provide non-NPK nutrients. Bulluck *et al.* [43] reported that calcium and magnesium concentrations in soils with OA increased by two-fold and more than double over the 2-year period respectively. In contrast, no increase and only slight increases in calcium and magnesium concentrations respectively occurred in soils with the synthetic fertilizers over the same period.

Soil micronutrients (e.g. manganese, copper and zinc) concentration increased over time in soils amended with OAs. Zhao *et al.* [45] reported that six-year consecutive applications of compost have resulted in significantly higher concentrations of Cu and Zn at 10–20 cm depth of the compost-amended soil, relative to the control, with an increase from 102.8 to 127.4mg kg^{-1} for Cu and from 111.9 to 165.7mgkg^{-1} for Zn.

In Ethiopia, the experimental findings of Mesfin and Yifru [46] indicated that organic wastes from sugar estates do have a potential to provide OM, exchangeable bases and micronutrients that have not considered as an OA in Ethiopian Agriculture previously. In addition to this, considerable number of studies concerning long-term fertility trials pointed out that compost and FYM applications increased the OC stock and, therefore, increased the CEC. This effect is due to the high negative charge of OM. This is important for retaining nutrients and making them available to plants [47]. Likewise, Eche *et al.* [23] also indicated that application of manure restored and maintained soil fertility by improving chemical properties of the soil in the long-term trial for sustainable soil productivity in Samaru, Nigeria.

2.4. Effects of Organic Amendments on Soil Biological Properties

Soil fauna and flora plays a key role for the functioning of the soil ecosystem. However, the level of transformation and other biotic processes depends mainly on the existence and availability of sufficient OM sources. If a minimum of crop residues and dead microbial biomass is not available, exogenous OM must added in order to maintain the necessary for microbial soil functions. Application of OA has positive effects on soil biota and associated soil biochemical parameters and overall soil biodiversity [37]. Repeated application of exogenous OM to cropland led to increase in microbial biomass by up to 100% and enzymatic activity increase by up to 30% [10]. If the soil remains drain and well aerated, OA, (compost and FYM) application to soils can generally stimulate soil biological activities.

The partially decomposed and altered products in FYM and compost supply energy to the soil microbial community like cyanobacteria that can convert atmospheric nitrogen in to plant available nitrogen form [48]. This in turn stimulates soil fauna, which feed on smaller organisms. However, nature and composition of the OA can influence the effect on the faunal population. For example, Leroy *et al.* [49] found greater earthworm numbers after application of FYM than composts that they attributed to the larger amounts of available carbon provided by manures.

Organic matter is the principal food sources for secondary consumers including the decomposers: bacteria, fungi and actinomycetes. As a carbon source, OA exert a great influence on the heterotrophic microbial communities [50]. Microorganisms e.g. bacteria, fungi, actinomycetes and microalgae play a key role in OM decomposition, nutrient cycling and other chemical transformations in soil [51]. This increases the overall fertility of the soil.

Yadessa *et al.* [52] concluded that proper and timely application of nutrients is one mechanism of pest management in agro ecosystems. Compost and manures are capable to suppress crop pathogens in the soil system when they applied in the appropriate place with specific type and rate. This is due to the reason that soils reach in OM creates favorable conditions for microorganisms and support a rich and varied population of soil organisms. Further, it is important to biological control of plant disease through the mechanisms of competition, antibiosis and hyperparasitism. Bulluck *et al.* [43] has reported soils with alternative OAs had higher propagule densities of Trichoderma species of fungi and nearly twice as many propagules of enteric bacteria than soils amended with synthetic fertilizers.

2.5. Effects of Organic Amendments on Environmental Quality

Modern and sustainable agricultural systems through application of OA aim at developing new farming practices that are safe and do not degrade the environment. With regard to environmental concern, OA as compost and FYM can prevent water and air contamination that would result from erosion and leaching problem. Composting stabilizes some of the nutrients in wastes so that they may not as readily leach out. This decreases the potential for ground and surface water contamination [10].

The use of compost on low OM soils results in improved moisture and nutrient retention, decreased soil erosion, reduced surface crusting, suppression of plant diseases and improved soil tilth. Composting of organic wastes kills weed seeds, pathogenic bacteria and viruses. There is also an increasing positive evidence of the impact that composts and FYM can have on soil carbon sequestration. Van-Camp *et al.* [53] highlighted that when organic materials, such as compost and manure are added to soil; at least a share of their OC is decomposed and producing CO_2, while another part is sequestered in the soil.

Through humification of organic materials added to the soil and formation of secondary carbonates, atmospheric CO_2 would transfer into the soil C pool. So CO_2 thus adsorbed is not immediately re-emitted to the atmosphere [54]. This implies that OA play a positive role in climate change mitigation by soil carbon sequestration, even if the size of which is dependent on their type, the rates and the frequency of application.

2.6. Challenges in Application of Organic Amendments

Competition of organic materials for the purpose of fodder or fuel, land scarcity, the cost intensive activities of organic materials gathering, storage and application are some of the constraints in utilization of OAs to improve soil fertility [55; 56; 57]. Due to those factors and since it is a practice with high labor and low yield, and only rich population will afford, application of OAs can't be result sustainable agriculture particularly in developing countries. In addition to this, OAs has more of long-term return rather than short-term positive effect [58]. As a result, other alternative measures such as physical and biological soil conservation measures should be given more attention/emphasis and it is better to use the combination of the organic and inorganic fertilizers.

Application of organic amendments to soils on a consistent basis may affect soil fertility in numerous ways like formation of nutrient overloading of the soil and will result water contamination. In addition, the cropland application of immature compost and FYM can produce environmental and agronomic problems [59]. In fact, if the compost and FYM has not been sufficiently stabilized, its application increases ammonia volatilization, decreases the soil oxygen concentration, produces some phytotoxic compounds and immobilizes soil mineral N. This could affect air and water quality.

3. Conclusion

Addition of OAs (Compost and FYM) acted significantly on the physicochemical and biological characteristics of the soil, especially on the soil fertility and its productive capacity even its impact depends on the type and the level of applied amendments. Organic amendment application can play a positive role in climate change mitigation by soil carbon sequestration, which in turn can reverse the process of soil degradation and environmental pollution.

However, the presence of competition of organic materials for different purposes, the cost intensive activities of organic materials (gathering, storage and application) and since it have more of long-term return rather than short-term positive effect, application of organic amendments can't be result sustainable agriculture particularly in developing country.

Therefore, application of organic amendments should be supported by other alternative measures such as physical and biological soil conservation measures and it is better to use the combination of the organic and inorganic fertilizers. Organic products for soil amendment must be produced in high quality and their stability must be accurately assessed. In addition, controlling the impact of compost and FYM on environmental quality is needed by acting on the applied doses.

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