Review Article

ORGANIC AMENDMENTS FOR SOIL RECLAMATION: A REVIEW

Abstract

The idea of sustainable soil management is based on the fact that current human activities must not harm the future generations. Erosion and other natural occurrences, as well as human activities, can deteriorate the soil. Lack of organic matter in comparison of nearby undisturbed areas is a common characteristic of degraded or disturbed soil. Animal manure, bio-solids, waste from fruit pulp, kitchen waste and paper mills, wood scraps, crop residues, *etc.* are just a few examples of the organic amendments that are produced in large quantity in the world and that have the potential to be employed extensively for the reclamation of soil. With the emphasis on amendment types and application rates for soil amelioration and biomass production, this review paper explores the mechanisms through which organic addition alters the soil attributes (physical, chemical and biological) and defines the significance of organic amendments in reclamation of the soil. One big application of organic amendments can hasten initial reclamation and result in net productivity, which is self-sustaining. While stable less decomposable compounds may produce effects that persist longer and easily decomposable organic additions may have instant but fleeting effects. In order to achieve mutually beneficial land reclamation, waste products from the agriculture, forestry and urban sectors are used as organic additions.

Keywords: Soil, agriculture, forestry organic matter, organic amendments, reclamation, waste products

Introduction

"Organic amendments improve organic matter and carbon content, nutrients' cycling, porosity, water holding capacity, enzyme activities and biodiversity in saline soil, and the integrated application of organic amendments with gypsum in cultivating glycophytes and halophytes is a highly promising strategy to enhance crop productivity in saline soil" (Suleiman *et al*., 2021). The findings of Anik *et al.* (2017) indicate that "the regular application of organic residues and manure help to enhance soil fertility and production sustainability". According to Zika and Erb's (2009) estimation, dry land degradation resulted in an annual loss of 2% of the world's terrestrial net productivity. Lack of organic matter in soil reduces its ability to hold water and higher runoff capacity brought on by decreased porosity (increased bulk density) and infiltration increases the runoff capacity. Han *et al*. (2021) observed that "the plant microbial desalination cell produced a larger effect than the soil microbial desalination cell". Toxins, pathogens, heavy metals and other contaminants that could be transported to surface or ground water by runoff or leaching are among the undesirable characteristics that are frequently associated with organic amendments (Larney *et al*., 2011). "The effectiveness of soil reclamation programmes depends on the ability to improve physical, chemical and biological properties of the soil to which the organic amendments greatly increase" (Gardner *et al*., 2010). After 8 to 9 years of reclamation, Zhu *et al*. (2022) noticed that the time since reclamation is a vital driving force for restoring the soil physico-chemical properties and bacterial communities in abandoned salt pans. Farooqi *et al.* (2023) concluded that food crops can be produced from freshly reclaimed salt-affected soil, and this can have added long-term benefits of carbon sequestration and climate change mitigation.

Organic Amendments Used in Soil Reclamation

Organic amendments contain reasonable amounts of macro- and micro-nutrients, which could be released to increase soil fertility, and field application of these organic amendments is necessary to evaluate their effects on soil health and crop productivity in short and long term (Sulok *et al.*, 2021).Conservation tillage is recognized as a sustainable management practice but its combination with the application of organic residue still constitutes a challenge in some areas (Martin, 2021). The study carried out by Libutti *et al.* (2023) reveals that "organic amendments, particularly compost, could be an alternative of chemical fertilizers to reach a trade-off between yield and nutritional status of the soil, meeting the needs of farmers and consumers as well as the targets for sustainable food production". Organic amendments are much more effective in increasing soil organic carbon and building up soil organic matter, as shown by meta-analysis (Han *et al.*, 2016; Siedt *et al*., 2021). Similarly, Yin *et al*. (2014) reported that the application of biochar to soil may be an appropriate management practice for increasing carbon content in soil. About 37 years after the application of different organic amendments, Koishi *et al.* (2020) noted that in a stockless management of soil organic carbon, cereal straw restitution offers a viable alternative solution to cattle manure for increasing and stabilizing soil organic carbon. Application of poultry manure, Anaerobic Digestate Solid Waste and mushroom compost @ 30 t ha^{-1} significantly improved physical, chemical and biological quality indicators of the soil, which are crucial for increasing crop yield (Unagwu, 2019). Andrade (2022) stated that cattle manure, biochar, or tropical peat with leaching can be used to reclaim some saline-sodic soil. A study carried out by Butnan *et al.* (2019) clearly reveals that the use of an unconventional organic fertilizer, *i.e.*, vermicompost, could be a best substitute for chemical fertilizer in improving growth of tomato plants in sandy soil if it is applied in adequately high quantity. Similarly, the beneficial effect of vermicompost could be enhanced through its combination with rice husk charcoal. In an experiment conducted by Huang *et al*. (2022), it was observed that phospho-gypsum with farmyard manure significantly decreased the soil salinity and sodicity but increased the soil fertility and soil organic matter. The findings of Ahmed *et al.* (2017) reveal that "utilization of biochar had positive effect on improvement in soil fertility and productivity as well as disease suppression of mulberry plant".

The results of an experiment conducted by Khatun *et al.* (2019) reveal that the organic amendments treated soil gave better results than that of control soil, and organic amendments can be used to mitigate the problem of soil salinity. Pardo *et al*. (2014) observed that the use of compost or pig slurry in combination with hydrated lime decreased the soil eco-toxicity, thus, it could to be a suitable management strategy for the remediation of highly acidic toxic elements (TEs) contaminated soil. Abate *et al*. (2021) observed that the combined application of *Chlorosis guayana* (*Rhodes grass* var. massava) + 125% gypsum and *Cynodon dactaylon* (*Panicum grass* var. maxima) + 125% G was the most efficient treatment for reclaiming the saline-sodic soil. The results of a study carried out by Wang *et al*. (2014) indicates that "a combination of green waste compost, sedge peat and furfural residue had the substantial potential to ameliorate the saline soil in coastal areas and it worked better than the incorporation of single amendment". The analysis of a study carried out by Mulyono*et al*. (2021) reveals that oil palm EFB (Empty Fruit Bunch) compost was the most suitable organic material with a global priority of 0.363, followed by rice husk charcoal (0.244), cattle manure (0.218) and guano (0.175).

Effects of Organic Amendment on Soil Properties

The use of organic soil amendment like Hasil Tani organic compound has the potential to improve soft soil in paddy cultivation area by enhancing soil quality such as soil strength, organic matter content, hydraulic conductivity, pH, electrical conductivity, exchangeable calcium, magnesium, potassium and cation exchange capacity to a range, which is high soil stability index and productivity for paddy cultivation (Rendana *et al*., 2018). The results of trial conducted by Yazdanpanah *et al*. (2012)indicate that pistachio residue is an efficient amendment to reclaim the saline-sodic soil and to improve the availability of macro-nutrients.Rogovska *et al.* (2014) found that biochar application significantly increased soil pH, readily available water content and soil organic carbon and decreased bulk density of soil. The high pH, carbon content and cation exchange capacity are the potential indicators of biochar and compost to sustain soil health in terms of liming effect on acid soil, nutrients and water retention, nutrients reserves and a suitable habitat for microbial life (Sulok *et al.*, 2021). Ding *et al.* (2021) found that "the vermicompost had a better effect than gypsum or sulfuric acid, and simultaneously, deep tillage improved the effect of these amendments on soil properties and yield of the crops". The results of an experiment conducted by Widowati *et al*. (2020) show that the types of soil amendment affect the fraction (sand, dust, or clay) of soil composition or constituents so that it may have an impact on physical properties of each type of soil. In a study carried out by Fang *et al.* (2020), it was concluded that the reclaimed soil variables after 10 years of reconstruction had basically returned to the undamaged state, but the reclaimed soil is more fragile due to the stronger correlation between variables. Chaganti *et al.* (2015) found "the combined application of gypsum and organic amendments more effective in improving the soil properties directly related to sodium removal including sodium leaching, hydraulic conductivity, exchangeable sodium percentage and sodium absorption ratio, and therefore, the soil amendments could have a supplementary benefit to accelerate the reclamation process". Farooqi *et al.* (2023) also found the soil treatment with gypsum in combination with farmyard manure most effective in increasing soil carbon (+169% over a period of three years).

"Organic amendments upon addition to the soil supply essential nutrients, *i.e.*, nitrogen, phosphorus, potassium and others secondary and micronutrients, improved the soil physical and chemical properties and enhanced the population of microbes and their activity" (Dotaniya *et al*., 2016). From a study carried out by Chaganti *et al*. (2015), the results demonstrated that the reclaimed water could be used by itself to leach and reclaim a saline-sodic soil, however, the reclamation effect was significantly enhanced in the presence of organic amendments such as composts and biochar. The results of a study carried out by Wang *et al*. (2020) demonstrate that the compaction effect of surface (at a depth of 10 cm) in the process of reclamation was visible, and the amount of compression and spring back was larger. According to the study of Imran *et al.* (2021) and Koishi *et al.* (2020), "the plant wastes and field biomass were promising for nutrient replenishment, while biochar was the main component for the enrichment of soil organic carbon". "Application of urban waste such as sewage sludge and municipal solid waste compost in conjunction with gypsum could be an option for reducing soil sodicity, however, if industrial waste is not mixed with domestic city waste, then the city compost could be an important material for the reclamation of sodic soil and supplementation of nutrients too" (Anonymous, 2018a).

Impact on Soil Biota

As per the study carried out by Hafez *et al.* (2021), "the addition of *Azospirillum* with the spent grain is strongly recommended for the amelioration of saline-sodic soil as it is more effective than compost to remediate and enhance fertility of the saline-sodic soil". Imran *et al.* (2021) observed that "the application of animal manure increased the concentration of soil macro- and micro-nutrients, benefiting soil reclamation and restoration". The results of an experiment conducted by Yousaf *et al*. (2022) reveal that "incorporation of organic amendments enhanced enzymatic activities, reduced oxidative stress, increased potassium concentration and decreased sodium concentration, resulting in improved growth of the two plant species". The results of an experimentconducted by Guo *et al.* (2022) demonstrate that "the addition of organic amendments significantly affected the soil microbial community structure and increased the soil microbial richness and functional changes". Alcivar *et al.* (2018) found that "the combination of biochar, humic substances and gypsum had superior effect on soil and both quinoa genotypes". "Animal-based residues and manure application enhanced the concentration soil macro- and micro-nutrients with the advantage of soil reclamation and restoration" (Imran, 2021; Amanullah *et al.*, 2021).

A study carried out by Mao *et al.* (2022) reveals that the application of organic amendments increased the diversity of soil bacterial community, as well as the relative abundance of beneficial salt-tolerant microbial taxa, enhancing the interactions among microorganisms and thus promoting the growth of melon. Soil salinity is one of the biggest widespread abiotic stresses severely restricting crop production. The findings of Awad *et al.* (2022) illustrated that the highest plant's self-production of proline and enzymatic antioxidants, *i.e.*, catalase enzyme, peroxidase and superoxide dismutase were realized when wheat plants were treated with vermicompost and sprayed with *Moringa* extract, while the lowest values of proline and enzymatic antioxidants were recorded with untreated plants (without soil and foliar application). The same trend was found for yield and its components, where the highest value of yield was realized with wheat plants treated simultaneously with vermicompost and *Moringa* extract. Impacts of organic amendments on microbial biomass and activity have been examined and depicted that little is known about how they affect the structure and makeup of soil microbial communities but a deeper comprehension of how organic modifications affect microbial diversity is anticipated with the help of cutting-edge molecular technologies (Pascault *et al*., 2010).

Nutrients and chemical Environment

As per the observations recorded by Martin (2021), the organic amendments increased the content of soil nutrients mainly right after their application, and the levels were adequate for the whole crop rotation. Taeprayoon *et al*. (2022) concluded that when growth performance of the study plants is considered, jatropha and acacia might be suitable for phyto-management of cadmium-contaminated soil. In a study carried out by Liu *et al*. (2022) reveals that the organic-inorganic coupling treatment of fly ash + organic fertilizer showed the maximum content of soil organic matter, soil moisture, water-stable macro-aggregates and maize yield, thus, they might be the most appropriate amendments for improving the reclaimed soil structure and fertility of that area. As per the studies of Amanullah *et al.* (2021), the field biomass were promising for nutrients replenishment, while biochar was the key component for the enrichment of soil organic carbon. After five years of experimentation, Anik *et al.* (2017) concluded that poultry manure was more efficient in increasing soil fertility than cow dung and rice straw, resulting in a significant increase in phosphorus from 22 to 63 mg kg^{-1} at crop harvest.

In an experiment, the organic amendments showed a positive effect on the growth of *Vachellia nilotica* and *Dalbergia sissoo* under saline conditions. Likewise, organic amendments enhanced the enzymatic activities, reduced oxidative stress, increased potassium concentration and decreased sodium concentration, resulting in improved growth of both the plant species (Yousaf *et al*., 2022). Organic amendments contain nitrogen in different amounts (Lashermes *et al*., 2010). The results from an experiment conducted by Yazdanpanah *et al*. (2012)indicate that the organic matter-amended soil showed the highest concentration of nitrogen. The amount of soluble cellulose- and lignin-like components, as well as the concentration of organic nitrogen, was the important indicators of prospective nitrogen availability. To forecast the potential nitrogen mineralization of organic additions, Lashermes *et al.* (2010) has created a typology based on the chemical and biochemical composition of those amendments. Elkhlifi *et al.* (2021) used phosphate-lanthanum coated sewage sludge biochar in ryegrass cultivation and found that it provided a large amount of phosphorus and decreased the content of calcium carbonate ($CaCO_3$) due to a decomposition reaction. Fan *et al.* (2018) found that vinegar residue reduced the sodicity of saline and saline-sodic soil.

In a greenhouse pot experiment, it was observed that the application of soil organic matter decreased the concentration of plant tissue copper, yet significantly only for Faba bean pod. Application of salts either lowered copper solubility in soil or reduced plant uptake by excessive salts in the rhizosphere. Then again, the plant adaptive mechanisms may modify copper phyto-availability (Matijevic *et al.*, 2014). When organic amendments are applied to soil, their inherent cation exchange capacity frequently increases, especially in the case of sandy deteriorated soil (Kasongo *et al*., 2011). On the other hand, after applying compost to carbonate rich soil, the phenomena like soil decarbonatization can be seen, which can result in a soil pH reduction (Sere *et al*., 2010). The results of Dume *et al*. (2016) indicate that the addition of biochar improved pH, electric conductivity (EC), cation exchange capacity (CEC), organic carbon (OC), organic matter (OM), total nitrogen (TN), exchangeable cations and available phosphorous in the soil but had no significant effect on soil texture. In another study, Herath *et al.* (2013) reported a 50-139% increase in soil saturated hydraulic conductivity after the application of corn stalk biochar @ 11 t/ha to silt loam soil, attributing this effect to increased soil aggregate stability and porosity and observed a significant improvement in soil saturated hydraulic conductivity with the application of biochar @ 75 t/ha.

According to Gardner *et al.* (2010), adding biosolids to mine tailings reduced the volumetric water-holding capacity of a silt loam soil but had no effect on a sandy soil due to decreased bulk density. Although Schneider *et al*. (2009) frequently reported conflicting and ambiguous results but it is generally true that adding organic amendments increase the saturated hydraulic conductivity. Findings of Saengwilai *et al.* (2020) indicate that the organic amendments immobilized cadmium in soil and enhanced growth and production of rice while reducing content of cadmium in rice grain. Likewise, it was emphasized that the selection of cultivars and amendments plays a key role in the success of low-cadmium in rice production. It is necessary for the contaminants to be denatured, degraded, sequestered, or otherwise rendered inactive in the soil for the protection of water resources' adjacent to land receiving organic amendments containing enteric microorganisms, human, or veterinary pharmaceuticals, hormones, or other contaminants (Larney *et al*., 2011).

Plant Growth and Yield

After 3 years of experimentation, Farooqi *et al.* (2023) recorded the maximum yield of wheat in third year after application of gypsum in combination with farmyard manure (51%), while the effect of green manure combined with gypsum also showed a significant increase in maize yield in year three (49%). Awad *et al.* (2022) realized maximum yield of wheat supplied with vermicompost and *Moringa* extract simultaneously. Kuziemska *et al*. (2021) found that all of the organic amendments increased the yield of test plant and reduced the toxic effects of copper on cocksfoot, however, the most effective fertilizer in terms of yield and protective effects against high levels of copper was cattle manure, in the case of which the tolerance indices were highest. Gebremedhin *et al.* (2015) reported that biochar significantly increased grain and straw yield of wheat (*Triticum aestivum* L.) by 15.7 and 16.5%, respectively over the NPK application. Similar effects have been reported by Agboola and Moses (2015), which showed that addition of rice husk biochar increased the growth and yield of soybean [*Glycine max* (L.) Merr.]. In another study carried out by Abbas *et al.* (2018), the results indicate that biochar could be used as an amendment in metal contaminated soil for improving growth of wheat plants and reducing cadmium concentration under semi-arid conditions.

Mine, Quarry Sites and Eroded Agricultural Sites

In a study, Mulyono *et al*. (2021) evaluated the organic materials as most suitable alternative in mine reclamation and found that oil palm empty fruit bunch compost was the most suitable organic material with a global priority followed by rice husk charcoal, cattle manure and guano. As per the results of Gardner *et al*., (2010), the addition of bio-solids proved more effective in improving attributes related to soil quality and fertility than the conventional use of inorganic fertilizers on reclaimed copper mine tailings sites in British Columbia. In addition, it increased the biological activity of mine tailings by boosting the total aerobic, total anaerobic, iron reducing, sulphate reducing and denitrifying microorganisms near the surface.

The intrinsic density of organic material is observed significantly lower than that of mineral soil. With increasing dry biosolids application rates between 50 and 250 Mg/ha, soil bulk density and penetration resistance reduced in the top 15 cm of copper mine tailings (Gardner *et al*., 2010). Management of saline and alkaline soil includes reclamation through amendments, salt leaching, improved agronomic, irrigation water and nutrient practices, alternate land uses and use of salt-tolerant varieties (Kaledhonkar *et al*., 2019). In a study, it was observed that Leonardite significantly enhanced grain production of Chorati (12.2 g plant^{-1}) and reduced the content of cadmium in rice grain to 0.14 mg kg^{-1}, which was considered safe for consumption (Saengwilai *et al*., 2020).

A study carried out by Leapheng *et al.* (2019) reveals that *Jatropha curcas* plant was suitable for phytoremediation of heavy metal contaminated soil, especially in combination with both compost and Ethylene Diamine Tetra-acetic Acid (EDTA). Irrigation induced waterlogged saline lands characterized by shallow water table and high concentration of soluble salts (ECe> 4 dS m^{-1}) in the root-zone have been reclaimed through large scale implementation of sub-surface drainage technology for restoring the enhanced crop productivity (Bundela *et al*., 2016). Results from a study by Larney *et al*. (2011) demonstrated that the drastically disturbed soil may recover productivity in the absence of organic amendments, *e.g.*, eroded check treatment, however, the organic amendments play a residual role in their ongoing maintenance. According to Castillejo and Castello (2010), one of the main issues with adding organic amendments to deteriorated quarry soil is the potential for over fertilization as higher rates of municipal solid waste compost were found to favour halophyte species like Mediterranean salt bush (*Atriplex halimus*) over native *Gypsiferous* species, whereas, low rates had no positive impact on soil characteristics. In contrast, according to Pedrol *et al.* (2010), the compost preserved plant species diversity and richness significantly increased metabolic activity in the edaphic flora of the soil.

Conclusion

Organic supplements are great for speeding up the processes of soil regeneration and, consequently, land restoration. Recalcitrant materials may have less intense but longer-lasting impacts, whereas, more degradable organic additions may have more intense but shorter-term effects. The availability of organic amendments, such as bio-solids from urban areas or manure from intensive livestock operations, may increase in the future as the demand for food, fuel and fiber rises, as predicted by forecasts for increased growth in the world population at the end of this century. A higher dependency will be placed on soil to serve as the receivers of such materials. The addition of organic amendments will have the most positive effects on soil quality and net primary production in disturbed or degraded soil. The significance of organic amendments in soil amelioration or rehabilitation as a first step in reclamation or restoration towards a long-term self-sustaining ecosystem would be clarified by research on the afore-mentioned subjects.

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