International Journal of Environment and Climate Change

Volume 13, Issue 11, Page 4068-4076, 2023; Article no.IJECC.109063
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Organic Amendments for Soil Reclamation: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i113586

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/109063

Review Article

Received: 20/09/2023
Accepted: 25/11/2023
Published: 01/12/2023

ABSTRACT

The principle that presents human activities and forms the basis of sustainable soil management must not negatively impact future generations. The soil can be degraded by human activity, natural events like erosion and other factors. Degraded or disturbed soil sometimes lacks organic matter when compared with neighbouring undisturbed areas. Organic amendments that are produced in huge quantity worldwide and have the potential to be widely used for soil reclamation include animal manure, biosolids, waste from fruit pulp, kitchen trash, paper mills, wood scraps, crop residues, etc. This review article explores the mechanisms through which organic addition alters physical, chemical and biological properties of the soil and defines significance of organic amendments in the soil reclamation, with a focus on amendment types and application rates for soil amelioration and biomass production. A large-scale use of organic amendments can speed up the initial reclamation process and produce self-sustaining net production. Though easily decomposable organic additions may have immediate but transient impacts, stable and less decomposable molecules may cause effects that last longer. Organic additions consisting of waste products from the forestry, urban and agricultural sectors are used to achieve land reclamation to attain mutual benefits.

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Keywords: Soil; agriculture; forestry organic matter; organic amendments; reclamation; waste products.

1. INTRODUCTION

Organic amendments improve carbon content, nutrients' cycling, porosity, water holding capacity, enzyme activity and biodiversity in saline soil, and integrated application of organic amendments with gypsum in cultivating glycophytes and halophytes is a highly promising strategy to enhance crop productivity in saline soil [55]. The findings of Anik et al. [11] indicate that enhancing soil fertility and production sustainability can be achieved through consistent application of manure and organic wastes. 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. [27] observed a greater effect due to the plant microbial desalination cell than due to 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 [36]. 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 [22]. After 8 to 9 years of reclamation, Zhu et al. [65] 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. [21] concluded that freshly restored salt-affected soil can be utilized for cultivation of food crops, which could provide substantial long-term benefits for mitigating climate change and carbon sequestration.

2. ORGANIC AMENDMENTS FOR SOIL RECLAMATION

Organic amendments consist of reasonable quantity of macro- and micro-nutrients that could be released to enhance soil fertility. In order to assess the short and long-term impacts of organic additions on soil health and crop productivity, field application of these amendments is required [56]. 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 [43]. The study carried out by Libutti et al. [40] reveals that compost and other organic amendments have the potential to replace chemical fertilizers in a way that balances soil nutrition and yield with simultaneously meeting consumer and farmer demands and advancing sustainable food production goals. Organic amendments are much more effective in increasing soil organic carbon and building up soil organic matter [26,54]. Similarly, Yin et al. [64] reported that applying biochar to soil could be a suitable management strategy to improve the soil's carbon content. About 37 years after the application of different organic amendments, Koishi et al. [34] 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 [58]. Andrade [7] stated that some saline-sodic soil can be reclaimed by using animal manure, biochar, or leaching tropical peat. A study carried out by Butnan et al. [12] clearly reveals that the use of 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. Huang et al. [29] observed that farmyard manure and phospho-gypsum considerably reduced the salinity and sodicity of the soil and improved its fertility and organic matter content. The findings of Ahmed et al. [4] reveal that the application of biochar improved fertility and productivity of the soil and prevented mulberry plant disease. Khatun et al. [33] reported 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. A more effective remediation technique for extremely acidic soil contaminated with toxic elements (TEs) was observed by Pardo et al. [46], when compost or pig slurry was used in conjunction with hydrated lime. Abate et al. [1] observed that the combined application of *Chloris gayana* (*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. Wang et al. [60] reported that saline soil in coastal areas was significantly improved by combining green waste compost, sedge peat, and furfural residue, and this technique performed better results than just applying a single amendment. Mulyono et al. [45] observed 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).

3. EFFECT OF ORGANIC AMENDMENTS ON SOIL PROPERTIES

The use of organic soil amendments like Hasil Tani organic compound has the potential to improve soil stability index and productivity of paddy [49]. Yazdanpanah et al. [62] indicated that pistachio residue is an efficient amendment to reclaim the saline-sodic soil and to improve the availability of macro-nutrients. Rogovska et al. [50] found that the use of biochar substantially enhanced the pH, readily available water content and soil organic carbon but decreased bulk density of the soil. Biochar and compost are useful in maintaining soil health in terms of liming- acid soil, nutrients and water retention, nutrients reserves and an appropriate habitat for microbial life [56]. Ding et al. [15] found that use of vermicompost gave better results than gypsum or sulfuric acid, and simultaneously, deep tillage enhanced the effect of these amendments on soil properties and crop yield. Widowati et al. [61] showed that the types of soil amendment affect the fractions of soil composition or constituents so that it may influence physical properties of the soil. In a study, Fang et al. [20] concluded that the variables of the reclaimed soil had essentially reverted to their initial state after ten years of restoration. Chaganti et al. [14] found the combined application of gypsum and organic amendments more effective in improving the soil properties that are directly related to the removal of sodium. Farooqi et al. [21] also found the use of gypsum together with farmyard manure as the most effective soil treatment for enhancing soil carbon.

When added to the soil, organic amendments supply essential nutrients, improve physical and chemical properties of the soil and increase the total amount of microorganisms and their activity [16]. According to Chaganti et al. [14], the results demonstrated that incorporation of organic amendments such as compost and biochar greatly improved the reclamation outcomes. Wang et al. [59] reported visible effect of compaction surface (up to 10 cm depth) in the process of reclamation and the larger amount of compression and spring back. Although plant wastes and field biomass showed good results for the purpose of replenishing nutrients, but biochar was found the main constituent for enriching the soil organic carbon [30,34]. Urban waste, such as sewage sludge and municipal solid waste compost, could be applied with gypsum to lower the soil sodicity. However, if industrial waste is kept separate from residential city waste, city compost could play a significant role in both nutrient supplementation and the reclamation of sodic soil [8].

4. EFFECT OF ORGANIC AMENDMENTS ON POPULATION OF SOIL MICROORGANISMS

Addition of *Azospirillum* with the spent grain is strongly for the ameliorated the saline-sodic soil as it is more effective than compost to remediate and enhance fertility of the saline-sodic soil [25]. Imran et al. [30] observed that the application of animal manure increased the concentration of soil macro- and micro-nutrients, benefiting soil reclamation and restoration. Yousaf et al. [63] stated that the application of organic amendments increased the potassium concentration, decreased sodium concentration and oxidative stress and improved the enzymatic activity. Guo et al. [24] noted 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. [5] found that gypsum, humic substances and biochar worked together more effectively to improve the soil and both quinoa genotypes. Manure and animal-based residues improved the concentration of macro- and micro-nutrient in soil, leading to the benefit of restoring and reclaiming soil [30,6].

The results of a study carried out by Mao et al. [42] reveal that the incorporation of organic amendments improved the interactions among the microorganisms and thereby encouraged the growth of melon by increasing the diversity of soil bacterial community and the relative abundance of desirable salt-tolerant microbial taxa. One of the most major and pervasive abiotic stresses that significantly limits agricultural productivity is salinity in the soil. Awad et al. [9] illustrated that wheat plants enriched with vermicompost and sprayed with *Moringa* extract showed the highest levels of plant self-production of proline and enzymatic antioxidants, such as catalase, peroxidase, and superoxide dismutase. The same pattern was observed for yield and its components. Pascault et al. [47] examined the impacts of organic amendments on microbial biomass and activity 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.

5. EFFECT OF ORGANIC AMENDMENTS ON SOIL FERTILITY

As per the observations recorded by Martin et al. [43], 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. [57] concluded that *Jatropha* and *Acacia* may be appropriate for phyto-management of cadmium-contaminated soil when growth performance of the research plants is taken into account. Liu et al. [41] demonstrated 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. While biochar was the essential ingredient for enhancing the soil's organic carbon content, field biomass showed promising for replenishing nutrients [6]. After five years of experimentation, Anik et al. [11] concluded that as the phosphorus levels increased significantly from 22 to 63 mg kg^{-1} during crop harvest, poultry manure proved to be a more effective soil fertility enhancer than cow dung and rice straw. The organic amendments positively impacted the development of *Dalbergia sissoo* and *Vachellia nilotica* under saline conditions. Similarly, the addition of organic amendments boosted the growth of both plant species by increasing potassium concentration, decreasing sodium concentration, reducing oxidative stress, and enhancing enzymatic activity [63]. Different quantities of nitrogen are included in organic amendments [38]. Yazdanpanah et al. [62] stated 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. Lashermes et al. [38] developed a typology based on chemical and biochemical composition of those amendments to predict the possible nitrogen mineralization of organic additions. Elkhlifi et al. [18] found that phosphate-lanthanum coated sewage sludge biochar supplied a significant quantity of phosphorus and lowered the amount of calcium carbonate ($CaCO_3$) because of the breakdown reaction. According to Fan et al. [19], saline and saline-sodic soils became less sodic when vinegar residue was added.

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. Salt application decreased the amount of copper solubility in the soil or lowered plant uptake of excessive salts in the rhizosphere. However, the phyto-availability of copper may be altered by plant adaptation mechanisms [44]. When organic amendments are applied to soil, their inherent cation exchange capacity frequently increases, especially in the case of sandy deteriorated soil [32]. 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 [53]. Dume et al. [17] noticed that the addition of biochar increased the soil pH, available phosphorus, cation exchange capacity, organic carbon, organic matter, total nitrogen, exchangeable cations and electric conductivity but it had no appreciable impact on soil texture. In another study, Herath et al. [28] 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 increase soil aggregate stability and porosity and also observed a significant improvement in soil saturated hydraulic conductivity with the application of biochar @ 75 t/ha.

According to Gardner et al. [22], addition of biosolids to mine tailings lowered the volumetric capacity of a silt loam soil, whereas, sandy soil showed no change because of decreased bulk density. Although Schneider et al. [52] frequently reported conflicting and ambiguous results but it is generally true that adding organic amendments increased the saturated hydraulic conductivity. Findings of Saengwilai et al. [51] indicated that while lowering the amount of cadmium in rice grains, the organic amendments improved rice growth and yield and immobilized cadmium in the soil. For protecting the water resources next to land receiving organic amendments containing enteric microorganisms, human or veterinary pharmaceuticals, hormones, or other contaminants, the contaminants must be denatured, degraded, sequestered, or otherwise rendered inactive in the soil [37].

6. EFFECT OF ORGANIC AMENDMENTS ON PLANT GROWTH AND YIELD

After three years of investigation, Farooqi et al. [21] found that applying gypsum along with farmyard manure increased wheat yield to a maximum in third year by 51%. Additionally, the application of green manure along with gypsum significantly increased maize yield in third year by 49%. Awad et al. [9] realized maximum yield of wheat supplied with vermicompost and *Moringa* extract simultaneously. According to Kuziemska et al. [35], all of the organic amendments increased test plant yield and decreased copper's toxic effects on cocksfoot; however, cattle manure was the most effective fertilizer in terms of yield and protective effects against high copper levels, as evidenced by the highest tolerance indices. In comparison to NPK application, biochar dramatically enhanced the grain and straw yield of wheat (*Triticum aestivum* L.) by 15.7 and 16.5%, respectively [23]. Similar effects have been reported by Agboola and Moses [3], showing that addition of rice-husk biochar in soil increased the growth and yield of soybean (*Glycine max* L.). In another study, Abbas et al. [2] indicated 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.

7. EFFECT OF ORGANIC AMENDMENTS ON RECLAMATION OF MINE AND ERODED SOILS

In a study, Mulyono et al. [45] 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 a study by Gardner et al. [22], in British Columbia, 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. Organic matter has been found to have a substantially lower intrinsic density than mineral soil. Soil bulk density and penetration resistance reduced in the top 15 cm of copper mine tailings with increasing dry biosolids treatment rates between 50 and 250 Mg/ha. Alkaline and saline soil management techniques include the use of salt-tolerant cultivars, enhanced agronomic techniques, reclamation through amendments, and management of irrigation water and nutrients [31]. Leonardite was found to dramatically increase Chorati grain production (12.2 g plant^{-1}) and lowered the amount of cadmium in rice grain to 0.14 mg kg^{-1}, which is suitable for ingestion [51].

A study carried out by Leapheng et al. [39] reveals that *Jatropha curcas* plant was an effective alternative for phytoremediation of soil contaminated with heavy metals, particularly when combined with compost and EDTA (ethylene diamine tetra-acetic acid). Subsurface drainage technology has been widely implemented to restore the enhanced productivity of crops on irrigation-induced waterlogged saline lands, which are characterized by a shallow water table and a high concentration of soluble salts (ECe> 4 dS m^{-1}) in the root zone [10]. Larney et al. [36] demonstrated that in the presence of organic amendments (*e.g.*, erosion check treatment), the severely disturbed soil may regain productivity. According to Castillej and Castello [13], one of the main issues with adding organic amendments to deteriorated quarry soil is the potential for over fertilization as the 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. [48], the diversity and richness of plant species retained in the compost greatly enhanced the soil's edaphic flora's metabolic activity of soil flora.

8. CONCLUSION

Organic supplements are great for speeding up the processes of soil regeneration and, consequently, land restoration. 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. Research on the aforementioned topics would provide light on the importance of organic amendments in soil rehabilitation or amelioration as a first step in reclamation or restoration towards a long-term self-sustaining ecosystem.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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