Review Article

Restoring soil fertility through organic amendments: Impacts on agriculture and human health

Abstract

The application of organic amendments in agriculture has become a vital approach to addressing key challenges in Indian agriculture, such as fragmented landholdings, inadequate irrigation, and declining soil fertility. These amendments, which are added to soil to enhance its physical, chemical, and biological properties, play a significant role in promoting sustainable farming. Organic amendments like compost, manure, and green manure serve as excellent sources of organic carbon and essential nutrients. They improve soil structure, enhance drainage, and facilitate nutrient cycling while mitigating soil alkalinity and fostering microbial activity, thereby supporting overall soil health. Research highlights the effectiveness of organic amendments in improving soil quality. Organic amendments also offer notable benefits for human health by reducing dependence on synthetic fertilizers and minimizing toxic residues. They decrease the risks of heavy metal contamination and pesticide exposure. Adopting organic amendments supports the broader goals of sustainable agriculture by enhancing biodiversity, improving soil fertility, and reducing environmental and health risks. Nevertheless, further research is needed to refine these practices, optimize their application, and thoroughly evaluate their effects on human well-being and agricultural productivity. Organic amendments offer a promising solution to meet the growing food demands of an expanding population while maintaining ecological balance and ensuring food security.

Keywords: Human Health, Nutrient Recycling, Organic Amendments, Soil Health, Soil Reclamation

INTRODUCTION

India overtook China to become most populous country in the world during the first quarter of 2023. India's population is expected to reach 1.5 billion by 2025, according to the latest recent estimate (United Nations Economic and Social Commission for Asia and the Pacific projection). It is impossible to feed that many hungry people with the current trend in food

production, therefore, India must increase its output of food grains by more than 4-5 million tons annually. The limitations of the Indian agricultural system are the reason for the discrepancy between required and actual yield.

Challenges and constraints of Indian agriculture:

- ✓ Small and Fragmented Land Holdings
- ✓ Shortage of Irrigation Facilities
- ✓ Lack of Mechanisation
- ✓ Absence of sound Agricultural Marketing Facilities
- ✓ Scarcity of Capital
- ✓ Inadequate Storage and Transport Facilities
- ✓ Climate change

India's fertilizer use skyrocketed in the mid-1960s as a result of the introduction of high-yielding, fertilizer-responsive rice and wheat cultivars, which ushered in the Green Revolution era. For instance, nutrient consumption increased from 2.26 million tonnes (m t) in 1970–71 to 28.97 m t in 2019–20. However, the partial factor productivity (kg food grain produced per unit of fertilizer nutrient used) exhibited a decline from 28 kg kg^{-1} in 1970-71 to 10 kg kg^{-1} in 2019-20 which shows the decline in soil fertility over the years (Shukla et al., 2022). Along with declining soil fertility, use of agricultural chemicals as a fertilizer/amendment/pesticide is known to cause various negative effects on human health (Table1). Additionally, chemical residues in food from unscientific agriculture pose health hazards and undermine customer confidence. Groundwater depletion, caused by inefficient irrigation techniques and overexploitation of water resources, leads to scarcity and affects both agricultural productivity and local communities' access to clean water. Additionally, decreased input use efficiency, such as inefficient use of fertilizers and irrigation, leads to economic losses and environmental burdens.

The key issue at hand is soil health, which is declining daily as a result of human activity, mostly poor resource and land management. Among the methods for reestablishing the health of the soil are

- ✓ Improving soil organic matter
- ✓ Correcting the nutrient deficiency in the soils
- ✓ Controlling the soil erosion
- ✓ Managing soil ecology
- ✓ Reducing toxic residues in the soil

- ✓ Reclamation of problematic soils

Sl. No.	Agro-chemicals	Effects
1	DDT(Dichloro diphenyl trichloro ethane)	Affects central nervous system, carcinogen
2	Potassium fertilizer	Decreases vitamin C and carotene content in vegetables
3	Nitrogen fertilizers	Infant disease, methemoglobinemia, also amines produced from the nitrogenous fertilizer cause cancer in human beings
4	Aluminium based fertilizers	High levels of lead to birth defects, asthma, Alzheimer and bone diseases
5	Calcium rich fertilizers	Developmental and neurological toxicity, growth retardation, cognitive delay, kidney, nervous and immune system damage
6	Cobalt	At high level leads to lung damage
7	Chlorpyriphos	Causes fetal malnutrition, pneumonia, muscle paralysis and even death to respiratory failure
8	Malathion	Damages nervous system if it enters the body

Table 1: Effects of various agro-chemicals on human and animals

Baweja et al. (2020)

To reclaim the problematic soils, we adopt different methods such as –

1. Physical methods - Levelling, scraping and sanding etc.
2. Hydrological methods - Leaching, drainage and irrigation methods etc.
3. Biological methods - green manuring, mulching etc.
4. Chemical methods – Amendments

Amendments are the substances added to soil to reclaim problematic soils by enhancing its physical, chemical and biological properties**.** Also, organic amendments enhance the growth of beneficial soil microorganisms and boost nutrient cycling to maintain overall soil fertility and productivity.

Classification of amendments:

According to resource:

a) Organic- sphagnum peat, straw, compost, manure, biosolids, sawdust and wood ash.
b) Inorganic- lime, gypsum, vermiculite, perlite, pea gravel and sand.

According to purpose:

a) Improve physical attributes
b) Improve chemical attributes
c) Improve biological attributes

Types of organic amendments:

1. Animal manure.
2. Green manure and crop residues
3. Municipal biosolids and septage
4. Food residues and waste
5. Waste from manufacturing processes
6. Compost

Benefits of using organic amendments:

Organic amendments are great source of organic carbon so they increase organic matter and the availability of different organic sources are listed in the table 2. They contain several plant nutrients (Table 3) that are beneficial for plants growth and development. These amendments improve drainage thereby reduce water use and hence maintains good soil structure. Also, they are capable of correcting soil alkalinity and cutting down expenses.

Table 2: Potential availability of different alternative organic sources in India

Alternative organic sources	Total availability (m t yr^{-1})
Crop residues	500–550
Municipal biosolid	48
Rice husk	20
Sugarcane bagasse	90
Groundnut shell	11
Sugarcane pressmud	9.0
Poultry manure	6.25–8
Coir pith	7.5
Food/fruit processing industries	4.5
Seri waste	5
Green manuring crop area	About 7 m ha

Indoria et al. (2018)

Table 3: Mean nutrient content of some composted organic sources

Organic source	Organic carbon (%)	Nitrogen (%)	Phosphorus (%)	Potassium (%)	C: N

Paddy straw-based poultry waste compost	23.05	1.89	1.83	1.34	12.20
Coir pith (in deep litter system)	30.03	2.13	2.40	2.03	14.1
Papermill compost	25.46	1.34	0.58	1.12	19
Pressmud compost	33.17	3.1	1.95	3.5	10.7
Sugarcane trash compost	28.6	0.5	0.2	1.10	56.2
Castor cake compost	23.0	3.48	1.24	0.84	10.85
Bio compost	16.0	1.10	0.70	0.64	17.4
Vermicompost	23.1	1.59	1.63	1.07	15.7
Wheat straw compost	35.33	0.92	0.60	1.11	38.4
Mustard straw compost	33.59	1.04	0.54	1.35	33.59

Indoria et al. (2018)

With the appropriate use of organic amendments organic farming has been shown to encourage soil health while promoting agroecosystem sustainability, in contrast to conventional farming, which depends heavily on synthetic fertilizers and pesticides (Reganold and Wachter, 2016).

Effect of organic amendments on soil health:

There are several indicators that depict the effect of agricultural inputs on soil health which includes physical properties like soil structure, bulk density, porosity, aggregate stability, and water-holding capacity, chemical properties *viz.*, nutrients (micronutrients and macronutrients), pH, electrical conductivity, organic carbon and cation exchange capacity, and biological properties like microbial population (bacteria, fungi and actinomycetes), enzymatic activities etc. Organic amendments are known to affect the physical properties of soil significantly. Li et al. (2004) reported that the application of sphagnum peat @ 68 t ha^{-1} for 3 years recorded significantly higher soil water content (0.32 m^3 m^{-3}), lower bulk density (0.90 Mg m^{-3}) and higher total porosity (86 %) compared to control *i.e.*, no application (0.11 m^3 m^{-3}, 1.49 Mg m^{-3} and 46 %, respectively). Use of pressmud, an agro industrial waste as an amendment @ 12.5 t ha^{-1} recorded significantly lower pH, lower EC and higher organic carbon during 2003 and 2004 (8.25 and 8.23, 0.27 and 0.22 dS m^{-1}, 0.45 and 0.47 %, respectively) compared to control (8.45 and 8.45, 0.41 and 0.41 dS m^{-1}, 0.24 and 0.252 %, respectively), thereby improving the soil chemical properties (Rangaraj et al., 2007). Sharma and Dhaliwal (2019) recorded that application of 50 % of N + rice straw compost @ 10 t ha^{-1} recorded significantly higher dehydrogenase (72.6 µg g^{-1} ha^{-1}), acid phosphatase (5.59 µg *p*-nitrophenol g^{-1} h^{-1}), urease (222 µg urea g^{-1} min^{-1}) and phytase (0.619 µg g^{-1} h^{-1}) soil enzymatic activities in comparison to other treatments. Rangaraj et al. (2007) observed that application of pressmud @ 12.5 t ha^{-1} resulted significantly higher population of bacteria, fungi and actinomycetes during 2003 and 2004 (33.36

and 34.98 × 10^6, 10.32 and 11.59 × 10^3 and 8.58 and 8.75 × 10^3 CFU, respectively) compared to no organics (27.27 and 29.11 × 10^6, 8.23 and 9.29 × 10^3 and 6.96 and 7.12 × 10^3 CFU, respectively). Udaysooriyan et al. (2009) they noted that applying 50% of the gypsum requirement (GR) combined with pressmud @ 15 t ha^{-1} resulted in significantly increased cation exchange capacity (17.74 and 13.04 cmol (p^+) kg^{-1}) and reduced exchangeable sodium percentage (26.45% and 30.53%). Litardo et al. (2022) they studied application of sugarcane filter cake and vinasse supported in greater absorption of P with values of 29.2 and 24.3 kg ha^{-1} respectively and the absorption of K was highest with compost (127.0 kg ha^{-1}).

Effect of organic amendments on crop productivity:

In order to increase the agriculture productivity, the farmers are indiscriminately applying the synthetic chemicals along with over exploitation of natural on farm inputs which proves to be a great concern to the environment. In order to minimize the reliance on chemical external inputs it is necessary to go for the application of different available organic sources to reduce the adverse effects of chemicals on the environment and to maintain good soil health as well. Application of paper mill sludge increased N, P and K uptake significantly from 0 % lime requirement (LR) to 60 % LR. Highest N, P and K uptake of 96.9 kg ha^{-1}, 17.4 kg ha^{-1} and 47.7 kg ha^{-1}, respectively was observed under 60 % (Kar et al., 2014). Rohitha (2020) demonstrated that the soil application of the recommended dose of fertilizers (RDF) combined with coconut shell biochar @ 10 t ha^{-1} and 50% of the lime requirement significantly enhanced soybean productivity and profitability. This treatment resulted in a superior seed yield of 26.86 q ha^{-1}, gross returns of ₹1,20,920 ha^{-1}, net returns of ₹68,288 ha^{-1}, and a benefit-cost ratio of 1.32 in contrast to the absolute control which yielded lower outcomes with a seed yield of 18.28 q ha^{-1}, gross returns of ₹53,205 ha^{-1}, net returns of ₹25,655 ha^{-1}, and a benefit-cost ratio of 0.91. Mittra et al. (2005) reported that the application of fly ash @ 10 t ha^{-1} + FYM @ 12.5 t ha^{-1} + RDF recorded significantly higher number of pods $plant^{-1}$ (17.9), pod yield (2945 kg ha^{-1}) and haulm yield (4789 kg ha^{-1}) followed by fly ash @ 10 t ha^{-1} + RDF (17.0, 2791 kg ha^{-1} and 4725 kg ha^{-1}, respectively). Sesbania as green manure and gypsum application produced the highest grain yields of 3788 kg ha^{-1} and 3677 kg ha^{-1}, respectively in rice (Baig and Zia, 2006). Kumar et al., 2014 reported that application of lime @ up to 0.6 t ha^{-1} produced significantly higher growth traits in ricebean such as pod filling (92.43 %), biological yield (1.88 t ha^{-1}), production efficiency (11.12 kg ha^{-1} day^{-1}), gross returns (₹ 39,098 ha^{-1}) and B-C ratio (2.29) compared to control (81.97 %, 1.22 t ha^{-1}, 6.36 kg ha^{-1} day^{-1}, ₹ 23,064 ha^{-1} and 2.01, respectively). Koushalya, (2018) found that the application of 75 per cent RDF + pressmud @ 5 t ha^{-1} recorded significantly

higher grain yield (4043 kg ha^{-1}), higher gross returns (₹ 1,13,708 ha^{-1}) and benefit cost ratio (3.0) of finger millet compared to other treatments. In a study, Umer Chattha et al. (2021) observed that application of 5% sugarcane pressmud (SPM) increased 100 grain weight (11.28% and 8.41% and), grain yield (13.62% and 20.69%) and biological yield (12.25% and 10.45%) in mash bean (*Vigna mungo*) under modest (10 mg/kg) and stronger Cd (20 mg/kg) stress conditions.

Effect of organic amendments usage on human health

The effectiveness of an amendment is assessed by its effects on human health in addition to agricultural productivity and soil health. Numerous harmful heavy metals are recognised to pose a serious risk to human health by producing cancer. So, detoxifying these elements is of huge importance. Application of biochar nano sheets @ 2 per cent (158.69 g pot^{-1}) recorded lower cancer risks in wheat grain which was estimated based on lower potential toxic elements contamination viz., cadmium (1.06×10^{-3} mg kg^{-1}), chromium (1.18×10^{-4} mg kg^{-1}) and lead (2.93×10^{-6} mg kg^{-1}), lower total cancer risk (1.08×10^{-3} mg kg^{-1}) and hazard quotient (1.61×10^{-2} mg kg^{-1}) (Yousaf et al., 2017). Hussain et al. (2021) reported that the application of sugarcane bagasse recorded lowest translocation factor (0.08), bioaccumulation factor (1.52) in paddy grown under As-contaminated irrigated water stress. Liu et al. (2018) studied that biochar has emerged as a promising material for adsorbing and thus decreasing the bioavailability of pesticides in polluted soils, due to its high porosity, surface area, pH, abundant functional groups, and highly aromatic structure, mainly depending on the feedstock and pyrolysis temperature. Khan et al. (2017) reported that amendments bind bioavailable fraction of toxic metals on their binding sites and decrease cadmium availability to plants. Also, these amendments decompose and release a variety of nutrients which may enhance the yield of the crop in contaminated soils. This indicated that amendments could immobilize Cd for longer periods which justified the application of such materials in the Cd-contaminated soils to ensure food security. In this way these amendments help us to escape from the health risks associated with cadmium. The greater reduction in Cd accumulation in plant shoots was recorded by 50%, 36.8% and 23.7% when compost (CP), press mud (PM) and moringa leaf extract (ME) were added at 3% rate into wastewater polluted soil respectively, over control Bashir et al. (2021).

Conclusion

The potential reduction in exposure to synthetic chemicals and the promotion of nutrient-rich crops suggest positive implications, While the direct impact on human health may not be fully understood. The use of organic amendments in long-term agriculture holds promising benefits for soil health, biodiversity and sustainable farming practices. Furthermore,

comprehensive research is crucial to assess its effect and ensure a balanced approach to maximize both agricultural productivity and human well-being.

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References

Baig MB and Zia MS. 2006. Rehabilitation of problem soils through environmentally friendly technologies-II: Role of sesbania (*Sesbania aculeata*) and gypsum. Agricultura Tropica Et Subtropica 2006; 39(1): 435-467.

Bashir S, Bashir S, Gulshan AB, Khan MJ, Iqbal J, Sherani J et al. The role of different organic amendments to improve maize growth in wastewater irrigated soil. Journal of King Saud University-Science 2021; 33(7):101583.

Baweja P, Kumar S, Kumar, G. Fertilizers and pesticides: Their impact on soil health and environment. Soil health 2020; 59: 265-285.

Hussain MM, Bibi I, Niazi NK, Nawaz MF, Rinklebe J. Impact of organic and inorganic amendments on arsenic accumulation by rice genotypes under paddy soil conditions: A pilot-scale investigation to assess health risk. Journal of Hazardous Materials 2021; 420: 126620.

Indoria AK, Sharma KL, Reddy KS, Srinivasarao C, Srinivas K, Balloli SS et al. Alternative sources of soil organic amendments for sustaining soil health and crop productivity in India–impacts, potential availability, constraints and future strategies. Current Science 2018; 115(11): .2052-2062.

Kar G, Kumar A, Sahoo N, Singh R. Acid soil amelioration with paper mill sludge and its impacts on biomass, grain yield, water footprints and nutrient uptake by rainfed groundnut. Journal of the Indian Society of Soil Science 2014; 62(3): 259-268.

Khan MA, Khan S, Khan A, Alam, M. Soil contamination with cadmium, consequences and remediation using organic amendments. Science of the total environment 2017; 601: 1591-1605.

Koushalya TN. Impact of treated sugar mill effluent and soil amendments on the productivity of finger millet (*Eleusine coracana* L. Gaertn.) M.Sc. (Agri.) Thesis, UAS, GKVK, Bangalore 2018.

Kumar R, Chatterjee D, Kumawat N, Pandey A, Roy A, Kumar M. Productivity, quality and soil health as influenced by lime in ricebean cultivars in foothills of northeastern India. The Crop Journal 2014; 2(5): 338-344.

Li H, Parent LE, Karam A, Tremblay C. Potential of Sphagnum peat for improving soil organic matter, water holding capacity, bulk density and potato yield in a sandy soil. Plant and Soil 2019; 265: 355-365.

Litardo RCM, Bendezú SJG, Zenteno MDC, Pérez-Almeida IB, Parismoreno LL, García EDL. Effect of mineral and organic amendments on rice growth and yield in saline soils. Journal of the Saudi Society of Agricultural Sciences 2022; 21(1): 29-37.

Liu Y, Lonappan L, Brar SK, Yang S. Impact of biochar amendment in agricultural soils on the sorption, desorption, and degradation of pesticides: A review. Science of the total environment 2018; 645: 60-70.

Mittra BN, Karmakar S, Swain DK, Ghosh BC. Fly ash- a potential source of soil amendment and a component of integrated plant nutrient supply system. Fuel 2005; 84(11): 1447-1451.

Rangaraj T, Somasundaram E, Amanullah MM, Thirumurugan V, Ramesh S, Ravi S. Effect of agro-industrial wastes on soil properties and yield of irrigated finger millet (*Eleusine coracana* L. Gaertn) in coastal soil. Research Journal of Agriculture and Biological Sciences 2007; 3(3): 153-156.

Reganold JP, Wachter JM. Organic agriculture in the twenty-first century. Nature plants 2016; *2*(2), 1-8.

Rohitha DS. Effect of coconut shell biochar on soil properties and productivity of soybean (*Glycine max* L.). M.Sc. (Agri.) Thesis, UAS, GKVK, Bangalore 2020.

Sharma S, Dhaliwal, SS. Effect of sewage sludge and rice straw compost on yield, micronutrient availability and soil quality under rice–wheat system. Communication in Soil Science and Plant Analysis 2019; 50(16): 1943-1954.

Shukla AK, Behera SK, Chaudhari SK, Singh G. Fertilizer use in Indian agriculture and its impact on human health and environment. Indian Journal of Fertilisers 2022; 18: 218-237.

Udayasooriyan C, Sebastian SP, Jayabalakrishnan RM. Effect of amendments on problem soils with poor quality irrigation water under sugarcane crop. American-Eurasian Journal of Agricultural and Environmental Sciences 2009; 5(5): 618-626.

Umer Chattha M, Arif W, Khan I, Soufan W, Bilal Chattha M, Hassan M U et al. Mitigation of cadmium induced oxidative stress by using organic amendments to improve the growth and yield of mash beans [Vigna mungo (L.)]. Agronomy; 2021. 11(11): 2152.

Yousaf B, Liu GJ, Abbas Q, Ullah H, Wang R, Zia-Ur-Rehman M et al. Comparative effects of biochar-nanosheets and conventional organic-amendments on health risks abatement of potentially toxic elements via consumption of wheat grown on industrially contaminated-soil. Chemosphere 2018;192: 161-170.