



Review Article

A Review on concerns about soil quality and innovative methods for improving soil health

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Abstract

Soil health is a major concern of the agriculture sector, instead of playing a critical role in food production healthy soil encompasses multifunctional capacity viz ecosystem services, nutrient cycling. Rapidly increasing population and urbanization enhance pressure on the farming system which severely affects soil fertility and health. Addressing challenges related to food security has often led to agricultural practices that neglect the soil's multifunctionality and health, resulting in reduced ecosystem service, degraded soils, and eventually, crop failure. Hence, to overcome soil degradation, the use of the innovative method is an effective approach that ameliorates the soil depleted pool against conventional method, have own setbacks. In this review, we have highlighted some innovative methods viz soil amendment, phytoremediation, PGPR as a biocontrol agent, grazing management, and adaption of conservation tillage. In this literature, all these methods have shown efficient results for addressing the soil health conservation and food security challenges from the degraded soils with economic feasibility.

Keywords microbes, PGPR, soil, soil conservation

Introduction

Soil health is the capability of the soil to perform a function in an ecosystem to maintain the quality of air and water, increase the production of plants and animals and promote their health [1]. It is the main source of nutrient, water, provide support to plant and four-dimensional constituent [2]. The biological health of the soil is the capacity to suppress the pathogens, support microbial and plant health [3]. Soil act as a complex habitat for many kinds of fungi, bacteria, and other microorganisms [4].

Soil chemical health is the availability and balanced proportion of plant nutrients. According to an estimation about 95% of food is produced through soil [5]. According to a recent report of FOA and ITPS, the soil has been degraded as we use it to increase the agricultural yield and to fulfill human needs [6]. As soil erosion and its degradation led to problems of food security and productivity [7]. PCB and heavy metals contamination caused by soil degradation harm human health [8].

Agroecological methods including soil conservation and organic farming have the potential to improve the sustainability of water; soil and ecosystem also maintain the productivity of food (IPES-Food 2016). Soil can improve by improving its different properties, as the ability of soil to maintain and fulfill the ecosystem and plant requirements of air and water is called physical health of soil [9]. Soil health and food security can be improved by spreading awareness about the sustainability and management of soil. Human society

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should also be aware of the significance of soil for food production which helps for biosphere maintenance [6].

Conservation of soil ecosystem

Degrading the soil ecosystem may lead to a decrease in the production and nutrient capacity of the soil. Soil can be improved by using green manure in rice crops. A healthy soil ecosystem should provide recycling of nutrients, biodiversity and increase soil microorganisms (10). Carbon content can increase by providing soil cover which also helps in the maintenance of soil aggregation. Water retention, nutrient retention, and rhizospheric interaction can be improved by increasing soil organic matter.

Soil performs ideally due to soil biodiversity and biochemical processes occurring in the soil [11]. Different pests and pathogens can also be suppressed by increasing microbial soil community [12]. Agricultural activity can affect soil health which can also be replenished by crop rotation. Crop rotations increase the biodiversity of soil, reduce the chances of pest attack, replenish nutrients and it is economically beneficial [13]. Other management practices such as low tillage or zero tillage practice can also increase the soil organic matter [14].

Essential Elements Required for Human Health

The significance of elements can be understood by the connection between soil health and food production [8]. Fertility of soil is the key factor that interconnects soil health, the nutritional quality of food, fruits, and vegetables that are organically produced have a high level of phytochemicals. Phytochemicals can promote health [15]. Toxicity and deficiency of any essential element in humans depend upon their concentration in soil. Few elements have no beneficial effect though they have some toxic effects even in small concentrations [16].

Figure 1, represents the factors affecting degradation of soil and innovative techniques to improve soil health to secure food safety;

Categorization of Soil Microbes

Beneficial Microbes

Rhizospheric microbes have beneficial effects, such as mycorrhizal fungi, N-fixing bacteria, mycoparasitic fungi, PGPR, protozoa, and biocontrol microbes [17]. Beneficial microbes can increase plant nutrition and growth in direct and indirect ways [18]. The use of chemical fertilizer can also reduce by understanding the interaction between rhizospheric microbes and their relationship [19]. AMF is the most common mycorrhizal association that stimulates abscisic acid production [20].

Pathogenic Microbes

Most microbes do not cause harm to humans but some bacteria, fungi, viruses, and protozoa cause diseases in humans due to alteration in their biomass which is caused by different biotic and abiotic factors. For example, valley fever is a disease caused by *Coccidioides spp.* Fungus is present in the soil. Their microscopic spores enter through the respiratory track of humans, it can live in an extreme environment and alkaline conditions [21]. Though fungus causes bone and skin problems by penetration, the threat is severe in case of inhalation [22].

Deterioration of Soil Health

Soil Erosion

The most prominent method which causes soil degradation is soil erosion. According to an estimate, 19.65 million km² area is degraded by erosion worldwide [23]. In arid and semi-arid regions water erosion is most common to cause damage to the soil ecosystem [24]. Water and wind are two agents which cause soil erosion. Wave erosion along the canal is caused by the combination of water and wind erosion.

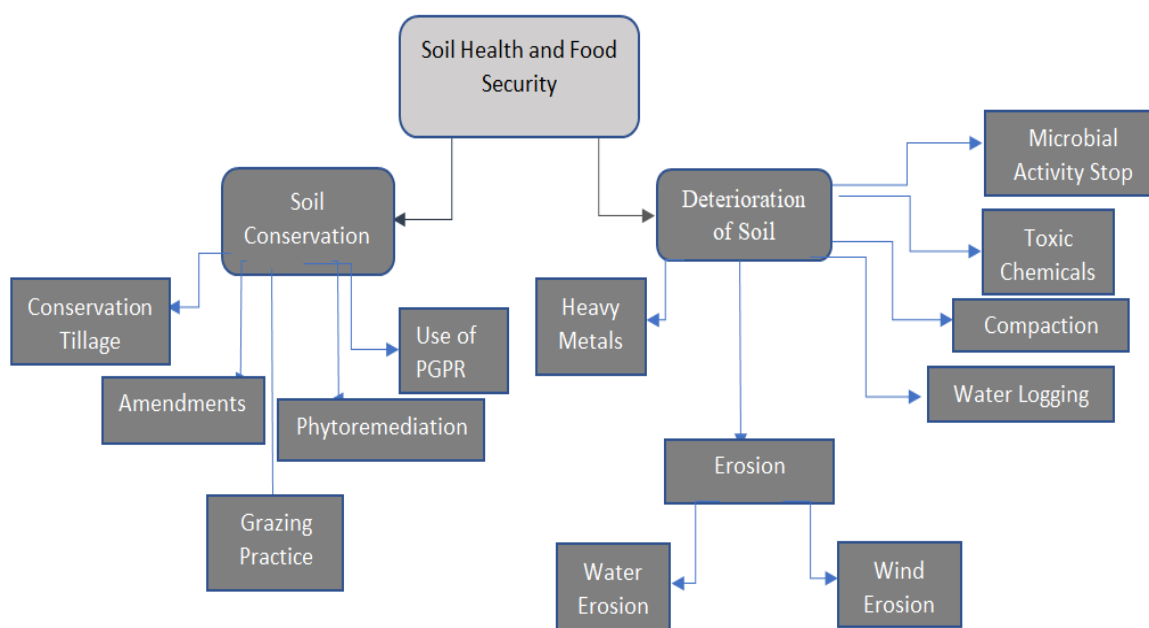


Figure 1. Soil deterioration sources and soil conservation methods to recover soil quality

Wind Erosion

Wind erosion is caused by blowing wind. The erosion process can be controlled by improving soil physical health, performing the zero-tillage process, and maintaining carbon sequestration in soil [25]. Wind erosions decrease the nutritional value of soil.

Water Erosion

Erosion caused by water is known as water erosion followed by detachment and transportation of soil particles. When erosion is caused by rainfall different factors influence the rate of water erosion such as intensity, slope, erodibility, steepness, and frequency of drop. Splash erosion, gully erosion, rill erosion are types of water erosion that degrade the soil more intensively than others [26].

Health Defect Due To Heavy Metals

Degradation of soil with heavy metals caused by sewage sludge and industrial waste enters into the food chain and cause human health problems due to accumulation in the body of humans and animals [27]. To overcome the toxicity of heavy metals, phytoremediation is used which improves soil health and decreases soil pollution [28].

Waterlogging

The state at which moisture content of soil increase and raise the level of groundwater [29]. 11.6 million ha area of India is degraded by waterlogging. In surface water logging excessive water is present on the soil surface and when water is present below the surface it refers to as sub-surface waterlogging [30].



Loss of Microbial Activity

The microbial community in the soil is lost by nanoparticles. By measuring the respiration of bacterial community effect of nanoparticles could be measured [31]. The microbial community of soil is also affected by climate change, they change their physiological properties and growth rate [32]. Nanoparticles and CuO disturb the microbial community, their enzymatic activity in rice flooded area and ZnO affect microbes in alkali soil [33].

Compaction

By using heavy machinery and continuous tillage soil becomes compacted. Soil compactions affect soil health by decreasing porosity and increasing bulk density which negatively affects the yield. Soil aggregates broke down and decrease the porosity to form soil crust [34].

Chemical Toxicity

Chemical degradation of soil causes soil pollution, accumulation of chemicals, and changes the soil reactions. Acidity is the state by which soil PH becomes decreased and unhealthy for cultivation. Soil acidity is caused by using acid-based fertilizers and also by acid rain [35]. The use of agrochemicals is the main source of accumulation in the soil to degrade soil health. Agrochemicals were used for weeding management and plant protection which causes toxicity in soil [36]. The use of sewage sludge to increase the fertility of the soil and the use of chemical salt is also a major source of toxicity in soil which harms the health of soil [37].

Health Defect Due To Heavy Metals

Soil Amendments

Numerous soil amendments (organic and inorganic) are used to improve soil health, mitigate the negative effect on soil and improve its quality and biochemical function. It brings soil reaction to the desirable range, considering exchangeable sodium percentage, soil reactions, and electrical conductivity of the soil that classified as saline-sodic, sodic, and saline soil which are significant reasons for land degradation. Saline soil contains soluble salts like sodium chloride and sulfate while sodic soil is dominated by sodium carbonate. These soil are reclaimed via inorganic soil amendment (contained minerals associated with soil fertility) as saline soil is reclaimed with freshwater plenty that leached soluble salts below the root zone, chemical soil amendments as iron pyrite and limestone also can be added while sodic soil can be reclaimed gypsum, sulfur, iron sulfate, and iron pyrite that also improve the soil properties as aggregation, porosity, and infiltration rate, replacing exchangeable sodium concentration from exchange complexes and bringing the pH in the neutral range[38].

However, organic soil amendment (animal manures composts, biochar, cover crops, green manures, crop residues, straws, etc.) is widely used to augment plant and soil health that a way of sustainable agriculture [39,40,41,42,43,44]. These amendments are extremely rich in macro-and microelements and organic matter that increase the soil fertility via providing microbial substrates and ameliorating microclimatic. As reported temperature decreased from 6% to 18% via studied legumes and mulches effects for the urban abandoned land restoration [45]. Studies show that soil amendments addition as organic and inorganic stabilizing the soil, increasing soil pH (3.2–7) and reducing the trace metal solubility >80%, and stabilizing the soil [46].

Phytoremediation

It is an environmental-friendly and cost-effective use of higher plants for rehabilitation of contaminated soil and groundwater [47]. Due to the capacity to combat soil pollution, it improves soil health that is achieved through phytovolatilization phytoaccumulation (phytoextraction), phytodegradation, or Phyto stabilization [48]. This strategy is important for heavy metal pollutants, organic pollutants, industrial effluents, sewage water, waste for landfills used as manure, etc. Nowadays, increasing use of wastewater in peri-urban areas mainly for flowers and vegetables growing and agrochemicals in agriculture causes soil pollution requisite to be cost-effective reclamation.

Soil degradation is triggered by soil pollution because agrochemicals excessive use also leads to soil groundwater pollution [49]. So, in agricultural production systems, it is a prerequisite to incorporate the phytoremediation strategy [50, 51]. The economic success regarding phytoremediation depends on pollution amount growth rate [52] and photosynthetic activity of plants [53]. It also helps to reduce pollutant adverse effects on animal and human health. The reclamation of HM contaminated environments via phytoremediation strongly depends on plant-microbiome interactions.

PGPR as Biocontrol Agent

The use of microbes to suppress plant disease is known as biocontrol offers a powerful alternative to synthetic chemicals. Increasingly use of chemical pesticides in terms of enhanced fiber and food production leads to environmental and human health hazards. Some pesticide use stopped due to hazardous nature hence eco-friendly and non-chemical strategy is needed that is PGPR is the most effective way for the management of plant disease [54, 55]. Due to the nontoxic nature of microbes, their treatments are sustainable over conventional chemical control methods.

PGPR possesses different mechanisms including antibiosis, which induces systemic resistance in plants, bio-surfactants, cell wall degrading enzymes, and volatiles [56]. *Paenibacillus*, *Acetobacter*, *Pseudomonas*, *Bacillus*, *Streptomyces*, and some other bacterial strains that are PGPR have been used as a bio-control agent [57]. Microbial species especially reside between higher plant and soil interfaces having plant-growth-promoting and biocontrol potential [58, 59].

Adaptation of Conservation Tillage

Three major principles of conservation tillage (CT) are reduction in mechanical soil disturbance, continuously ground surface cover with soil mulch cover, and crop species diversification [60]. CT practices consist of numerous forms viz, reduced (minimum) tillage, zero tillage (No-till), ridge tillage, mulch tillage, and contour tillage [61]. The main reason behind CT adoption over conventional plow tillage is the adverse effect on soil health via fading organic carbon, and erosion.

CT has a positive impact on soil health as improve soil physical parameters (water holding capacity, soil aggregation, infiltration rate porosity, bulk density, and soil strength), microbial population, organic carbon, nutrient level, reduce soil erosion, and depletion of the nutrient pool via crop species diversification and conserve soil moisture. CT also has an impact on crop yield due to its effect on nutrient and water use efficiencies [62], root growth [63], and agronomic yield [64]. CT also contributes to the environment as reduce runoff that carries along with soil sediments and residual agrochemicals.

Grazing Management

Global land comprises 26% of grasslands [65] that globally meet increasing population demand because of their use of about 34 million km² as livestock grazing [66]. Livestock is considered as agriculture's key GHG (greenhouse gas) emitter, contributing > 1/3 of agricultural emissions [67]. Soil C changes, livestock induced can have greater impacts on the production systems GHG balance [68,69]. The most significant SOC (soil organic carbon) reservoirs are grazing lands comprising >30% of total global SOC [70].

There is a need to improve grassland management for carbon stock enhancement that could improve soil fertility [71], and enhance the resilience of increase agricultural systems resilience to extreme weather events [72], and mitigate agricultural GHG emissions [73]. Intensive grazing in northern China resulted in decreased carbon stocks, reversed by animal exclusion over 30 years [74]. In the stepper region of China, carbon stocks at moderate grazing intensity were higher than at low and high grazing intensities [75]. So, there is a need for some grazing management approaches as

The pyric herbivory (PH) approach includes rotational patch burning (a primary mechanism) for moving livestock induce impacts across the landscape, concentrating grazing animals, with a constant continuous stocking over the entire management unit [76]. Adaptive multi-paddock (AMP) grazing, improve ecological function via the use of multiple paddocks per herd [77]. This approach is achieved via short period grazing, animal numbers adjustment according to available forage, providing recovery periods to accommodate seasonal variation (inter and intra) in the growth of the herbaceous plant, and for forage,



regrowth leaving sufficient post-grazing plant residue. There is a need to highlight that the AMP grazing approach is not alike to rational grazing, which is used for diverse grazing management approaches, subdivide the grazing area into any paddock number.

Conclusion

Soil health is an essential tool in environmental sustainability. Moreover, it directly involves food production that ultimately impacts public health. In this literature, we have reviewed innovative methods for degraded soil conservation. These methods especially PGPR as a biocontrol agent and conservation tillage practices emerged as strong contenders worldwide. In addition, phytoremediation reduces heavy metal toxicity, grazing management, and soil amendment improves soil health via nutrient cycling, plant biomass production, surface water infiltration, wildlife habitat, and soil- biodiversity. In this way, an innovative method for the conservation of degraded soil has been made extremely efficient and cost-effective.

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