Agricultural soil reclamation and restoration of soil organic matter and nutrients via application of organic, inorganic and bio fertilization (Mini review)

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Abstract: Food security is directly related to the ability of the land to support the population. Causes for land degradation are numerous and include the decline of soil fertility, development of acidity, salinization, alkalinization, deterioration of soil structure, accelerated wind and water erosion, loss of organic matter and biodiversity. Therefore, it is of critical importance to increase soil health and restore degraded soils in order to achieve sustainable development. Restoring the soil quality for crop production through the appropriate soil management and conservation techniques is important for all nations, primarily those at risk with respect to food security. Soil organic matter (SOM) plays a central role in maintaining soil functions and preventing soil degradation. Both organic matter and microorganism serve as a reservoir of plant nutrients. This study concluded that soil organic carbon and other mineral and nutrients restoration were noted with the soil modification and incorporation of various organic amendments. Plant residues and field biomass were promising for nutrients replenishment while biochar was the key component for the enrichment of soil organic carbon. Animal-based residues and manure application enhanced soil mineral and micronutrients concentration with the advantage of soil reclamation and restoration.
1. Introduction

Land degradation, either natural or induced by humans, is a continuing process. It has become an important issue through its adverse effects on national natural resources, food security, and the livelihood of the world population [1]. Restoring the soil quality for crop production through the appropriate soil management and conservation techniques is important for all nations, primarily those at risk with respect to food security [2]. Soil organic matter (SOM) plays a central role in maintaining soil functions and preventing soil degradation. Both organic matter and microorganism serve as a reservoir of plant nutrients [3]. Microbes also help to build soil structure and provide other benefits. In Microorganisms Fungi come in many different species, sizes, and shapes in soil [4].

Many fungi aid plants by breaking down organic matter or by releasing nutrients from soil minerals. Some fungi produce plant hormones, while others produce antibiotics, including penicillin [5]. There are even species of fungi that trap harmful plant-parasitic nematodes. Bacteria are the most numerous type of soil organism: every gram of soil contains at least a million of these tiny one-celled organisms [6]. There are many different species of bacteria, each with its own role in the soil environment. One of the major benefits bacteria provide for plants is in making nutrients available to them. Some species release nitrogen, sulfur, phosphorus, and trace elements from organic matter [7]. Others break down soil minerals, releasing potassium, phosphorus, magnesium, calcium, and iron [8]. Still, other species make and release plant growth hormones, which stimulate root growth.

2. Role of organic amendments in soil reclamation and restoration

Organic amendments improve the physical soil conditions and chemical functions like sorption capacity, mobilization of nutrients by mineralization, short term immobilization into soil organisms, long term fixation into stable humic substances and supply of organic substances [9]. This system maintains soil fertility and plant nutrient supply from various sources through an integrated approach [10]. Organic matter supplies macro and micronutrients to plants and improves soil chemical and physical properties. Incorporation of organic matter increase nutrient availability and provide food for soil microorganisms. Organic matter acts as a soil conditioner and considers nutrients reservoir, which prevents loss of nutrients by leaching or erosion [11]. [12] studied various organic sources (PM, FYM, GM, PM, SR) for enhancement of soil physio-chemical properties and crop productivity. They reported that organic amendments increase soil quality, aeration in soil and microorganism population in soil [13]. They concluded that maximum 1000-grain weight for 10, 12 t ha\(^{-1}\) was recorded in poultry manure and 30 t ha\(^{-1}\) FYM. They also recorded the highest grain yield and biological yield of maize at 10, 12 t ha\(^{-1}\) PM. [14] investigated the influence of various organic and inorganic phosphorous fertilizers for P utilization efficiency on maize crop. Combine application of organic and inorganic P fertilization enhanced plant height, grain yield, biological yield, leaf area and chlorophyll contents as compared to control treatment. [15] reported that availability and uptake of phosphorus from organic manures in groundnut (Arachis hypogea L.) corn (Zea mays L.) had a significant direct and residual effect compared to inorganic single super phosphate on the biomass, P content and uptake in both groundnut and corn. They reported that organic matter increases soil quality, aeration in soil and microorganism population in the soil. [16] stated that organic inputs applied in the soil produce organic anions during decomposition, which can compete with P for the same sorption sites and thereby increase P availability in the soil. They reported that organic residues increase soil quality. Interestingly, they observed that at equal levels of P from inorganic and manure sources, more yield was obtained in manure applied fields [17]. [13,18] conducted an experiment on two hybrids of corn and organic sources, poultry manure (PM), farmyard manure (FYM) and urea and with various combination of these (PM, FYM, and urea in such a way to supply 200 kg ha\(^{-1}\)) on sandy loam soil. Both hybrids have differed significantly in the number of cobs plant\(^{-1}\) 1000 grain weight and grain yield while harvest index (HI) remain the same for both hybrids.

3. Role of microbes in soil reclamation and restoration

Biofertilizers are known to play a number of vital roles in soil fertility; crop productivity and profitability [19]. Biofertilizers are the products containing living cells of different types of beneficial microbes (bacteria, fungi, protozoa, algae and viruses). Some of the commonly used beneficial
microbes in agriculture include *Rhizobia, Mycorrhizae, Azospirillum, Bacillus, Pseudomonas, Trichoderma, Streptomyces species* etc. Beneficial microbes are essential for decomposing organic matter in the soil and increase essential macro-nutrients (nitrogen, phosphorus, potassium, sulfur, calcium and magnesium) and micro-nutrients (boron, copper, chlorine, iron, manganese, molybdenum and zinc) availability to crop plants [20]. Beneficial microbes not only improve crop growth and productivity by increasing photosynthesis and producing hormones and enzymes but also improve crop quality by controlling different insects and various plant diseases [21,22]. Beneficial microbes reduce the use of chemical fertilizers and thereby reduce environmental pollution caused by chemical fertilizers [15]. Integrated use of organic, biofertilizer with a small number of chemical fertilizers results in higher crop yield than chemical fertilizers alone [23,24]. [25] reported that biofertilizers are known to play a number of vital roles in soil fertility; crop productivity and profitability. Beneficial microbes are essential for decomposing organic matter in the soil and increase essential macro-nutrients (nitrogen, phosphorus, potassium, sulfur, calcium and magnesium) and micro-nutrients (boron, copper, chlorine, iron, manganese, molybdenum and zinc) availability to crop plants. [17,26] investigated the mode of survival of *Biophos (Phosphobacterial inoculum)* and their effectiveness to enhance P availability. The results of the study suggested that the microbial population was highest in soils supplemented with the farmyard manure [1,3,14]. A comparison of the control with *Biophos* and rock phosphate (RP) with *Biophos* treatments indicated that wheat grain yield increased 21% and 35% respectively, due to enhanced availability of phosphorus. [27] observed the effect of Azospirillum alone and in combination with other biofertilizers on the yield of leafy vegetables. They concluded that yield increased 15.25 and 14.95 % over the untreated control. In general 6.68, 11.83 and 14.46 % more yield was obtained due to inoculation with the Azotobacter + Azospirillum, respectively. [28] reported that Rhizobial inoculation alone and combined with fertilizer, produced significantly higher nodule number, pod number, pod weight, nut yield and yield of groundnut as compared to uninoculated ones. Combined treatments of *Rhizobium* and fertilizers gave the highest nut and Stover yield.

4. Role of inorganic fertilization in soil reclamation and restoration
Phosphorus (P) is the second most important crop nutrient after nitrogen that increases crop productivity and profitability on P-deficient soils in Khyber Pakhtunkhwa [3,5]. Adequate phosphorus results in higher grain production, improved crop quality, greater stalk strength, increased root growth, and earlier crop maturity. Crop phosphorus nutrition depends on the ability of the soil to replenish the soil solution with phosphorus as the crop removes it and on the ability of the plant to produce a healthy and extensive root system that has access to the maximum amount of soil phosphorus. The combined use of organic and mineral fertilizers increases each other’s efficiency. Interaction of chemical, organic and biological sources and their effective management not only to sustain crop productivity and soil health but they also optimize the use of chemical fertilizers for different crops in different cropping systems. The present study is therefore designed to study the effect of organic sources, biofertilizers, and inorganic P fertilizers under maize and soybean cropping systems. [29,30] reported that appropriate source of P application had a considerable impact on growth, yield and yield contributing parameters. They concluded that among various P sources, DAP and SSP resulted in higher productivity and profitability and net return, respectively [31,32]. They suggested that growing of maize should be treated either SSP or DAP to get higher yield and maximum net return in maize wheat cropping system. [33] conducted an experiment on different dates of P application with various rates. They concluded that the maximum number of leaves, plant height, fresh weight of leaf, dry weight of leaf and other phonomological and physiological parameters were significantly affected by P application at the rate of 90 kg ha⁻¹ before a0 days of sowing.

5. Role of integrated fertilization (organic+inorganic+biofertilization) in soil reclamation and restoration
[34,35] studied that maize yield was more when NPK was applied in combination with FYM than without FYM. They reported that the yield of maize was increased by 20% when the half dose of NPK mixed with FYM, while 18 % when FYM was mixed with a full dose (120 - 90 -60) of NPK.
They reported that organic amendments increase soil quality, aeration in soil and microorganism population in the soil. [36,37] evaluated the influence of the application of farmyard manure (FYM) in combination with three levels of mineral fertilizers on yield of rice. They reported that application of FYM at 10 t ha\(^{-1}\) increased grain yield of rice by 25 %. The also reported that highest grain yield was obtained by the use of FYM at 10 t ha\(^{-1}\) and chemical fertilizer at 120-60-45 kg NPK ha\(^{-1}\). [38]observed that root length and nutrient uptake of wheat increased significantly by combining organic manure and N fertilizer, which ultimately enhanced grain and straw yield. They reported that organic amendments increase soil quality, aeration in soil and microorganism population in the soil which leads to nutrients availability and better soil health. [39,40] studied the influence of biofertilizers on maize yield and found that *Azospirillum brasilense* or commercial biofertilizers Cerealain with half rate of N (144 kg ha\(^{-1}\)) significantly increased maize grain yield, biological yield and other yield contributing parameters. [41] studied the response of guinea grass to biofertilizers inoculation and nitrogen. Inoculation with VAM gave the highest green forage, dry matter and crude protein. Effect of three green gram cultivars viz. NM-51, NM-54 and NM-92 to microbial inoculation was studied by [42]. Growth and yield components were highest in cv. NM-92 with inoculation. [14,43] reported that the effectiveness of Phosphorous fertilizers influenced by differences in Physico-chemical properties of soils, climate, availability of other major nutrients and the form in which Phosphorous is applied. FYM can considerably influence availability, uptake, leaching and fixation of Phosphorous. [44] evaluated the influence of phosphorous sources and various application methods. They concluded that all growth and yield contributing parameters were significantly influenced by phosphorous source DAP treated with 90 kg ha\(^{-1}\) by application method 2/3 P at side dressed with first irrigation. [45,46] also reported that application of farmyard manure (FYM) to soils with high pH, not only supply Phosphorous but also on decomposition, provides acid compounds that increase the availability of mineral forms of Phosphorous in the soil [14,47]. Many studies concluded that low productivity is primarily related to management practices [48-75]

Organic manure typically has several advantages due to balanced nutrient supply, including micronutrients, increased soil nutrient availability due to increased soil microbial activity, decomposition of harmful components, improved soil structure and root growth, and increased access to soil water [76-85]. At the other hand, soil fertility is characterized as soil quality that provides the right amount of plants or plants to grow and the right balance for this growth [86-92]. Soil organic matter, on the other hand, is critical to crop production and sustainable soil fertility [93-108].

6. Conclusion and future prospect

This study concluded that soil organic carbon and other mineral and nutrients restoration were noted with the soil modification and incorporation of various organic amendments. Plant residues and field biomass were promising for nutrients replenishment while biochar was the key component for the enrichment of soil organic carbon. Animal-based residues and manure application enhanced soil mineral and micronutrients concentration with the advantage of soil reclamation and restoration. In future scenario combine integration of biochar, plants based residues, animal wastes and beneficial microorganism should be treated for degraded soil and for its remedial action.

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