Integrated Soil Fertility Management

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Abstract

Soil is an organic thin layer of earth's crust, a living media. Soil is the basis entity for farming, without which farming can't be practiced. The human greed has led to the exploitation of the soil to a great extend in the recent times. Soil fertility depletion and soil quality decline have been threatening the ecological and economic sustainability of crop production. This is the major concern for the sustainability of Indian agriculture. This has made the soil exposed to excess chemicals in the form of fertilizers, insecticides, pesticides etc. Integrated Soil Fertility Management involves the use of both chemicals and organic matter. Agronomic practices are also to be followed by taking care of plant densities and weeding, so that nutrients can be used efficiently. World has been observing World Soil Day on December 5 to maintain the optimum level of soil health. In this lieu, United Nations General Assembly declared 2015 as International Year of Soils, creating awareness amongst the stakeholders and to promote sustainable use of soil.

Keywords

Soil · Soil management · Soil health · World soil day

5.1 Introduction

In carrying out sustainable agriculture, deterioration in the fertility of the soil is a major concern. Maintaining optimum soil fertility, Indian farmers, have been practicing agricultural system which ensures modest and stable yields. The increased

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population has led to the introduction of high yielding varieties of seeds, intensive excess of chemical fertilizers, pesticides and extensive tillage. India is highly affected by land degradation. Rain-fed areas are seriously affected by land degradation.

Year 2005 was declared as International Year of Soil with the following objectives to be achieved:

(i) To generate awareness among society and decision-makers the vitality of soil in human life.
(ii) Provide education to public about the role of soil in food security, climate change adaptation and mitigation, essential ecosystem services, poverty alleviation and sustainable development.
(iii) Enact according to the policies and programs for the sustainable management and protection of soil resources.
(iv) To adapt sustainable soil management activities to develop and maintain healthy soils for various land users and population groups.
(v) With a well planned process of Sustainable Development Goals initiatives should be carried out.
(vi) Rapid capacity enhancement for soil information collection and monitoring should be taken care at the regional, national and global level (Patel 2016).

It is to be remembered that all stakeholders associated with agriculture all over the world have to put in all the efforts to promote scientific management of soil resources for soil protection, conservation and sustainable productivity. This goal can be achieved by (i) consider technical cooperation and investment in R & D from all over the globe. (ii) targeted soil research and development is to be focused on identified gaps and priorities (iii) Quantity and quality of soil data and information is to be enhanced: data collection (generation), analysis, validation, reporting, monitoring and integration with other disciplines (iv) novel methods, measurements and indictors for the sustainable management and protection of soil resources. (v) initiation of policies and programs to educate farmers and create awareness to promote regenerative landscape and integrated management of soil and other natural resources viz., water, vegetation. Biodiversity is also to be taken care of to be able to achieve sustainable agricultural production that is good for the environment and farm profits (Patel 2016).

For the recovery of soil health, Integrated Soil Fertility Management (ISFM) has to be adopted. The involvement of both chemical fertilizers and organic matter (crop residue, compost and green manure) along with the practices of crop rotation and legumes as inter-crops (crop which fix atmospheric nitrogen) can lead to improvised soil health (Mundt 2002; Srinivasarao et al. 2012; Kumar 2017). Also studies carried out in recent times have found that the application of combined inputs and practices can almost double the crop yield compared to fertilizers applied separately (Agegnehu and Bekele 2005; Våje 2007; Dercon and Hill 2009). India along with other various countries has seen soil fertility decline as a major problem (Sanchez et al. 1997; Bationo et al. 2006; Sanginga and Woomer 2009; Vanlauwe et al. 2010).

5.2 Characteristic Features of Soil

Soil is habitat for various living organisms which interact amongst themselves and are responsible for the life which exist on this planet. Living organisms of the soil control water infiltration, mineral density and nutrient cycling. Microorganisms fungi and bacteria associate with organic matter in the soil to break it down into yet smaller molecules, earthworms digest organic matter, recycle nutrients and thus makes the surface soil richer. Along with the living component soil has minerals and nutrients. Carbon is one of the most important variable within the soil, which assists in many processes like development of soil structure, water storage and nutrient cycling. Soil carbon is available in three forms, viz., living carbon, labile carbon and fixed carbon. Microbes, plant roots, nematodes, earthworms etc. belong to living carbon. Labile carbon comprises of stable compounds as humates and glomalins. Sequestered carbon includes the fixed carbon plus the total living biomass. If soil possesses high organic carbon content then rainfall infiltration and retention is enhanced. Although, it takes around 500 years for the formation of top soil, soil erosion happens at a much faster rate. To produce nutritionally dense food, structural, biological and mineral health of the soil (N, P, K) should be considered (Patel 2016).

5.3 Soil: Our Vital Resource

Soil is one of the most complex biological materials on our planet. Soils are responsible for 95% of our food. 10% of the total CO_2 emitted is stored in soil. If scientifically composted, half of the kitchen waste could have nurtured our soil. Being a reservoir for minerals, organic matter, water and air, it provides a complete balance of nutrients for plant growth. Food, feed, fuel, fibre, water and medicinal/herbal products are important for human well-being. Soils play an important role in the carbon cycle. Soil also happens to be largest pool of organic carbon, which is the key factor in mitigating and adapting to climate change. It also turns out to be the appropriate for storage and distribution of water. According to FAO, a third of all soils are degraded due to erosion, compaction, soil sealing, salinization, depletion of soil organic matter and nutrients, acidification, pollution and other processes caused by unsustainable land management practices. Even if scientific approaches are researched and adopted, the global amount of arable and productive land per person in 2050 will be only one-fourth of the level it was in 1960. Hence, it is must for policy makers and farmers to appreciate soil functions and assess the risks it is running right now (Patel 2016).

5.4 Status of Indian Soil

About 18% of world's human population and 15% of livestock population is reared in India possessing just 2% of world's geographical area and 1.5% of forest and pasture land. In India out of a total of 328.7 million hectares (MHA), 142 MHA are net cultivated area. Out of this 40%, i.e. 57 MHA are irrigated and rest 60% i.e. 85 MHA are rain-fed. Out of 328.7 MHA about 120.4 MHA (37%) suffer from various kinds of land degradation, viz., water and wind erosion (94.9 MHA), water logging (0.9 MHA), soil alkalinity/sodicity (3.7 MHA), soil acidity (17.9 MHA), soil salinity (2.7 MHA) and mining and industrial waste (0.3 MHA). Intensive agriculture, greater mining of nutrients has led to deplete the soil fertility and deficiencies of secondary and micronutrients, depleting water table level and its quality. These all have caused soil erosion and degradation to such an extent that only proper methodologies, technologies and awareness can bring this resource somewhere near to the naïve soil (Anonymous 2016a; Patel 2016).

5.5 Causes and Management of Soil Degradation

Ever-growing demands of the growing population for food, fodder and fibre has led to the excessive pressure on land, further degrading the soil quality. Without investigating the chemistry and status of the soil, nutrients like nitrogen, phosphorus and potassium have been applied indiscriminately to the arable soil. This leads to the imbalances due to excess of certain nutrients and deficiency of another (Dhok and Metkari 2011).

Large scale irrigation canals, deforestation and removal of natural vegetation, agriculture related activities, overgrazing, over exploitation of vegetation for domestic purpose, flawed use of land led to various soil problems like salinization, flooding, drought, erosion and waterlogging. In turn, these processes reduced agricultural productivity leading to social insecurity. Global warming due to the emission of greenhouse gases is also a major cause for soil degradation.

5.5.1 Soil Erosion

This is the most common and major factor responsible for the degradation of natural resources.

Soil erosion remains one of the most prevalent problem since ancient times. This was recognized by the British government using 1930s (Shah 1997; Reddy et al. 2004). In mountainous regions, soil erosion is more severe than in plains. Practicing inappropriate methods for hilly regions like tilling along the slope, lack of crop cover during heavy rainfall etc. makes the erosion severe (Basu et al. 1960; Vittal et al. 1990). Soil degradation is through the loss of topsoil which results in the production of low and unstable crop yields in rainfed semiarid to sub-humid subtropics of India (Vittal et al. 1990). Wind causes erosion in the arid and semiarid regions of India, which includes Rajasthan, Haryana, Gujarat and Punjab. This type of erosion is called wind erosion which is enhanced by removal of natural vegetative cover resulting from excessive grazing and extension of agriculture to the marginal areas (Sidhu et al. 2010; Sidhu et al. 2013).

5.5.2 Slaking and Dispersion

Slaking and dispersion leads to the mechanisms of soil structural collapse and degradation, which in turn changes soil from one type to another (Dhruvanarayana and Babu 1983). Slaking happens when there is a breakdown of aggregates into smaller aggregates or single particles. Usually the process occurs when the dry clay becomes wet. This makes the clay to swell and the air within the pore spaces aggregates is compressed, resulting in pressure which leads to explosion of the aggregates. Addition of organic matter helps in the reduction of slaking by reduction in the rate of aggregate wetting and by more strongly binding the soil particles together.

The separation of clay particles from the aggregates when the soil is wet is called dispersion. Usually lime is used to avoid the problem of dispersion (Moody and Cong 2008).

5.5.3 Salinization and Alkalization

The enhancement in irrigation amenities has enabled to achieve efficiency in food production. This resulted in an increase of net irrigated area in India from 22 M ha in 1950 to about more than 68.2 M ha in 2016. Although this expansion helped to achieve targets of higher production, but made the level of groundwater level to rise. In turn, it made the soil to deteriorate through accumulation of salts (Abrol and Bhumbla 1971; Anonymous 2016b).

5.5.4 Acidity

Most of the acid soils in India belong to laterites and latosolic soils eg. Ferruginous red soils, ferruginous gravelly red soils, mixed red and black, or red and yellow soils. About 6.98 M ha area is affected by acid soils, which is about 9.4% of total geographic area. Acid soils develop in humid and per humid areas. There are various problems caused due to acidic soils, which are mostly associated with physical and chemical properties and chemical properties. Kaolinite dominated light textured acid soils have very high saturated hydraulic conductivity leading to heavy percolation losses. The efficiency of these soils can be enhanced by light and frequent irrigation practices. Mulching of crop lands with paddy straw can be done to reduce the problems of high evaporative demands on crusting soils. Mulching reduces the loss of water by evapo-transpiration, thus saves irrigation water up to 15–20% depending up on the crop. Incorporation of paddy husk and powdered groundnut shells followed by light irrigation can avoid hardening of red loamy soils. This technique retains moisture in the soil for a longer time can be carried over for rabi crops. Poor water efficiency is due to poor aggregate stability. Stability of aggregates can be achieved by application of compost, paddy straw and green manuring. Liming followed by light irrigation is the most effective technique, which helps in achieving improved chemical and biological properties of acid soils and increase water use efficiency (Maji et al. 2008).

5.5.5 Reduction in Organic Carbon

Pedogenic processes are responsible for the chemical deterioration of Alfisols, Ultisols and Oxisols leading to nutrient depletion. In India about 3.7 M ha land is deteriorated due to reduction of organic matter. In-situ burning of crop residues or their removal, no or least addition of organic residues and intensive agriculture leads to the depletion of soil organic carbon. Use of balanced and integrated inorganic and organics, proper management of crop residues, etc. are desirable options for sequestering organic carbon in soils (Aulakh 2011).

5.5.6 Nutrient Imbalance

To achieve high crop yields, balanced nutrient supply is essential, but nutrient loss happens in various forms, viz., NH_3, N_2O, NO and N_2 and discharge to water through runoff, leaching and erosion. During the green evolution era the usage of fertilizers increased drastically in agriculturally developed states like Punjab and Haryana to cope up the increasing demand of the ever growing population and nature of hybrid varieties. In high intensive cultivated areas of rice-wheat cropping system in Indo-Gangetic Plains poor soil health has been studied. With the incorporation of both fertilizers and organic manures, N imbalance and N losses can be improvised without sacrificing the crop yield (Aulakh 2011).

5.5.7 Pollution Caused by Toxic Substances

The impact of pollution varies depending on the rainfall pattern, depth and geology of aquifer. This is true in cases of both geogenic and anthropogenic factors responsible for causing pollution. Aquitards are the naturally occurring minerals in different regions, which control the concentration of geogenic pollutants such as arsenic (As), uranium (Ur), fluoride (F), boron (B) and selenium (Se) in alluvial aquifers. In most of the cases as is found in drinking groundwater. pH, oxidation-reduction, associated or competing ions are the geochemical properties which along with evaporative environments have significant effects on As concentration in groundwater. Oxi-hydroxides of iron conrol the conditions of metals in aquifers or surface waters in natural conditions. Iron precipitates as hematite gets deposited on the surface of particulate suspensions under oxidized conditions (Goswami 2005). Environmental pollution such as eutrophication arise when excessive fertilizers used are washed to the water bodies. Minerals like fluoride, boron and nitrate pose a major environmental hazard. According to a WHO report, the permissible limits for fluoride, boron and nitrate are 1.5, 1 and 45 ppm respectively (Patel 2016). In India and China fluorosis is the most severe and widespread. Seventeen states of India are endemic with fluorosis cases to be around 66 million (UNICEF 1999). Phytoremediation plays an important role in the controlling and decreasing toxins from the soils. The use of plants is the simplest and cost effective method in terms of technology (Bavandi 1975; Beeton 1969; Alkorta and Garbisu 2001; Alkorta et al. 2004; Khakbaz et al. 2012).

5.5.8 Soil Sealing and Capping

The never ending desire of human has led to the continuous expansions of fertile and productive soils. This leads to the drastic and often irreversible land use changes such as conversion of forest to agro-industrial land, extractive mining activities, as well as extensive horizontal expansion of cities have been resulting in the soil sealing and capping. Options like vertical expansion rather than horizontal, adoption of apartment system in place of bungalows etc. Waste and unproductive soils would be used for the establishment of new cities and industries. Artificial, impenetrable surfaces interfere with the essential environmental, economic and social functions performed by soil (Sutton et al. 2009).

5.6 Programs on Soil Management

Soil is a non-renewable resource, thus policies, strategies and the processes regarding the use of soil have to be formed. For a food-secure world, FAO and its members initiated the Global Soil Partnership (GSP) to improve governance of the soil resources. Soil being a limited resource, has to be used judiciously, hence formation of coherent policies with the implementation of standard practices and methods have to be followed so that the soil usage can be regulated. Scientific techniques in agriculture such as practices for tillage, fertilizer application and crop rotation have to be adopted so that soil fertility, structure and carbon sequestration can be maintained. Use of latest technologies with the involvement of Geographical Information System (GIS) and remote sensing a global/national soil map can be created to represent different soil types. Through mapping and web-based software, GIS is used to display, analyze and collect soil data and processes, so that different types of soils can be identified (Patel 2016).

For the first time since India's independence in 11th five year plan (2007–2012) importance of proper soil management was acknowledged. Soil Health Cards Program was developed in 2006 for betterment of farmers' knowledge on soil and soil management practices. The soil profile received after analysis of soil, farmers receive current status of their soil. Accordingly most suitable fertilizers can be applied without further harming the soil and providing the suitable required nutrient to the soil. This program was piloted in Gujarat and later on to other states to drastically improve the available database on soil. Due to the success of this scheme its implementation has been done at national level. To carry out this schemes a number of soil testing labs have been established, the soil samples are diagnosed in large numbers (Patel 2016).

5.7 Socio-Economic Impacts and Future Challenges

It is seen commonly that severely degraded lands are mostly inhabited by marginal farmers and tribal populations, who are poor and less literate. Due to poor soil the farmers are forced to find out more agri-land, hence converting forest area into cultivatable land, thus reducing the forest area. Or else farmers try to get marginal boost in the yield by application of surplus fertilizers, which in turn further depletes the condition of the soil. This whole scenario seems to be a vicious circle from which it is impossible to escape. Soil scientists and environmentalists are making an effort to evaluate the precise magnitude of soil degradation and its impact on the environment. Fields of science and farming, both require their due innovations so that the goals are achieved. Apart from this the natural resource data, soil status also should be made available from the remote sensing satellites. This would provide characterization of natural resources including soil and conserve the natural resources and rejuvenate the degraded wastelands, which offer potentially enormous means of poverty alleviation and sustainable livelihood (Reddy et al. 2004).

5.8 Conclusion and Future Prospective

All over the world, soil health has been identified as a major concern. Governments have initiated certain programs for the benefits of farmers. At the same time scientists are trying to use available techniques and tools at their best to improve the soil health as well as reclaim the lost land. With the use of proper methodology, techniques and programs we can surely succeed. Thus integrated soil fertility management will enhance our land fertility, productivity and yield, which will provide us the scope of pulling our population out of poverty and distress.

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