EC AGRICULTURE
Review Article

Soil Health Issues for Sustainability of South Asian Agriculture

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Abstract

Even though, the economic and agricultural growth in South Asia has improved in recent times, still food security and malnutrition is the biggest concern in these countries. Poverty in Asia is influenced by food insecurity, population densities, small land holdings and climate changes which also influence nutritional status. The present paper focuses on the concerns related to food, nutritional security and soil health issues in South Asian countries with special emphasis on cause and effects of soil related constraints and strategies to be adopted to manage and alleviate the problem. Some of the important soil health management strategies viz., site specific nutrient management (SSNM), integrated nutrient management (INM), crop residue recycling, and use of compost, vermicompost, and soil health card based interventions are promising in South Asian condition. National level policy interventions are needed to promote sustainable use of soil and water resources include prohibiting residue burning, reducing deforestation, promoting integrated farming systems and facilitating payments for ecosystem services. A wide spread adoption of these measures can improve soil quality and agronomic productivity of fragile and degraded ecosystems.

Keywords: *Soil Health Issues; Soil Quality; Site Specific Nutrient Management (SSNM); Integrated Nutrient Management (INM)*

Introduction

Almost one fourth of global population is being fed by South Asian Countries with 14 per cent of cultivable land [1]. Even though, the economic and agricultural status has changed in recent times in South Asia, still millions of people remain food insecure. South Asia, with over 40 percent of the world's poor and 45 percent of the undernourished, has the highest concentration of poverty and hunger in the world. The enormity of malnutrition in South Asia can be gauged from the fact that it is the home of nearly two-thirds of the world's undernourished children. More than 56 percent of the world's low-birth weight babies are born in South Asia [2]. India houses 25% of undernourished people and highest number of children suffering from malnutrition.

Majority of the population of South Asia live in rural areas and rely on agriculture directly or indirectly, More than 80 per cent population in Nepal and Sri Lanka, more than 70 per cent in Afghanistan, 65 per cent in India live in rural areas (Table 1). In spite of that, over a period of time per cent population living in rural areas decreased, still primarily remain rural societies. Per cent contribution of agriculture to gross domestic product (GDP) has declined over a period of time, even though Afghanistan and Pakistan accounts one fifth and one third in Nepal (Table 2). In India, the per cent share reduced from 33.44 (in 1980) to 16.28 (in 2017).

Country	1980	1990	2000	2010	2016	2017
Afghanistan	84.01	78.82	77.92	76.26	74.98	74.75
Bhutan	89.87	83.61	74.58	65.21	60.57	59.83
India	76.90	74.45	72.33	69.07	66.82	66.40
Pakistan	71.93	69.42	67.02	65.00	63.77	63.56
Bangladesh	85.15	80.19	76.41	69.54	64.92	64.14
Nepal	93.91	91.15	86.60	83.23	81.06	80.66
Maldives	77.75	74.16	72.29	63.57	61.05	60.62
Sri Lanka	81.39	81.47	81.62	81.77	81.69	81.62

Table 1: *Per cent rural population in South Asia (Source: www.api.worldbank.org).*

Country	1980	1990	2000	2010	2016	2017
Afghanistan	-	-	-	-	26.21	21.08
Bangladesh	32.82	30.49	31.68	22.72	17.00	14.05
Pakistan	26.51	23.06	22.93	24.14	23.28	23.22
Bhutan	42.91	34.38	32.88	26.80	16.80	16.64
Nepal	57.90	48.80	44.72	38.24	33.18	29.15
India	33.44	27.21	27.65	21.86	17.52	16.28
Maldives	-	-	-	8.76	5.63	5.63
Sri Lanka	27.1	26.68	19.92	8.49	7.48	7.69

Table 2: *Per cent share of agriculture in Gross domestic product in South Asia (Source: www.api.worldbank.org).*

South Asia's record in reducing malnutrition is one of the world's worst. These depressing numbers seem to contradict the fact that South Asia has expanded its food production significantly and the Green Revolution has done its wonders. Therefore, there is need to find out the reasons of this pattern. Studies reported that around 45% of childhood deaths were caused by malnutrition during 2011. Prolonged malnutrition in early life resulted in irreversible effects in early life, including impaired mental development, lower economic efficiency, lower birth weight of offspring, and possibly augmented menace of certain chronic disease in adult life. Iodine is one of the cause of impaired cognitive development in children [3]. Malnutrition, a consequence of poverty influences a child's nutritional status through numerous ways: obstructing food security and access to varied and nutritious food, reducing a child's ability to accept satisfactory care, and restricting access to health services and treatment. South Asia in particular is heavily loaded by poverty with over one third of the world's extreme poor exist in India in 2010 (and another 5% residing in Bangladesh). Poverty in Asia is influenced by food insecurity, population densities, and small land holdings and climate changes (flooding, drought, soil erosion *etc.*) which also influence nutritional status. Most of the people in South Asia are dependent on poor health soils leading to malnutrition, with more than two billion people suffering from micronutrient deficiency.

This food insecurity and hunger is aggravated by faster growth in population, inappropriate utilization of resources and inadequate investment on agriculture, poor agricultural infrastructure. All South Asian countries represent very low food security level ranging from 33.8 (Nepal) to 48.6 per cent (Sri Lanka), according to Global food security Index, 2013. Thus, ensuring food and nutritional security to rapidly increasing population of the region remains one of the major challenges in South Asia.

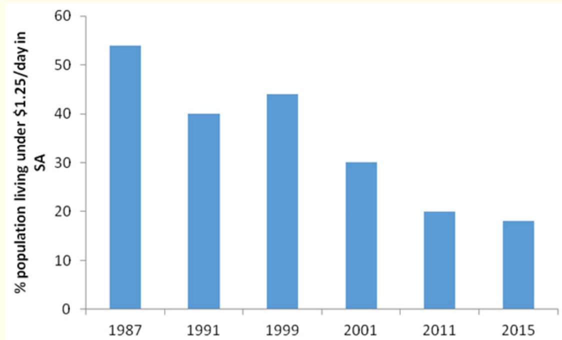

Figure 1: *Per cent population living under $1.25/ day in South Asia [4].*

Agriculture holds the key to ensure domestic food security which in turn inextricably linked to social and national security. The green revolution had an immense influence on reducing the poverty and food security by increasing the food production tremendously. In South Asia, out of 73% of the total agricultural land, almost half of Southeast Asia's land area is in agricultural use. After Green revolution, agriculture have positively impacted on crop yields in Asia, resulting in a remarkable increase in yield by means of chemical fertilization, irrigation and intensified use of pesticides led to serious ecological consequences. Agricultural activities have caused a serious degradation of the soil secondary salinization polluted ground water and eutrophication of rivers and lakes [5] in many Asian countries.

Stagnation/decline in yields in Asia ascribed due to soil organic carbon (SOC) and its impact on nutrient supply. Several workers have studied losses of SOC, predominantly C and N, under rigorous cropping and continuous cultivation [6,7]. The long-term sustainability and productivity of cropping systems are directly related to the maintenance of soil organic matter. In intensive cropping system, crop residues are used for multipurpose viz. domestic use, grazing for animal, mulching, a large portion of the residues is burnt on-farm primarily due to shortage of labour, resulted in need to improve SOC by adding organics to the soil. Increasing organic matter inputs via agricultural management is the key to increase in SOC content [8].

In South Asia, assessment of carbon sequestration in soils is made on the basis of the available information on the area and soil C dynamics for different land use and soil management practices. Out of 642 million hectares (Mha) of land, 218 Mha is occupied by cropped area, 85 Mha comprised by forest and woodland, 13 Mha is under permanent crops and 94 Mha is permanent pasture (Table 3). Estimates of area affected by soil degradation processes include 82 Mha by water erosion, 11 Mha by wind erosion, 13 Mha by waterlogging, 33 Mha by salinization, and 83 Mha by desertification (Table 4).

Country	Total area	Land area	Agricultural area	Arable land	Permanent crops	Permanent pasture	Forest and woodland	Irrigated crop land
Afghanistan	65.2	65.2	38.1	7.9	0.14	30.0	1.4	2.4
Bangladesh	14.4	13.0	9.1	8.1	0.4	0.6	1.3	4.4
Bhutan	4.5	4.7	0.6	0.15	0.02	0.4	3.0	0.04
India	328.7	297.3	180.8	180.8	8.1	10.4	64.1	54.8
Iran	164.8	163.6	60.5	60.5	2.2	44.0	7.3	7.5
Nepal	14.7	14.3	4.9	4.9	0.09	1.8	3.9	1.1
Pakistan	79.6	77.1	27.2	27.2	0.7	5.0	2.5	17.8
Sri Lanka	6.6	6.5	2.4	2.4	1.0	0.4	1.9	0.6
Total	678.5	641.7	323.6	323.6	12.7	93.8	85.4	88.6

Table 3: *Land use (Mha) in South Asia [9].*

Country	Soil erosion		Desertification		Salinization	Water logging	Nutrient depletion	Ground water depletion
	Water	Wind	Dryland	Irrigation land				
Afghanistan	11.2	2.1	1.5	0.7	3.1	0.0	0.0	0.0
Bangladesh	1.5	0.0	0.0	0.0	3.0	0.0	6.4	0.0
Bhutan	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
India	32.8	10.8	60.0	8.1	7.0	8.5	3.2	0.0
Iran	26.4	35.4	2.0	1.2	16.0	0.6	0.0	-
Nepal	1.6	0.0	0.0	-	0.0	0.0	0.0	19.5
Pakistan	7.2	10.7	3.4	6.1	4.2	3.7	0.0	0.0
Sri Lanka	1.1	0.0	0.1	0.0	0.0	0.0	1.4	0.0
Total	81.8	59.0	67.0	16.1	33.0	12.8	10.9	19.5

Table 4: *Extent of soil degradation (M ha) in South Asia [9].*

Depletion of SOM, a widespread problem in the region, is exacerbated by soil degradation. Most soils have extremely low SOC, ranging from 8 to 10 g kg^{-1}. Depletion of SOC pool depends on soil degradation processes and fertility management (Table 5). Low additions of chemical fertilizers and organic amendment cause depletion of SOC [9]. The study carried out in an area of 3 Mha, total SOC loss was 42.8 Tg C within a 27-year period. This decline was attributed to removal of crop residue, changes in cropping systems, soil degradation processes such as decline in soil structure and aggregation, soil fertility. The low levels of soil organic carbon adversely affected crop yield and use efficiency of input.

Country	Fertility/mining soil degrading processes and practices
Bangladesh	Soil degradation and nutrient depletion Intensive tillage, puddling Accelerated erosion
Bhutan	Soil burning Deforestation
India	Residue removal for fodder and fuel Excessive grazing, and using dung for fuel Unbalanced fertilizer use Accelerated erosion, desertification, and soil degradation
Nepal	Deforestation
Pakistan	Accelerated erosion Monoculture
Sri Lanka	Accelerated erosion Deforestation and shifting cultivation

Table 5: *Land use, management practices and degradation processes leading to decline in soil organic matter content [9].*

In south Asia, seventy per cent of population live in rural areas, and predominantly depends on rainfed agriculture, having small land holdings. Crops grown in the region are important both for regional and global food security. About 31 per cent of rice and 18 per cent of wheat in global production would meet from South Asia. Uneven rainfall, high temperature, degraded soils with low available water content and multi-nutrient deficiencies are important factors contributing to low crop yields in these regions. One of the most important challenges facing rainfed agriculture is its sustainable development through conserving and enhancing the capacity of land and other natural resources to sustain it [10]. The soils are highly degraded with low SOC, due to rapid oxidation process in dry regions or tropical regions [11,12]. Deficiencies of micronutrient is responsible for yield decline in intensive cropping systems [13]. The results of table 6 revealed that in rainfed regions of India, extensive deficiencies of N, P and K as well as micronutrients Zn, Fe and B occurred, due to poor fertility of soils, loss of fertile soils, soil mineralogy which determine the retention and release of nutrients [14].

Location	Limiting nutrient (Low/deficient)
Rajkot (Gujarat)	N, P, S, Zn, Fe, B
Rewa (Madhya Pradesh)	N, Zn
Akola (Maharashtra)	N, P, S, Zn, B
Kovilpatti (Tamil Nadu)	N, P
Bellary (Karnataka)	N, P, Fe, Zn
Bijapur (Karnataka)	N, Zn, Fe
Solapur (Maharashtra)	N, P, Zn
Hisar (Haryana)	N, Mg, B
SK Nagar (Gujarat)	N, K, S, Ca, Mg, Zn, B
Bengaluru (Karnataka)	N, K, Ca, Mg, Zn, B
Ballowal - Saunkri (Punjab)	N, K, S, Mg, Zn

Table 6: *Emerging nutrient deficiencies in dry land soils under diversified rainfed production system of India [15-17].*

Impact of soil degradation is extremely severe in densely populated South Asia. Accelerated soil erosion is one of the principal cause of soil degradation. There are serious productivity losses up to 20 % due to erosion in Asia, especially in India, China, Iran, Israel, Jordan, Lebanon, Nepal and Pakistan [18]. According to UNEP, 1994 in South Asia, 36 Mt of annual loss caused by water erosion in cereals, equivalent to $5400 million, with a further $1800 million loss due to wind erosion. In South Asia, annual economic loss of $600 million estimated for nutrient loss by erosion, whereas, $1200 million due to soil fertility depletion [19]. In arid and semi-arid regions, salt-affected soils occupy 950 million ha, which is nearly 33% of the potentially arable land area of the world, severely threatened crop productivity by build-up of salt in the root zone. In South Asia, waterlogging and salinization affected annual economic loss of $500 and $1500 million, respectively [19].

Relationship between soil health indicators and crop productivity and food production

The health and quality of soil determine agricultural sustainability and environmental quality, which jointly determine plant, animal and human health [20]. Soil processes and properties that have highest sensitivity to changes in soil functions can be defined as indicators. Indicators are a composite set of quantifiable attributes which are derived from functional relationships and can be monitored via field sampling, field observations, survey or compilation of existing information, remote sensing etc. Scientific importance of an indicator of soil quality/ health depends on i) its sensitivity to alterations in soil management, ii) good correlation with the beneficial soil functions and other variables which are difficult to access or measure iii) helpfulness in revealing eco system processes iv) comprehensibility and utility for land managers v) easy to measure and cheap . Soil quality indicators are divided into two major groups, analytical and descriptive. Descriptive indicators are inherently qualitative and can be used in gauging soil quality. Some of the descriptive indicators include surface sealing/soil crusting, rills, gullies, ripple marks, sand dunes, salt crusting and ponding or standing water. Crop yield (grain/biomass production), plant vigour, rooting pattern and other features of crops have been used as indicators of soil quality. Soil indicators may directly monitor the soil or monitor the outcomes that are affected by soil, such as vegetation, productivity, water used/unit time and air quality. The indicators that indirectly monitor the soil health are crop yield/unit area/unit time, plant biomass/unit area/unit time, legume/non-legume crop ratio, water use efficiency/unit time, nutrient use efficiency/unit water used/unit time and quality of produce such as cereal grain protein, concentration of toxic elements in food grains, fruits, vegetables etc. The differences in these indicators are used to assess the variations in soil quality with changes in conservation, land use and soil management practices. Based on the soil types and other deviations, different set of key indicators for assessing soil quality have been suggested by various researchers. Aeration, increased infiltration, macro-pores, distribution and stability of aggregates, soil organic matter, soil resistance, erosion and nutrient run off are some of the indicators for enhanced soil quality. In a study conducted in Alfisols under sorghum-castor system, the key soil-quality indicators identified were available N, K, S, microbial biomass carbon (MBC) and hydraulic conductivity (HC) while under sorghum - mungbean system easily oxidizable N ($KMnO_4$ oxidizable - N), DTPA extractable zinc (Zn) and copper (Cu), microbial biomass carbon (MBC), mean weight diameter (MWD) of soil aggregates and hydraulic conductivity (HC) were the significant soil quality indicators identified in rainfed Alfisols of semiarid tropical India [21]. These indicators significantly influenced the overall soil quality and soil functions which ultimately showed impact on the mean yields and Sustainable Yield Index (SYI) of sorghum and mungbean.

Selected indicator	Rationale for selection
Organic matter	Defines soil fertility and soil structure, pesticide and water retention and use in process models
Top-soil depth	Estimate rooting volume for crop production and erosion
Aggregation	Soil structure, erosion resistance, crop emergence an early indicator of soil management effect
Texture	Retention and transport of water and chemicals, modelling use
Bulk density	Plant root penetration, porosity, adjust analysis to volumetric basis
Infiltration	Runoff, leaching and erosion potential
pH	Nutrient availability, pesticide absorption and mobility, process models
Electrical conductivity	Defines crop growth, soil structure, water infiltration, presently lacking in most process models
Suspected pollution	Plant quality, human and animal health
Soil respiration	Biological activity, process modelling, estimate of biomass activity, early warning of management effect on organic matter
Forms of N	Availability of crops, leaching potential, mineralization/immobilization rates
Extractable N, P and K	Capacity to support plant growth, environmental quality indicator

Table 7: *Key soil indicators for soil quality assessment [22-24].*

Strategies for improved soil Health

Buildup of soil organic carbon

In order to enhance the organic matter of soil, use of organic manures (FYM, composts, vermi-compost), legume crop-based green manuring, tree-leaf-based green manuring, inclusion of legumes in crop rotation, sheep-goat penning need to be practiced in the semi-arid and arid tropics [12]. Enhancement of soil biological health and fertility through development and promotion of bio pesticides and bio-fertilizers on large scale, reduction in use of toxic plant protection chemicals and identification of suitable gene pools for enhancing microbial diversity. Land cover maximization by growing legumes, pasture grasses would enable in protecting the land from adverse impacts of high energy rainstorms and extreme temperatures, create favourable soil habitat conditions for higher biological activity and carbon sequestration.

Crop residue recycling

Agricultural crops generate substantial amounts of residues. The increasing trend for organic agriculture specifies an economical opportunity for crop residue in Agriculture. Residues of crop when used as mulches can help conserve soil moisture and improve soil fertility. The partially green crop residue having narrow C: N ratio (30:1), which expedite composting, can aid as a substitute to high energy derived fertilizer and provide a feasible option for eco-friendly organic farming [25]. Residue incorporation significantly increased soil available K, organic carbon, total nitrogen content and reduced the bulk density in rice [26]. An increment of 11% in soil organic carbon was observed under no tillage and residue incorporated treatments compared to non-incorporated [27].

Conservation agriculture (CA)

CA encompassing three essential principles viz. permanent soil cover, minimal soil disturbance and crop rotation [28] has emerged as one of the viable options for addressing the productivity and resource related constraints, with prospective for sustainable intensification of cropping/ farming systems in rainfed regions. It can augment the productivity, capture land degradation, enhance the soil carbon content and contribute positively to the biodiversity. In CA systems the permanent residue or vegetative cover on the surface of soil reduces erosion, increase water infiltration, improves soil aggregation, increases surface soil organic matter, reduces soil compaction, moderates soil temperature, suppresses weeds, increases microbial activity and reduces GHGs emissions [29].

Resorting to no-till and retaining residues on the soil, enhanced the soil carbon sequestration and the enhancement in soil carbon ranged from 0.12 to 0.29; 0.09 to 0.29; 0.12 to 0.29 and 0.14 to 0.56 Mg C ha^{-1} yr^{-1} in the continents of Asia, Africa, America, and the USA, respectively [30]. Soil C improvement is associated with several benefits leading to enhanced agricultural productivity. Improvement in crop productivity up to 100-350 kg ha^{-1} with each ton of soil organic carbon build up among various dryland crops under long term experiments [31].

Nano technology

Nano-technology is an innovative, novel and interdisciplinary scientific approach which involves designing, development and application of materials and devices at molecular level in nano-metre scale i.e. at least one dimension ranges in size from 1 to 100 nano-metres [32]. Nano-materials can be classified into three types based on their origin: natural, incidental and engineered [33]. Natural NMs have existed from the beginning of the earth's history and still occur in the environment (i.e. soil clay colloids, remnants of DNA strands). Incidental NM occurs as a result of industrial or mining processes whereas the engineered nano materials (ENM) and engineered nano particles (ENP) are (i) semiconductor, metal and metal oxide-based materials (ii) carbon-based materials and (iii) polymers. There are 'smart' nano-scale devices, which can be installed for the efficient delivery of fertilizers, herbicides, insecticides and plant growth regulators, among others. The designing of nano-scale carriers are done in such a way that they can anchor the plant roots to the surrounding soil and organic matter; hence, resulting in improved stability against degradation in the environment and ultimately reducing the amount to be applied [34]. Nano - fertilizer is an encapsulation of fertilizer within a nanoparticle through which nutrient can be delivered to the plant. As compared to chemical fertilizers, nano-fertilizers are required in lesser amount and economically cheap. In water logged conditions nano fertilizers remain available in the emulsion form throughout the water layer. Under arid conditions, foliar application with 640 mg ha^{-1} (40 ppm concentration) of nanosize phosphorus registered significant increase in yield which gave 80 kg ha^{-1} P equivalent yield of pearlmillet and clusterbean [35].

City composting

The policy for urban waste composting is a worthy initiative under Swachh Bharat Abhiyan. Urban waste conversion to compost could solve the problem of waste disposal as well as act as an organic source of nutrient to crops. City compost is enriched with carbon and can be applied to carbon depleted soils to enhance C content and improve both biological and physical properties of the soil. Creation of awareness among the farmers about the uses of city compost by all concerned authorities is essential [36].

Erosion control

The top soil, rich in organic matter, microorganisms and where most of the earth's soil biological activity occurs is lost by erosion. The appropriate application of soil and water conservation technologies on an extensive scale would help in reducing the losses due to soil erosion. Soil health management approaches viz. growing of cover crops, residue recycling, reduced tillage etc. also would aid in minimizing the impacts of erosion.

Reclamation of problem soils

A problem free soil environment is vital for realizing higher food production. Soil related constraints affecting crop production influences the input use efficiency of crops and thus affects economics of crop production [37]. Table 8 presents major soil chemical constraints and reclamation measures to be adopted.

Soil Type	Characteristics	Reclamation measure
Saline soils	Higher amount of water soluble salt	Lowering down the water table depth through subsurface drainage Leaching of soluble salts After reclamation application of FYM at 5 t ha^{-1} at 10 - 15 days before sowing alleviates the problems of salinity.
Sodic soils	Predominance of sodium in the complex with exchangeable sodium percentage (ESP) exceeding 15 and pH > 8.5	Ploughing the soil at optimum soil moisture regime and application of gypsum based on the gypsum requirement Impound water and create provision for drainage to leach out the soluble salts
Acid soils	Low pH < 6.0 Predominance of H^+ and Al^{3+} Deficiency of P, K, Ca, Mg, Mo and B	Application of lime as per lime requirement test uniformly by broadcast and incorporation Amendments like dolomite, basic slag, flue dust, wood ash, pulp mill lime may also be used on lime equivalent basis

Table 8: *Problem soils and reclamation measures to be adopted.*

Rehabilitation of Tsunami affected soils

All the seven SAARC nations are earthquake prone, however, the countries viz., India, Maldives, Sri Lanka, Bangladesh, Pakistan having connected with Ocean are prone to Tsunami incidences following earthquakes in and around their vicinity. 26th December 2004 massive earthquake (9.3 magnitude on Richter scale with its epicentre in Sumatra, Indonesia), followed by tsunami traversing up to African on South-West Monsoon track was immensely damaged in India, Sri Lanka and Maldives. The coastal artisanal fishing and mixed farming system was severely impacted and thus livelihoods of farmers got derailed. Crop losses are given in table 9. The permanent loss of human lives (12399 in India) and livestock resources (4338) due to washing away in tsunami water was irreparable. Loss of fishing craft is another major damage in the tragedy. Instant losses to farmers due to damaged rice, vegetable, plantation, aqua farms and permanent losses due to impaired soil and water quality (salinization) are the two dimensions of the impact. Permanent or high tide submergence of lands under ocean and impaired drainage of lowlands are the other constraints created by tsunami. There is need to make these countries permanently adoptable to such exigencies.

Country (States/districts)	Annual (ha) and Plantation crops (ha or number)
India (Andaman and Nicobar Islands, Tamil Nadu, Pondicherry, Andhra Pradesh and Kerala)	28032
SriLanka (Jaffna, Mullaithevu, Trincomalai, Batticaloa and Ampara etc. 10 districts)	4134 ha and 27710 home gardens
Maldives (28 islands)	11700 home gardens

Table 9: *Crop losses in different regions due to Tsunami.*

Restoration of agriculture and soil fertility management in Tsunami affected lands

Coastal regions of tsunami impacted lands with coarse soil texture and heavy rainfall have been reclaimed naturally [38]. The reduced ECe values of pond and well waters in Andaman and Nicobar Islands after two years of tsunami also revealed the neutralizing impacts of rain [39] (Figure 2 and 3). In soils, where salinity could not got reduced (due to high tide submergence daily) needs to be managed suitably. In this direction, tidal water entry curtailing assumes great importance. Retaining structures like walls, gabion structures and tripods are used besides bio shields development. Earthen structures are erected that are protected with plantation of trees like Casuarina. Mangrove species (*Avicennia marina* or *Rhizophora* spp. monocultures in Tamil Nadu) and native coastal vegetation (*Ipomea biloba*, *Pandanus* etc.) needs greater emphasis than new introduced species. Integrated Mangrove Fishery Farming System (IMFFS) developed at M. S. Swaminathan Research Foundation (MSSRF) in collaboration with The International Union for Conservation of Nature (IUCN) at Rameshwaram, Tamil Nadu and Sorlagondi, Nalli and Basavanipalem villages of Krishna Mangrove Wetlands area of Andhra Pradesh comes handy. In this approach ponds are created with planting of mangrove tree species on bunds and fish are grown in ponds utilizing saline waters. It thus provides both protective and productive functions. In water logged conditions with high saline waters and turbidity, sea weeds culture could be most promising. Crab fattening was easiest option for high tide inundated soils. If standing water is not saline, then raft cultivation of crops especially vegetables was desired.

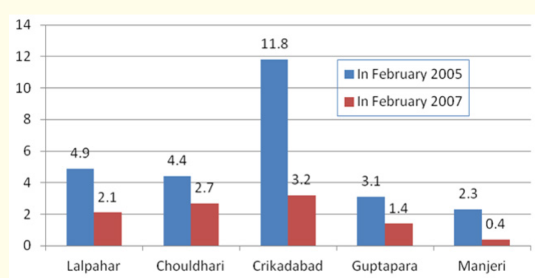

Figure 2: *ECe changes due to rainfall in pond water in Andaman's [38].*

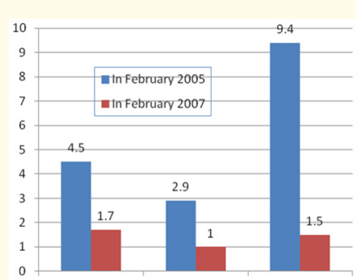

Figure 3: *ECe changes due to rainfall in well water in Andamans [38].*

Suitable crops needs to be identified for saline waterlogged soils. Rice is the most obvious choice for tsunami soils but salt tolerant varieties cultivation need to be emphasized. A new potential crop, Noni (*Morinda citrifolia* L.) with tolerance to waterlogging and salinity with many pharmaceutical compounds in its biomass would be best bet for cultivation in tsunami saline soils. Modified land configuration techniques i.e. broad bed and furrow systems that reduce contact of water with crops when grown on beds and fish/rice culture in furrows were taken up. In such situation, salinity built up on bunds is reduced. Mulching of crops would also come in handy in reducing evaporation and thus salt build up.

Integrated nutrition of crops with inorganic fertilizers and organics like crop residues and manures coupled with amendment gypsum application on heavy soils will improve the chemical and physical properties of soils for crops cultivation

Government programmes for soil health improvement

Soil is the key natural medium for the food production. Food and nutritional security of any nation can be achieved only through healthy soils. The major second generation problem in agriculture is the soil health deterioration. The South Asian countries are frequently documenting the emergence of multi nutrient deficiencies, drastic depletion of soil organic carbon, and deterioration of physical, chemical and biological health of the soil in all most all the cropping systems. This has alerted all the south Asian governments to take the appropriate initiatives in respective countries to restore and improve the soil health for sustainable soil productivity in the region.

Different farming approaches improve the soil health based on certain principles of sustainable soil management. All these management practices aim at improving the productivity, protecting soils and the environment. Such practices are organic farming, minimum tillage farming, Zero tillage farming, agro ecology, conservation agriculture, natural farming, agroforestry, integrated soil fertility management and etc.

In South Asia there are currently a number of soil health management programmes with a specific focus on soil health improvement for sustainable productivity.

In India, Soil Health Card Scheme (SHC) was launched by Govt. of India in February 2015 [40]. As per the scheme, the soil health card will be provided to farmers by analysing the farmer's soil sample in authenticated soil laboratory. Based on the soil test results the soil health card will give information to farmers on nutrient status of the farmer soil. Also gives the recommendation on appropriate dosage and kind of nutrients to be applied to improve the soil fertility. For every 2 years, the soil will be analysed and soil health card will be issued to all the farmers in the country so that nutrient deficiencies are identified and amendments applied. This soil health card scheme will promote balanced and integrated use of plant nutrients consequently soil health will be improved for sustainable soil productivity. A good progress has been achieved by Soil Health Card Scheme (SHC) in India by distributing 10.48 crores of Soil Health Cards by December 2018.

Government of India has given high preference for integrated nutrient management (INM) to make agriculture more productive, climate resilient and sustainable by adopting comprehensive Soil health management practices (SHM) under the umbrella scheme of National Mission on Sustainable Agriculture. The scheme launched from 2014 - 15. In this programme, the government is promoting soil test based application of fertilizers in conjunction with organic sources and bio fertilizers. This practice leads to reduction in use of chemical fertilizers based on soil health card recommendation by 8 - 10% and increase in the yield of crops by 5 - 6%.

Further, about 2000 model fertilizer retail shops are opened across the country over a period of three years. This model shops provide mandatory services like selling of good quality fertilizers at genuine rates, soil and seed testing, promotion of balanced use of nutrients and etc., for sustainable soil management.

Swachh Bharat Mission: Government of India launched "Swachh Bharat Mission" on October 2nd 2014 to improve the living environment. The name of the scheme spells out in Hindi language which means "Clean India". Objective of the mission is to prevent many health problems and improve the aesthetic of the cities, towns and villages. Subsequently during 2016 Department of fertilizers notified a policy on promotion of city compost which fully complement the "Swachh Bharat Mission". Solid and liquid waste management in the cities, towns and villages is one of the key components of the programme. Conversion of urban waste into useful compost, solve the problem of waste disposal and supplies an organic fertilizer to agriculture and improves the soil health.

Organic carbon in Indian soils has been depleting over the years. In this scenario the compost prepared from waste collected through "Swachh Bharat Mission" is a good source of carbon and plant nutrients. The application of this compost over the period improves the soil health, improves water retention capacity of soils. During 2016 - 17 a significant progress has been made in this scheme by producing about 1 lakh MT of compost from the waste. Appropriate technologies such as vermi-composting, NADEP composting, individual or community bio gas plants have been adopted to produce more organic fertilizer from the waste disposed and used in agriculture and improve the soil health for sustainable soil productivity.

Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA): The scheme was enacted by Govt. of India during 2005 recognised as an ecological act with major focus on improving the livelihood of rural poor through regeneration of natural resource base in rural India. The environmental services such as improving the soil fertility and soil health, improving biodiversity, soil erosion control, reclamation of degraded soils and carbon sequestration. This also includes ground water recharge, rain water harvesting. Increasing percolation and conserving the rain water for supplemental irrigation through farm pond technology and thereby increasing the area under irrigation. In short, the environmental services have an impact at the local farmer and village level to regional implications at larger scale for improving soil health, climate change mitigation and carbon sequestration for sustainable agriculture [41].

Across India, there are several studies suggested that, Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) had a positive impact on the environmental services including soil health improvement and agricultural productivity. Out of several studies pertaining to MGNREGA, there are only a few studies that have actually attempted to quantify the impact [42].

Improving the soil health

The excavated tank silt from MGNREGA works applied to farmer's field upon technical advice improved the soil fertility of degraded lands pertaining to below poverty line (BPL) families, Scheduled caste and Scheduled tribe farmers. The evaluation of the soil fertility after two to three years in the treated fields has increased the organic carbon content by two to three folds [43].

Potential of soil carbon sequestration

The MGNREGA works has the potential to enhance the carbon sequestration. One study projected that the potential of carbon sequestration under three kinds of plantations by 35,000 trees in about 80 ha. After, 30 years of plantations 7,700 tonnes of carbon sequestered indicating the enormous potential of carbon sequestration under MGNREGA works across India [43].

Water percolation and rise in groundwater

Several micro-level studies of MGNREGA works across India pertaining to rain water conservation, desilting of lakes and other traditional water bodies and tree plantation works for biodiversity enhancement has improved the water percolation and improved the ground water recharge. The study on these kind works indicated that, the percolation potential of the villages improved by 1,000 - 28,000 cubic meters per year. In one village, the construction of percolation tanks improved the recharge by 24% in one watershed. The rise in water levels of wells in the arena of watersheds is between 10 to 40 feet [44]. The rise in groundwater increased the area under irrigation and crop area also increased.

MGNREGA Activities	Local scale services for Soil health and Agricultural productivity	Regional and Global scale services for Soil health and Agricultural productivity
Water conservation and harvesting	Ground water recharge, soil moisture retention and protection (erosion control), Flood control (reduced risk), Providing irrigation and drinking water and improving soil quality (nutrient cycling).	Water conservation
Irrigation provisioning and improvement	Providing irrigation, improved - agriculture and livelihoods, increased crop production.	Reduce the need for methane producing large dams
Renovation of traditional water bodies	Improved storage capacity, irrigation availability, ground water recharge, soil quality (nutrient cycling), biomass production and crop production	Water conservation
Land development	Land reclaimed for agriculture, improved - irrigation availability, hence agriculture and livelihood improvement.	Increased agricultural productivity
Drought proofing	Soil moisture retention and protection (erosion control) and soil quality (nutrient cycling), Flood control (reduced risk), biomass production (Fuel wood) and local climate regulation.	Water conservation, carbon sequestration, biodiversity conservation
Flood control	Better drainage, higher land productivity (erosion control) and Flood control (reduced risk).	Water conservation

Table 10: *MGNREGA Activities for improving Soil health and Agricultural productivity [43].*

Reduction in vulnerability of production systems: The perception based studies across India have indicated that the potential to reduce the vulnerability of production system to climate irregularities by strengthening the livelihood and water security through water harvesting and conservation. Desiliting of lakes, channels and other traditional water bodies and thereby increase in water availability and also increased the crop yields, thus reducing the vulnerability of production systems [45].

Neem coated urea scheme: The scheme was introduced to improve the soil health. Neem coated urea acts as a slow release fertilizer and supplies the required nitrogen to plants appropriately and this practice insists the farmer to use urea judiciously / reduced application of chemical fertilizer and diversion of urea towards non-agricultural purpose. This also increases the crop yield besides improving the soil health.

The Indian soil crisis with emerging multi nutrient deficiencies, depletion of organic carbon and deterioration of soil health is being treated by several initiatives taken by the government. The treatment programmes like Site Specific Nutrient Management (SSNM) which enhances the nutrient use efficiency, balanced application of nutrients and there by improves the soil fertility and soil health. It emphasises the variable rate application of nutrients for balanced nutrition and also to improve the soil health.

Government of India has implemented the nutrient based subsidy since 2010 for supplying fixed subsidy on annual basis for Nitrogen (N), Phosphate (P), Potash (K) and Sulphur (S). This helps in providing fertilizers to the farmers at affordable price for their balanced use to increase the crop productivity.

Organic farming: National Project on Organic Farming (NPOF): The National project on organic farming (NPOF) is a central sector scheme launched in 2004, with the view to promote organic farming practices to reduce the burden on chemical fertilizers, to ensure effective utilization of farm resources and to cater domestic and international organic market. The National Project on Organic Farming is promoting organic practices as a major objective. The project also promoted the four bio fertilizers viz, *Rhizobium*, *Azotobacter,* *Azospirillum* and PSB and two organic fertilisers: city waste compost and vermicompost, there are large numbers of organic inputs being produced and promoted for sustainable soil health management in the country. The conversion of crop residue waste into biochar reduces the farm wastage which is otherwise burnt. The difficult to decompose crop residues with low cost biochar making kiln at the farmer level can convert into biochar and its subsequent application increases the organic matter and carbon sequestration in soil maintaining soil physical, chemical and biological health. All these soil management practices are suitable to improve the soil health across south Asian countries.

Climate smart agriculture to improve soil health: Climate smart agriculture is the priority in South Asia for climate change mitigation and adaptation. In India, under the National Innovations on Climate Resilient Agriculture (NICRA), several agro technologies have been developed for strengthening the resilience of farmers to the adversaries of climate change. Improved soil and water conservation techniques have been developed for sustainable soil management. These techniques are more or less suitable to all the countries of south Asia.

Agroforestry for soil health improvement and ecosystem services in India: The global forest area is shrinking and same with India and South Asian countries as well. In this scenario the growing trees on farms for all kind of local needs is very much necessary besides biodiversity enhancement. Agroforestry is mentioned by IPCC as one of the instruments to fight climate change. The intangible benefits offered by agroforestry system have been widely recognised by India and South Asia. The benefits may also refer as ecosystem services include microclimate moderation, biodiversity conservation, carbon sequestration, protecting water sources, soil erosion and pollution control. The national agroforestry policy, which deals with the practice of integrating trees, crops and livestock on same piece of land, was launched during 2014 by the government of India. Agroforestry has the potential to achieve sustainability in agriculture while optimising its productivity and mitigating climate change impact. Many studies have confirmed that the agroforestry system controls the soil erosion, reduces the risk of floods and enhances the biodiversity of the dryland production system. Agroforestry system is also supports the livelihood of the small and marginal farmers in the country. The environmental services offered by the agroforestry production system are enormous and thereby improves the soil health for sustainable agriculture.

In India, across the diversified agro-climatic regions there are different region-based traditional agroforestry systems oriented with livelihood activities of local people and they are very efficient in conservation of local resources. Examples for such systems are home gardens in Kerala and north east India, Kangeyam tract in south India, Khejri - based in north west, *Acacia nilotica* based in the central parts, alder based in the Himalaya and many more such systems. These systems conserve soil erosion, improve soil fertility; provide quality water for local consumption, fodder for livestock, fuel and timber for use as energy and construction material and traditional crops for food security. Recently about 300 new cases of ecosystem services are found at the global level [46]. Some of the examples are watershed management in Karnataka, Payment of ecosystem services in Himalayan National Park, Kullu district of Himachal Pradesh and Cardamom based agroforestry system in north east India, etc. The recent assessment report on millennium ecosystem will be considered as baseline for evaluating indirect benefits of agroforestry system. In that context, there are few case studies evaluating the agro forestry - based ecosystem services. While evaluating the cardamom based agroforestry ecosystem the parameters such as nutrient use efficiency, biomass and soil loss were evaluated and the results revealed that, soil loss (kg ha^{-1}) in different land use systems, including cardamom - based agroforestry (30 kg ha^{-1}), forest - based (74 kg ha^{-1}), horticulture based agroforestry (145 kg ha^{-1}) and rainfed agriculture (477 kg ha^{-1}) indicates minimum soil loss is from cardamom based agroforestry system [47].

Conclusion

The South Asian countries are resource poor and majority of the inhabitants rely on farming as a source of livelihood. These regions experience vagaries of climate and are often subjected to extreme calamities leading to soil degradation, decline in soil organic matter and eventually leading to decline in production. There have been many changes in agricultural management in recent decades. While these have resulted in very positive soil health outcomes, there is still a need to broaden the adoption of practices that protect and improve soil which is virtually a non-renewable natural resource. In particular, reduction in tillage and retention of crop residues on the fields play key roles in improving soil structure and water retention properties as well as maintaining or increasing yields. Wider adoption of these practices will be supported by better information but there are areas where long-established practices work against these principles. Growing of cover crops, use of vermicompost, tank silt application, crop residue recycling through mulching and compost, INM, SSNM and green leaf manuring are some of the useful technologies in maintaining soil health.

Way forward

- In developing countries like SA countries, operational aspects linking to crop production and up-keeping soil and environmental health have hardly been addressed. Database generation is required for key indicators of soil health, for different soil types, cropping systems, and management practices under various agro-ecoregions for quick assessment of soil health with a view to identifying degrading production systems.
- Diagnostic tools/techniques for estimating intrinsic fragility and/or recovery potential of the soil under land degrading production systems is lacking. Therefore development of such a diagnostic tool with simple, robust and process based indicators, both quantitative and qualitative, will help to discern why a particular (management/cropping) system is favorable or unfavorable to soil health, and its causality and the rate and degree of recovery (i.e. its resilience) of a degraded system on rehabilitation measures, if undertaken.
- There is very little quantitative evidence or information to address an important research question as to what is the level of soil organic carbon required to maintain a desired range of soil functional properties in different climatic conditions. Since it is difficult, to increase total SOC by large amount, the understanding and identification of specific fractions of SOC that show large impacts of management will be of critical importance in evolving suitable management practices.
- Site specific nutrient management supported by nutrient balance studies can help improve soil fertility status leading to enhanced yield and profitability.
- Adoption of erosion control measures in highly prone areas would assist in lowering the risks encountered by erosion.

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