

Technological interventions

for soil health improvement and sustainable agriculture

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Deforestation coupled with anthropogenic pressure on soil ecosystem and climate change has led to dramatic changes in the sustainability of the soil. Researchers are highly focussed towards climate resilient agriculture, regenerative agriculture, natural farming, resource conservation technology, use of latest tools and techniques for soil quality assessment etc for soil health improvement and sustainable agriculture. Despite the cutting edge science and emphasis on the promotion of technological interventions, still their adoption is not up to the mark. There is a need of identifying the bottlenecks in its large scale adoption and thus, saving the precious soil from degradation.

Keywords: Agriculture, Soil health, Sustainability, Technology

SOIL health is the corner stone of human civilization. Soil serves as one of the largest sink of atmospheric CO₂, sustains all forms of life, provide clean water, food grains and stable ecosystem. However, since the last few decades the state of soil degradation is rampant. The detrimental effects of intensive tillage practices coupled with mono-cropping with input intensive practices for decades especially in tropics and subtropics has deteriorated soil quality. The loss of soil organic carbon, erosion, over-mining of nutrients, loss of soil moisture, poor physical conditions, degradation of soil biological activities etc. has raised a serious concern. All these factors act as a driving force to look for alternative farming technological interventions and their promotion to overcome the constraints of poor farming practices. Globally, resource conservation technology (RCT) considered as a route towards sustainable agriculture. In India, also the practices started to find ground and along with conservation agriculture (CA)

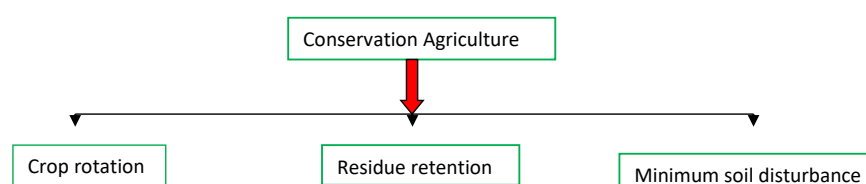
practices, the other technologies like precision agriculture, nano-fertilizers, Integrated Nutrient Management (INM), agroforestry, water conservation etc. become quite necessary to cope up with the issue of resource dwindling and climate change.

Resource conservation technology

The issue of resource conservation gained momentum for indiscriminate resource degradation and need to reduce the cost of production, increase profitability and productivity and to make present agriculture more competitive. As per Food and Agriculture Organisation (FAO), the aim of Conservation Agriculture (CA) is to conserve, improve and make the use of natural resources efficiently through integrated management of soil, water and

biological resources combined with external inputs. There is immense opportunity for capturing carbon in soil, store nutrients, reducing erosion, improving physical structure, proliferation of soil microbes etc on adoption of these agronomic practices. Conservation Agriculture is rapidly gaining popularity as the farming practice that promotes good soil health.

Crop rotation: Crop rotation practice helps to eliminate the problems associated with yield reduction, reduces disease and pest infestation and improves the nutrient supply to diverse group of microflora in the soil. By growing of more crops in a particular season, the soil built the resilience and sequester more Carbon. Intercrop brings economic benefit as the chances of crop failure loss is also less. The advantages of the intercropping





Crop rotation

over mono cropping practices are mainly due to differences caused because of competition for the natural resources.

Residue retention: The practice of maintaining permanent soil cover is one of the prime principles of CA even when regular crops are not in the field. In order to maintain the soil health, soil should not be kept bare open as it leads to disturbance of soil structure, promotes runoff, soil erosion, clogging of pores, loss of moisture, nutrients and reduces microbial diversity. Additionally soil cover reduces weeds and increases the yield.



Crop residue

Minimum soil disturbance: Minimum disturbance of soil helps in overall sustainability of the production system in three broad categories: (i) agronomic benefits that improve soil productivity; (ii) economic benefits that improve the production efficiency and profitability; and (iii) environmental and social benefits that protect the soil and make agriculture more sustainable.



Wheat crop under no tillage practice

Precision Agriculture (PA)

Precision agriculture is a technology driven farm management tool that obtains, processes and predicts the management by considering the variability in the field. The PA undoubtedly decides the application of resources on time, at right place and in right amount and manner for increasing profitability, reducing the losses and protecting the environment. Nowadays with advancement in the information communication and technology (ICT), use of unmanned aerial vehicles (UAV), variable applicators, hyperspectral remote sensing have been applied very effectively to monitor variation in soil and plant systems. so that necessary steps should be taken. Nevertheless, PA has got the potential to reduce chemical application, increase productivity, prevents soil loss, efficient use of water, creating potential knowledge of technology and improving the condition of the farmers.

Biochar

Biochar is considered a biomass heated at high temperatures with limited or no oxygen in closed containers. The product produced as biochar having high porous structure, increased pH, potential for high moisture and nutrient holding capacity, high carbon content, and low rate of decomposition. The effects of biochar on improving soil fertility largely depend on the type of feedstock's as well as the pyrolysis temperature. Based on their impact on soil system, biochar can become a novel fertilizer directly or indirectly. Despite its number of benefits, several researches shows its negative effects and uncertainties still exist in its application, thus necessitates long term studies.

Nano-fertilizers

The use efficiency of nutrients has to be increased substantially through improved management practices in an environmental friendly manner. Nano-technology emerged as one of the frontier areas that address these issues efficiently with plentiful applications in the field of agriculture. The, development of nano-fertilizers paved the way to fast delivery of nutrients, more uptakes through rhizosphere or leaf, matching with the crop demand and eco-friendly in nature. Due to the high surface area, they increase the more metabolic reactions that in turn increase photosynthetic rates thereby increasing dry matter production and yield.

Biofertilizers

Biofertilizers are often considered as bio inoculants as they possess living or latent cells of microorganisms that in turn make efficient use of plant nutrients through their rhizosphere interactions when inoculated either through seed or soil. Biofertilizers mainly includes, blue green algae (BGA), rhizobium, azotobacter, azospirillum, phosphate solubilising and mobilising bio inoculants (PSB) and plant growth promoting rhizobacteria (PGPR). The beneficial microbes sustain the crop production either as

biofertilizers or as symbionts. They modify the rhizosphere for congenial environment for more activity, helps in growth of plants by releasing plant growth hormones, helps in nodulation, root growth, resistance to pathogens, increasing the efficiency of photosynthesis etc. The biofertilizers being cost-effective, eco-friendly and non-toxic can serve as a good substitute to expensive chemical fertilizers.

Agroforestry

Agroforestry is considered to be a land management system that integrate woody perennials and herbaceous plants and/or animals in a spatially arrangement or rotation or both in which ecological and economic interactions occurs between both tree and non-tree components. Agroforestry creates a congenial environment for soil biodiversity to promote soil carbon sequestration through both above and below ground portions. Soil erosion is immensely checked under agroforestry owing to deep rooted architecture and soil binding properties, promotes infiltration, macro-aggregate formation. Agroforestry system have got the potential to facilitate the transition to multifunctional agricultural system that would take care of ecosystem functioning and sustain crop productivity.

Integrated Nutrient Management (INM)

The intensive agriculture over a long period led to second generation problems like declining fertility, nutrient imbalance and deficiencies,

loss of organic carbon, decline in response ratio, partial factor productivity, water table decline and overall deterioration of soil health. INM strategy refers to maintaining soil fertility at an optimum level of productivity through management of inorganic, organic and biological sources of nutrients in an integrated manner. The results emanated from long term fertilizer experiments clearly demonstrates that imbalance dose of nutrients deteriorates soil quality and crop productivity while balanced and INM practice sustains the yield, improve soil health and promotes soil biodiversity. Promotion of balanced and INM strategies among farmers is highly needed for getting healthy crops, fertile soil and sound environment.

Watershed interventions

Watershed management aims for land and water resources and implemented in an area that drains to a defined point along a river or stream. The watershed programmes have been introduced with a focus to develop both natural and social capital. The creation of water conservation structures had important hydrological implications that include reduction of runoff, reducing the soil erosion, increasing the infiltration and peak flows also get reduced. The watershed interventions pointed out to have positive impact on soil fertility, soil and water erosion, conservation of soil and water, cropping pattern, crop productivity, water table, availability of water for human and animals, checking migration,

livelihood security and huge impact on socio-economic, and environmental variables.

Phytoremediation

The heavy metal (HM) pollution in soil is increasing both due to natural processes and anthropogenic activities. Heavy metals are non-biodegradable, thus persist in soil and enter the human body through biomagnification. Thus, they pose a serious threat to human as well as environment. Phytoremediation is one such strategy through which, polluted soils can be revegetated in a cost-effective manner. It involves important ways of remediation i.e. Phytostabilization, Phytoextraction, Phytovolatilisation, Phytofiltration, Phytodegradation and Rhizodegradation. Further, use of genetic engineering, chelate assisted remediation, making the phyto-accumulators more efficient in growth, biomass and tolerance for highly efficient eco-friendly nature of phytoremediation needs to be explored in future.

Water management

Effective water management is quite necessary for having good harvest and reducing the water footprints. The goal is to keep the water balance between field capacity and minimum allowable water balance to satisfy the needs of the crops. The global demand of water for agriculture is expected to increase 19% by 2050. In addition to water demand escalation, the wastage of water is a major issue due to poor water management



Farmers practice



Integrated nutrient management

practices. The water management through irrigation could be efficiently done through adoption of drip, sprinkler, surface and subsurface methods of irrigation. However, land configuration changes is must for reducing rate of runoff and increasing the infiltration, so that water could be saved. It includes methods of bunding, trench, contour farming, terracing, vegetative barriers, land levelling, deep tillage and dead furrows. Apart from this, strip mulch, stubble mulch, ameliorants, antitranspirants, *in situ* water conservations must be employed for increasing the efficiency of water use in agriculture.

Way forward

Awareness related to better soil health management at present times is highly needed and proven technologies must be advocated on farm scale for effectively improving

soil health. Chemical intensive agriculture is not sustainable for long term. Therefore, prudent soil management techniques must be advocated and promoted for resource efficient and smart agriculture. The interventions of INM, good water management practices, inclusion of biochar, nano-fertilizers, conservation agriculture, agroforestry, phytoremediation, watershed level approach, precision agriculture etc are highly needed at present times. Its high time that focus must be on restoring organic matter in soil, reducing the soil erosion and energy inputs, increasing the infiltration thus, conserving precious natural resources in an eco-friendly manner without compromising with quality and quantity of produce.

SUMMARY

Degradation of the natural resources is a serious environmental

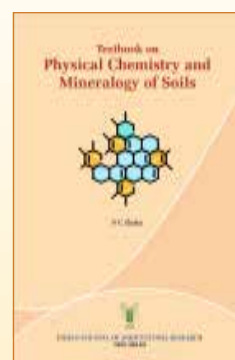
issue that has threatened ecosystem health and overall food security across the globe. The over exploitation of soil and water resources leads to decline in use efficiency of inputs. Thus, enhancing the natural resource base becomes of paramount importance. The technologies like conservation agriculture, precision agriculture, use of biochar, nano-fertilizers, agroforestry, water management, biofertilizers, phytoremediation etc provide an opportunity to harness the benefits of efficient utilization of resources in terms of environmental, economical and social manner. The resource conservation practices have shown lot of advantages over traditional practices by means of improving soil health and crop productivity.

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Textbook on Physical Chemistry and Mineralogy of Soils

Physical chemistry of soil and soil mineralogy are the two pillars which form the basic foundation of soil science. Once the students become familiar with these basic concepts, they can easily understand the other properties of the soil, say physical and biological properties, pedology and soil fertility. To become an expert of soil fertility, comprehensive knowledge of all the soil properties is essential which in turn is supported by the knowledge of physical chemistry of soils and soil mineralogy.

The present Textbook on 'Physical Chemistry and Mineralogy of Soils' has been written very cogently by the author who has been a teacher with an experience of nearly four decades of teaching in a premier Institute that is ICAR-Indian Agricultural Research Institute. The book includes all the topics prescribed by ICAR for the Postgraduate students of Soil Science. The introductory chapter describes basic definitions of soil science. Chapters like 'Bonding in solid structures', 'Elements of crystallography', 'Chemical thermodynamics' and 'Electrochemistry of soils and clays' are basic in nature and have been dealt very lucidly for easy understanding of students. Two chapters on characterisation of soil minerals are practical oriented. Other chapters focus on the structures of soil minerals, weathering and formation of minerals in soil environment, adsorption and ion exchange on soil colloids, double layer theory of soil colloids—its evolution and application, chemisorption and precipitation reactions in soil, soil organic colloids and their properties and chemistry of submerged soil. This book will be very much useful for the Postgraduate students of Soil Science.



TECHNICAL SPECIFICATIONS

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