

## **SOIL SCIENCE RESEARCH – A VIEW FOR THE FUTURE**

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**In 1948, a visionary of the stature of Pandit Jawahar Lal Nehru prophesied that it was science alone that would solve the problems of hunger, malnutrition and poverty. Accordingly, India followed a path of science led growth of its agriculture. This strategy paid rich dividends, since country has made significant progress in terms of growth in output and yields of many crops and commodities. Since independence, yields have multiplied almost three times for rice, four times for wheat, two and one half times for sorghum, three times for pearl millet, four times for maize and two times for oil seeds. Impressive productivity gains of this magnitude laid the foundations of self-sufficiency in food grains. It is no exaggeration to say that Green Revolution was, in fact, an embodiment of yield revolution. For future, whether the vision is for the second Green Revolution in 40% area where the first Green Revolution has already been realized, or the dream is to have a repeat Green Revolution in 60% of the areas where its fruits have yet to be harvested, story of new Green revolution will only be pieced together through sustainable yield increase. This emphatic statement is a reality in the face of nearly diminished chances of area expansion for agriculture.**

**Remarkable rise in productivity has not necessarily been confined to staple food grains alone. Steep surge has also been witnessed in productivity of fruits, vegetables, milk, fish, poultry and meat. Today, India is the largest producer of milk, fruits, cashew nuts, coconuts and tea in the world, the second largest producer of vegetables, sugar, rice, cotton and fish, and the third largest producer of tobacco. These unparalleled developments in the history of agriculture have raised country's head with pride and provided necessary impetus to make incisive voice and decisive contribution at different world fora.**

Achievements in agriculture have been an outcome of knowledge and technologies emanating from the efforts of various disciplines belonging to basic, natural and physical sciences. Soil Scientists have been in the fore-front in pursuits on maximization of crop productivity and production by developing and employing techniques and practices like efficient soil tillage and water application methods, management of soil physical conditions, chemical properties and fertility status. About one half gains in productivity in the presence of irrigation and high yielding varieties have been attributable to a right mix of soil management technologies and use of agro-inputs – particularly fertilizers.

India's Green Revolution has proved Paddock brothers – the authors of 'Famine 1975', wrong. However, sustainable growth in food grain productivity and production maintained until about late 1990s is either stagnating or showing signs of decline. It was during the VIII Five Year Plan (1992-97), when agricultural GDP grew at a rate exceeding 4%. During the X Five Year Plan it has fallen to about 2%. Therefore, today the greatest challenge before Indian agriculture is to sustain the agricultural growth so that it can feed its burgeoning population from shrinking land area. It also tops world in terms of livestock population. Since contribution of land area to built up total production to meet calorie and nutritional needs of growing human population and to assure adequate feed and fodders for overwhelming number of livestock has largely been utilized and need for additional food, fodders and other items remains unrelenting, the major focus, I reiterate, has to be on sustaining productivity growth rates.

According to National policy on Agriculture, India has committed to expand agricultural growth at a rate of 4%/annum, which comprises of crops (food grains, oilseeds and cash crops), horticulture, livestock, fisheries and forestry and logging. In 2003-04, respective contribution of these sectors was: 48%, 19%, 28%, 4% and 4%. While growth in crop sector remains most dominating from food self sufficiency and security angles, as in the past, share of horticulture, livestock and fisheries to agricultural GDP is likely to grow in the future. These sectors strengthen diversification

of food basket, which is necessary to: (i) keep pace with the optimum energy and nutritional requirements, (ii) move from subsistence to decent living propelled by rising incomes, (iii) satisfy ever changing consumer demands on specific variety and quality of produce, (iv) moderate risks, contain environmental degradation and economic pressures and (v) stay competitive in the domestic and foreign market places. Seen through mounting demand for land to satisfy needs of other sectors of economy, hereafter, there is going to be further pressure on already stressed soil and water resources to produce more food, nutrition, bio-energy, fodder, fuel and income with less and less inputs – both native and man-made. More than ever, it is now necessary to balance economic, environmental and social elements of farming in support of sustainable growth of agriculture in all its aspects. Economic issues will hinge upon producing higher incomes to sustain interest in farming and to attract more investments in best management practices. Compared to that environmental concerns (changing climate seen largely through global warming and abnormal rain and temperature patterns) will call for conserving and improving quality of soil, water, vegetation and air and perform with enhanced efficiency to minimize biosphere disintegration. Whereas, to measure up to the social demands, it will be imperative to: (i) assure availability of food in abundant quantities, acceptable nutritional quality and at affordable prices, (ii) enhance, create and maintain employment opportunities in agriculture through on-field intensification and off-field vocations and (iii) face the challenges of hyper-competitive farm markets.

My overall thesis for sustainable growth of agriculture is to harmonize economic, environmental and social imperatives. This strategy is of topical relevance because ignoring their judicious mix is at the root of falling quality of natural resources, rising risks related to climate change and declining productivity growth rates of staple food grains and other agriculturally important commodities. It is also a fundamental cause of perpetuating yield gaps between possible and actually realized potentials that have decelerated the total factor productivity growth. Consequently, farming has become increasingly input and cost intensive, less profitable and more risky. So sordid is the state of agriculture that at least 40% of the cultivators would like to quit farming if

given an alternative source of livelihood. The unabated growth in human population, growing demand for natural resources and the consequences of environmentally damaging technologies are all contributing to the growing threat to planet earth. The manner in which we use our soil, water, biodiversity, renewable energy sources, synthetic agro-inputs and how these impact the health of pedosphere (soil) through its interaction with biosphere (microbes, plants and animals), lithosphere (parent rocks), hydrosphere (water) and atmosphere (air) will determine the quality of life and sustainable growth of agriculture. Looming effects of climate change manifested as global warming and unpredictable monsoon patterns are adding another list of risks to agriculture. You galaxy of Agricultural Scientists and other luminaries gathered in this premier institute of Soil Science and Soil Management have a unique role in reversing these disquieting trends and developments adversely impacting sustainable march of agriculture. Exploiting natural resources for maintaining food and nutritional security without destroying the ecological balance and quality of an area is projected as the topmost national priority during XI Five Year Plan. In that pursuit, soil is to be considered as an integral part of other natural resources. For instance, “Water resources may be destroyed or increased threefold, depending on how the soil is managed” ([www.yearofplanetearth.org](http://www.yearofplanetearth.org)). This happens since ‘soils make up a key link and buffer systems within the world’s hydrological cycles’. Almost two thirds of the fresh water is held in the soil. Stream and groundwater flows are regulated by physical and terrain characteristics. Soils also are integral part of climate and environmental pollution through mediation of the carbon cycle and emission of greenhouse gases and neutralization of toxins originating from weathering of rocks and recycled through human actions.

I now touch upon some specific consequences of managing soils in isolation of other natural resources and anthropogenic yield-propelling interventions. Simultaneously, I also intend to highlight the role of soil science and responsibility and responsiveness of soil scientists in mitigating the influence of existing and emerging adversaries of sustainable development of agriculture. Apart from increase in cropped area and high yielding varieties, Green Revolution was realized with the liberal application of several

agro-inputs to soil. Intensification of agricultural practices attained through heavy doses of energy, fertilizers and water produced many side effects. This happened because generally economic benefits of these technologies were pursued more than their environmental consequences. For instance, excessive tillage of soil pumped more carbon into atmosphere. This action of man deprived soil of native nourishment and physical integrity. It also turned out to be a major source of carbon-di-oxide and thereby global warming. Mindless use of water caused nutrient leaching, accelerated runoff and erosion and surfacing of salinity, water logging, biodiversity loss and more use of energy. Combined effect of these negative developments is being manifested as ongoing climate change, faster depletion of water, degradation in quality of soil, vegetation, air and water and high cost of cultivation. Additionally, sub-optimal and unbalanced fertilizer use has spurred micro- and secondary-nutrient deficiencies in soils. Continued inefficient use of fertilizers and its role in environmental pollution and warming of planet earth are well documented. Above all, inefficient fertilizer use is a key factor pushing up the cost of cultivation and pulling down the profitability of farming. A preferential treatment to fertilizers and less emphasis on organic manures is responsible for emergence of multiple nutrient deficiencies, soil fragility and loss of resilience to maintain its renewable character. In all, absence of holistic soil management practices, which balance economic benefits and curative measures to preserve quality of soil, water and biodiversity and investments on fertilizers and energy, is leading to decline in productivity, profitability and stability of agriculture and rise in farmers' distress.

Soil scientists have share of their blame in this debacle because they generally treat soil in isolation of other natural resources. They have been and continue to pursue narrow disciplinary subjects and came out less in open to reinforce their efforts with the power and strength of other science disciplines. Majority of the soil scientists are rather self-centered and they care less for interactive processes which other natural resources assert on soil or where interdisciplinary working with soil-physics, -chemistry, -biology, -engineering and spatial sciences becomes necessary to provide holistic soil management practices for economic, environmental and social benefit. Soil scientists will gain in

stature by playing a key role in interdisciplinary projects on soil survey and land use, nutritional security, climate change and water use. Infusing a system-wide perspective (holistic natural resource management approaches) and trans-disciplinary working will expectedly mitigate incidence of depletion and degradation of soil and other natural resources, break the barriers impeding sustainable growth of agriculture.

All said and done, mission of Soil Scientists like other disciplines of agricultural sciences is to raise productivity of food, nutrition, fiber and fuel from the nearly fixed land area. In accomplishment of this mission, far greater efforts are necessary now to include the needs and concerns of resource-poor farmers but against the background of: (i) non-sustaining soil quality; (ii) falling quantity and condition of water; (iii) rising global warming and its adverse effects on waning biodiversity and declining crop productivity; (iv) increasing costs of inputs and decreasing profitability, and (v) hyper-competitive trade and farm markets due to opening of economies. These emerging scenes and scenario, therefore, call for plans and preparedness for the future by analyzing uncertain threats and untapped opportunities, crafting new natural resources management technologies and precision farming practices for sustainable growth of competitive agriculture. Apparent imperative is to put in place an innovative research portfolio, a holistic curriculum for education and real-time technology transfer in support of stable, productive and profitable agriculture. As expressed above, I like many others hold the view that chances to succeed are fewer with the business as usual approach. Key words of new business plan for Soil Scientists are: reprioritized research portfolio, time appropriate HRD, system-wide perspective, multi-disciplinarity, efficient and precision agriculture, development research and markets. I suggest following 10 Point Plan to modernize Soil science Research that extends much beyond the boundaries of production agriculture

1. Integrate soil with other natural resources so that its native characters link with human use in all its aspects. The fundamental requirement of this agenda is to develop base line information on natural resources and their carrying capacity. Employment of spatial sciences and spatial statistics is imperative to capture

- nuances of existing and emerging temporal and spatial variability. Understanding and describing basic aspects of soils as part of natural systems will allow soil scientists to suggest soil management techniques to decelerate spread of soil degradation.
2. Move away from necessary function of soils related only to production agriculture to its regulatory functions like environmental, ground water pollution and biodiversity conservation. Need would be to focus on understanding functional relationships among ecosystem components. What is being suggested is to characterize ecosystem good and services and ecosystem stability, resilience, sustainability and integrity. Since shifts in ecosystem characters are anthropogenic in nature, soil scientists need to launch specific studies that ultimately contribute to valuation and optimum use of ecosystem services beyond crop production imperatives.
  3. Focus efficient agriculture as the foundation of sustainable agriculture. The goal of efficient agriculture has to have more productivity per unit of land and man-made inputs without compromising soil and other natural resources quality. Research design will have to adopt a holistic natural resources management plan overlain with activities and actions that emphasize vertical use of land, maximize integrated agro-input use and minimize wastage. This will call for consortia of disciplines and institutions working together to solve the problem of inefficient agriculture by balancing the environmental, economic and social goals on the one hand and aspirations of all stakeholders on the other.
  4. Without enforcing the principles of precision agriculture, reaching the goals of efficient agriculture will be an oxymoron. Transferring conventional principles and tools of precision agriculture (site specific soil management with the sophisticated techniques like GPS, GIS and computer aided treatment design and application) remains a challenge in the Indian context, where small and marginal farms and resource poor farmers dominate. Need is to develop farmers' friendly soil test kits and decision support aids. It is also important to build farmers' capacity to adopt and utilize these test kits and decision support aids in field fertility management. In pursuance of this goal, development of

- decision support software, which imbibes a fertilizer recommendation program based on soil series and soil testing, will be necessary. Working with technology transfer agents, soil scientists will need to work for social mapping and develop matching training modules to empower those engaged in village-based agri-business and agri-management services.
5. **Replace commodity or single issue orientation to research with system-wide perspective – cultivation to consumption and beyond. Modernization of existing production systems and designing of diversified ones for economic benefit and environmental good will necessitate perceiving research on agro-ecosystem basis. This strategy when combined with economic capability, indigenously held knowledge and emerging market preferences will help prescribing most viable sustainable land use plans.**
  6. **Agro-inputs are important but there are limits to their extent and exclusive use supporting sustainable surge in agricultural productivity. Evolving techniques and technologies that integrate native and synthetic inputs with natural resources and conservation technologies is among the key areas of research. Need is to broaden the scope and depth of integrated nutrient management systems. In this regard, research involving generation of conservation agricultural practices and new product inventions through industrial technologies, harnessing the power of a vast array of QTLs for designing plant types with tolerance to biotic and abiotic constraints and exploiting the power of soil biodiversity is necessary to derive maximum advantage from conventionally followed integrated nutrient management systems.**
  7. **Research leading to preparedness to deal with the consequences of depleting water availability, weakening biodiversity, rising temperatures and aberrating climate is necessary for survival of man and his animal support system. These are global problems; require multidisciplinary approach with infusion of frontier technologies and tackling with trans-national partnerships. In my opinion, Soil Scientists of today and tomorrow need to be more proactive when it comes to participation in the global challenge programmes. Partnerships of this nature also provide a platform for learning about the use and application of the**

most modern tools and techniques necessary for solving the intransigent problems like uncertain changes in climate impinging upon potential performance of crop genotypes, sustenance of water resources, soil quality and biodiversity integrity.

8. **Food self-sufficiency goals need to include nutritional security goals. This aspect of societal well-being comes in the forefront since globally more than 800 million people suffer from malnutrition. Situation with reference to micronutrient deficiencies is the most alarming. Respectively, about 50% and 40% of the world population is exposed to zinc and iron deficiency disorders. The problem becomes further compounded since deficiencies of these micronutrients are widespread in soils and crops also. Currently, there is no standard method of relating micronutrient deficiency in soils to their suboptimal levels in humans. While Zn deficiency can be alleviated and Zn supply in produce boosted to some extent by treatment with Zn fertilizers, possibilities on managing Fe deficiency and raising its content in the produce through agronomic measures are economically unfavorable. Bio-fortification offers unique opportunity to create genotypes that are Zn and Fe dense. However, bio-fortification alone may not be one shot solution to eliminate trace element malnutrition. It, therefore, becomes essential to launch appropriate studies jointly with plant scientists, soil scientists and human nutritionists as partners to establish sustainable solutions to minimize micronutrient malnutrition.**
9. **Human health is not only influenced by suboptimal supply, but can be seriously imperiled by presence of some harmful elements in soils. A volume of information is now available that highlights that human health can be adversely affected due to presence of excessive levels of metal and non-metallic ions, pesticide and herbicide residues, organic and inorganic pollutants contributed by industrial activity, excessive burning of petroleum products and so on. Intolerable soil contents can also harm useful soil biology. While deficiencies are easy to cure, management of pollutants and contaminants is relatively difficult. The problem becomes more serious if adverse elements originate from land itself (geologic origin); example arsenic in North and typically so in north-eastern**

**India. Soil scientists need to initiate studies on bioremediation, preventive management options and soil treatment to deal with these adversaries of human health. Use of frontier technologies like biotechnology, nano-technology and nano-biotechnology have shown promise in this regard. Nano sized particles of magnetite have already been established to scavenge arsenic from soils and waters.**

- 10. Soil scientists must assume a leadership role as they did in 60s and 70s. Soil scientists need to demonstrate their contributions and value to all those who till and depend on land, policy makers and funding authorities and institutions. This becomes all the more important when the users of land are responsible for its degradation leading to global warming. Apart from public, soil scientists need to engage with those who are responsible for scripting policies on land use and commit investments in fulfillment of their objectives. Needless it is to mention that the final resolution requires targeted technological innovations in soil science which improve health of the soil while concurrently providing economic benefits.**

**I will be failing in my duty, if I do not talk about modernization of education in soil science, the strategy which is basic to develop time and need appropriate human resource. Similar to my thoughts on future Soil Science Research, I consider interdisciplinary educational programs will be pivotal to train the next generation of soil scientists. Course curricula in soil science must mirror natural resources management for environmental security, employment generation and county's economic progress. In that pursuit, it will be necessary to enrich the course curricula by harmonizing economic and social goals with biodiversity conservation, decelerating climate change, and preserving quality of soil, water and vegetation. Overexploitation of natural resources, changing land use and management patterns forced by rising demand for food and other goods, intellectual property rights, globalization of trade and opening up of economies will require inclusion of topics related to these internal and external pressures. Since humans induce soil problems, their role will be integral of solutions also. While future soil scientists require broad training rooted in traditional**

soil science (soil-chemistry, -physics, -microbiology and pedology) complemented by analytical, quantitative and geospatial modeling skills, the web-based distribution of 2D maps and data will become more important than ever to disseminate information widely. Three D and 4D soil landscape models will facilitate to better communicate knowledge on soils to students, policy makers and public at large.

To sum up, it has become more urgent than ever for the Soil Scientists to change the ways of projecting, identifying and prioritizing research on natural resources management or while strengthening education and training in Soil Science. Above all, we should not forget that the future of soil science does not only depend upon new research data and facts but requires genuine motivation, enthusiasm and dedication for the subject matter. In that endeavor, my lecture provides some base material to have a fresh look on soil as a natural resource endowment for sustainable development of agriculture in all its aspects. I sincerely look forward to this genuine effort of mine on collation and review of the state of soil science research and my recommendations to open the doors for the happening of second and/or repeat Green Revolution in the country. Typically, I emphasize the realization of a repeat Green Revolution in rain-dependent regions, which have generally been bypassed by the first Green revolution. This goal may be reached only, I repeat only, if soil scientists work towards optimum and efficient management of soil as integral part of other natural resources and as participants in the interdisciplinary and trans-institutional research and education programmes.

Thank you very much.