Vision 2030

Indian Institute of Soil Science
(Indian Council of Agricultural Research)
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India

www.iiss.nic.in

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PRINTED : June 2011

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Published by the Director, Indian Institute of Soil Science, Nabi Bagh, Berasia Road, Bhopal - 462 038. Laser typeset and printed at M/s. Neoprinters, Govindpura, Bhopal

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Foreword

The diverse challenges and constraints as growing population, increasing food, feed and fodder needs, natural resource degradation, climate change, new parasites, slow growth in farm income and new global trade regulations demand a paradigm shift in formulating and implementing the agricultural research programmes. The emerging scenario necessitates the institutions of ICAR to have perspective vision which could be translated through proactive, novel and innovative research approach based on cutting edge science. In this endeavour, all of the institutions of ICAR, have revised and prepared respective Vision-2030 documents highlighting the issues and strategies relevant for the next twenty years.

In the recent years, a declining trend of total factor productivity and compound growth rates of major crops and low nutrient use efficiency have been observed primarily due to deterioration of soil health. The main reasons for soil health deterioration are wide nutrient gap between nutrient demand and supply, high nutrients' turnover in soil-plant system coupled with low and imbalanced fertilizer use, decline in organic matter status, emerging deficiencies of secondary and micronutrients, nutrient leaching and fixation problems, impeded drainage, soil pollution, soil acidity, salinization and sodification, etc. Wide spread micro and secondary nutrient deficiencies in soils also lead to wide spread occurrence of mineral deficiency disorders such as anemia, goiter, dental caries, etc. The emerging challenges and opportunities needs to be addressed by Indian Institute of Soil Science (IISS), Bhopal and call for a paradigm shift from traditional research to innovative demand driven research on crucial areas.

It is expected that the analytical approach and forward looking concepts presented in the 'Vision 2030' document will prove useful for the researchers, policymakers, and stakeholders to address the future challenges for growth and development of the agricultural sector and ensure food and income security with a human touch.

Dated the 30th June, 2011
New Delhi

(S. AYYAPPAN)
Secretary, Department of Agricultural Research & Education and
Director General, Indian Council of Agricultural Research
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Preface

The Indian Institute of Soil Science (IISS) has emerged as a leader in the basic and strategic soil research in the country. It has achieved significant success in the areas of integrated nutrient management, impact on soil under long-term cropping, technology for the preparation of enriched composts, soil test based nutrient prescription, generation of district-wise GIS based soil fertility maps, organic farming practices, carbon sequestration in soils, sink capacity of soils for heavy metal pollutants, recycling of wastes, quality standards for municipal solid waste composts etc.

The institute has to take up the emerging challenges of food security and safety, soil and water quality, organic waste recycling, global climate change, environmental protection etc by reorienting it's research pursuits addressing the emerging issues viz., Enhancing Nutrient and Water Use Efficiency, Sustaining Soil and Produce Quality, Soil Biodiversity and Genomics, Climate change and carbon sequestration, Minimizing Soil Pollution etc. The first systematic effort to envision the challenges and opportunities, and to formulate its own strategy was undertaken in the last year of 20^{th} century by preparing 'Vision 2020'. The next attempt was after five years by preparing "IISS Perspective Plan 2025' to address changes that had taken place. The present document, IISS Vision 2030 articulates the strategic framework for innovation-led sustainable productivity of soil resources with minimum environmental degradation.

I consider it our privilege to express our deep admiration and immense gratitude to Dr. S. Ayyappan, Director General, ICAR for his encouragement and guidance in bringing out this document IISS Vision 2030. I am also grateful to Dr. A.K. Singh, DDG (NRM) for his valuable suggestions in the preparation of this document. I also thank Dr. P.S.Minhas, ADG (SWM) and Dr.J.C.Dagar, ADG (Agronomy) for going through the document and valuable help. I express my sincere thanks and gratitude to Dr. V.S Tomar, Chairman, Dr. R.K. Gupta, Dr. P.K. Chhonkar, Dr. P.S. Minhas, Dr. Biswapati Mandal, Dr. P.K. Aggarwal, members RAC for guidance in preparation of this document.

I wish to express my sincere appreciation to the Progrmme Leaders, Project Coordinators and Scientists of the institute who have contributed valuable information for their respective programmes. Special thanks are due to Dr. K. Sammi Reddy, Principal Scientist and In-charge PME Cell for compiling IISS Vision 2030 document. The help received from Smt. Kirti Singh Bais, Personal Assistant in typing this manuscript is gratefully acknowledged.

25 June, 2011
Bhopal

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Preamble

Despite significant growth in agriculture during the last four decades, most of our important soil based production systems are showing the signs of fatigue. Soils of India broadly fall into five main groups, viz., red soils, black soils, alluvium derived soils, soils of arid region and soils of Himalayan and Shiwalik region. These soils differ in their productivity and need differential management practices depending on soil physical and chemical properties and biological conditions, rainfall/availability of water for irrigation and crops and cropping systems.

The conservative estimates showed that the demand for foodgrains would increase from 192 million tonnes in 2000 to 355 million tonnes in 2030. Contrary to increasing food demands, the factor productivity and rate of response of crops to applied fertilizers under intensive cropping systems are declining year after year. The current status of nutrient use efficiency is quite low in case of P (15-20%), N (30-50%), S (8-12%), Zn (2-5%), Fe (1-2%) and Cu (1-2%) due to deterioration in chemical, physical and biological health of the soils. Continuous cropping leads to decline in organic C levels by 50-70% to equilibrium levels dictated by climate and precipitation. The major reasons identified for soil health deterioration are: wide nutrient gap between nutrient demand and supply, high nutrient turn over in soil-plant system coupled with low and imbalanced fertilizer use, emerging deficiencies of secondary and micronutrients in soils, soil acidity, nutrient leaching in sandy soils, nutrient fixation in red, laterite and clayey soils, impeded drainage in swell-shrink soils, soil salinization and sodification etc.

Enhancing sustainable food production through improved soil health require integrated strategies for the use of land and water resources: a) agricultural intensification on the best arable land, b) rational utilization of marginal lands for agriculture, and c) prevention and restoration of soil degradation. The future research activities in the domain of nutrient management and fertility improvement need to address crucial issues: (i) assessment of nutrient substitution rates or fertilizer equivalent value of diverse organic materials having potential for use as soil fertility restorer inputs, (ii) developing newer fertilizer products using low-cost and locally available minerals and assessing the potential of such modified materials to minimize losses and improve use efficiency of nutrients, (iii) developing precision agriculture tools involving precise fertilizer application based on soil tests, (iv) customized fertilizers through fortification, nano-fertilizer materials needs much attention in future. Future soil research must tackle the issue of micronutrient malnutrition that is affecting human health and productivity. Bio-fortification has been identified as a major thrust area.

There is a need to characterize the vast amount of biodiversity of soil fauna and flora which plays a critical role are recycling of nutrients in bio-solids and manures, removal of environmental contaminants, reclamation strategies of degraded soils, and improvement in soil physical conditions by enhancing aggregation and C sequestration. There are still many questions about the interactive effects of increasing temperatures and CO_2 concentrations on plant growth and development. Hence future research strategies would be (i) Assessing the effect of CO_2 on growth and development of soybean-wheat and the other prevalent cropping systems under different temperature regimes, (ii) Development of mitigation strategies, (iii) Modeling the interactive effect of CO_2 and temperature on SOC dynamics. Prevention is the best method to protect the environment from contamination by heavy metals. Preventing heavy metal pollution is critical because cleaning contaminated soils is extremely expensive and difficult. Various approaches are used in different

countries to assess the level of heavy metals in contaminated soils. There is an urgent need to formulate heavy metal standards to assess soil quality.

Water resources will come under increasing pressure in the Indian subcontinent due to the changing climate. It is projected that most irrigated areas in India would require more water around 2030 and global net irrigation requirements would increase relative to the situation without climate change by 3.5–5% by 2025, and 6–8% by 2075. Therefore, we need long-term strategies for enhancing water productivity.

The institute is well equipped to take up the emerging challenges of food security and safety, soil and water quality, organic waste recycling, global climate change, environmental protection etc by reorienting it research pursuits addressing the emerging issues viz., Enhancing Nutrient and Water Use Efficiency, Sustaining Soil and Produce Quality, Soil Biodiversity and Genomics, Climate change and carbon sequestration, Minimizing Soil Pollution etc. The first systematic effort to envision the challenges and opportunities, and to formulate its own strategy was undertaken in the last year of 20th century by preparing 'Vision 2020'. The next attempt was after five years by preparing “IISS Perspective Plan 2025' to address changes that had taken place. The present document, IISS Vision 2030 articulates the strategic framework for innovation-led sustainable productivity of soil resources with minimum environmental degradation.

'IISS Vision 2030' document narrates key challenges and opportunities in sustainable soil resource management vis-à-vis crop production sector in the next two decades for developing an appropriate strategy and a road map to articulate role of Indian Institute of Soil Science in shaping the future of soil research in India for sustainable growth of agriculture.

Soil Research Scenario

The present world population of 6 billion is expected to reach 8 billion by the year 2030. It is expected that most of the increase in population would occur in developing countries where nearly 1 billion people suffer from chronic malnutrition. Many developing countries face major challenges to achieve food, fibre, fodder, fuel, income, equity and social justice in a sustainable manner, considering available per capita land area, severe scarcity of fresh water resources and particular socio-economic conditions. Higher crop productivity, income, employment and environmental services will have to be achieved from the land that is already being farmed. The Indian population, which increased from 683 million in 1981 to 1210 million in 2010, is estimated to reach 1412 million in 2025 and to 1475 million in 2030. To feed the projected population of 1.48 billion by 2030 India need to produce 350 million tonnes of food grains. The expanded food needs of future must be met through intensive agriculture without much expansion in the arable land. The per capita arable land decreased from 0.34 ha in 1950-51 to 0.15 ha in 2000-01 and is expected to shrink to 0.08 ha in 2025 and to 0.07 ha in 2030. So the current food-grains production of 218 mt (2009-10) is produced from the net arable land of 141 m ha. Soil and water management form the basis for sustainable system of productive agriculture. Soils of India broadly fall into five main groups, viz., red soils, black soils, alluvium derived soils, soils of arid region and soils of Himalayan and Shiwalik region. These soils differ in their productivity and need differential management practices depending on soil physical and chemical properties and biological conditions, rainfall/availability of water for irrigation and crops and cropping systems.

Factor productivity

The total factor productivity is used as an important measure to evaluate the performance of production system and sustainability of its growth pattern. The partial factor productivity of fertilizers is declining in intensive cropping systems in India. The partial factor productivity of fertilizers during the last three and half decades showed a declining trend from 15 kg food grains/kg NPK fertilizer in 1970 to 5 kg food grains/kg NPK fertilizer in 2005. In urgency for higher production, no serious attention was given to the long-term soil quality, and sustained high productivity. As a consequence, the annual compound growth rate of major crops has declined from 3.36% in 1981-85 to 0.11% in 2001-05. Such gloomy trend was also registered in case of pulses and oilseeds, while cotton exhibited even negative growth rate. The inputs mainly include nutrient supply, irrigation, energy, plant protection measures and cropland. The current status of nutrient use efficiency is quite low in case of P (15-20%), N (30-50%), S (8-12%), Zn (2-5%), Fe (1-2%) and Cu (1-2%).

The decline in partial factor productivity and compound growth rates of major crops under intensive cropping systems and low nutrient use efficiency are results of deterioration in soil quality. Continuous cropping leads to decline in organic C levels by 50-70% to equilibrium levels dictated by climate and precipitation. The major reasons identified for soil quality deterioration are: wide nutrient gap between nutrient demand and supply, high nutrient turn over in soil-plant system coupled with low and imbalanced fertilizer use, emerging deficiencies of secondary and micronutrients in soils, soil acidity, nutrient leaching in sandy soils, nutrient fixation in red, laterite and clayey soils, impeded drainage in swell-shrink soils, soil salinization and sodification etc.

Soil Quality and Assessment

It is known that agricultural intensification can have negative effects at different scales, such as, increased soil erosion, soil fertility decline and reduced biodiversity at the local level, depletion and pollution of groundwater and eutrophication of surface waters at the regional level, and changes in atmospheric composition and climate on a global scale. Enhancing sustainable food production will require integrated strategies for the use of land and water resources: a) agricultural intensification on the best arable land, b) rational utilization of marginal lands for agriculture, and c) prevention and restoration of soil degradation. Soil degradation is a severe problem in countries like India with high demographic pressure. For preventing and restoring soil degradation, the main issues will be controlling soil erosion and sedimentation with the associated risks of eutrophication of surface water and contamination of groundwater, combating desertification and enhancing soil carbon sequestration to improve soil quality/productivity and mitigate the greenhouse effect.

For sustaining better soil quality under intensive systems of agriculture, the emphasis should be on developing of workable soil quality indicators and methods to assess and monitor soil quality, assessment of soil quality under different land use management systems (cropping system, tillage, water and nutrient use practices) and to identify the effect of management practices aggrading/ degrading/ sustaining soil quality. Also strategies need to be formulated to decide the amount of organic matter to be in the form of organic manures/organic waste/residue each year to maintain or build up the soil organic matter (SOM) level in various soil types.

Trends in soil fertility change

First systematic soil fertility map of Indian soils was published in 1967 by Ramamurthy and Bajaj (1969). At that time around 4% samples were high in available P. The soil fertility map published in 2002 (Motsara, 2002) indicate that around 20% of soil samples are high in available P. Recently prepared GIS based district-wise soil fertility maps of India (Muralidharudu et al. 2011) showed that the soils of about 57% districts were low in available N, 36% medium and 7% were high. Similarly, soils of about 51% districts were low, 40% were medium and 9% were high in available P. Available K status showed that the soils of about 9% districts were low, 42% were medium and 49% were high in available K status. The high P status in some soils is due to non-judicious use of phosphatic fertilizers by the farmers. This suggests that the considerable portion of soils in the country may have become rich in available P as the farmers continue to use the phosphatic fertilizers. Therefore, if the farmers apply P as per the soil tests, there is a chance to save a lot of valuable phosphatic fertilizers by the year 2030. The deficiency of nitrogen might continue to remain same in Indian soils, as they are low to medium in organic matter content. The three estimates (Ramamurthy and Bajaj, 1969; Ghosh and Hasan, 1980; Motsara, 2002) of soil fertility for K indicate an increase in the percentage of samples testing high over the years. The situation indicate an increase in the K-supply position of soils, however, quite possibly it could be due to poor representative character of sampling, noncognizance of pedological classification of soils, and lack of control over the choice of sampling sites. The situation, however, could be tackled in a better way with well planned geo-referenced soil sampling, integration of remotely sensed data with laboratory analyses and representation of spatial soil fertility in the form of maps in a more meaningful way in future. Also some bench-mark sites could be used in the dominant cropping systems in different

soils to monitor the change in soil fertility and its relationship with the yields. Thus, there is a need to monitor long-term changes in soil fertility to evolve strategies for improving the soil fertility.

Scenario of plant nutrient demand and supply

The growth in fertilizer consumption slowed down during 1990s and after achieving a record consumption level of 18.1 m t of NPK in 1999-00, the NPK consumption stabilized around 16-18 mt upto 2005. However, it again gained momentum since then with current consumption level being 26.5 m t in 2009-10. However, still there is hardly any national or foreign direct investment into fertilizer manufacturing. The same fertilizer plants based on medieval feedstock as neptha are still in business. At present level of crop production, crops remove around 30 m t of NPK whereas the consumption is around 26 m t which leaves a gap of 4 mt. The projected food grain production removes about 45 mt of NPK with an expected foodgrain production of 350 mt in 2030 and 36 mt fertilizer nutrient additions if the current trend in fertilizer consumption observed over the last twenty years (Linear trend, R^2 = 0.86) is continued for the next 20 years, thus maintaining the negative gap to 9 m t. This may be a potential threat to the soil quality and sustainable agriculture. The use of nutrients through organic inputs is therefore, imperative for maintaining the sustainability of the system. To balance the gap, the present contribution of organic inputs towards nutrient additions is around 6.0 million tonnes and that need to be increased.

Imbalanced fertilizer nutrient use

The fertilizer consumption in India is grossly imbalanced since beginning. It is tilted more towards N followed by P. Further decontrol of phosphatic and potassic fertilizers resulted in more than doubling the prices of phosphatic and potassic fertilizers. Thus, the already imbalanced consumption ratio of 6.2:4:1 (N: P: K) in 1990-91 has widened to 7:2.7:1 in 2000-01 and 5:2:1 in 2009-10 as against favourable ratio of 4:2:1. As food grain production increased with time the number of elements becoming deficient in soils and crops also increased. The number of elements deficient in Indian soils increased from one in 1950 to 9 in the year 2005-06 which might further increase by the year 2030 if the imbalanced fertilization continues.

Emerging multi-nutrient deficiencies

Different soils have unique inherent problems that come in the way of achieving the sustainable high productivity. The problems include acidity in hill and laterite soils, nutrient leaching in sandy soils, nutrient fixation in red, laterite and clayey soils, impeded drainage in swell-shrink soils, volatilization losses of N from calcareous soils, Zn deficiency in low organic matter, sandy, high pH and high water table soils, B deficiency in highly calcareous leached acid soils, Fe and Mn deficiency in rice-wheat system largely on sandy soils. Analysis of more than 0.25 million soil samples revealed wide spread deficiency of Zn (49%) followed by S (41%), Fe (12%), Cu (3%), Mn (4%) and B (32% in some selected areas such as Bihar).

Suggested thrust areas of research for sustainable crop production through better soil quality include, creation of databases on soil, water and air resources to make projections for the future and also inventorization of the available organic/ bio-fertilizers, crop residues, city wastes, etc. and their availability at regional/national level for strategic planning and their utilization. Delineation and mapping of macro and micro nutrient deficiencies using GIS and GPS tools and also simulation modeling may receive attention to aid in nutrient management decisions for important agro-ecosystems.

Some research areas that need urgent attention for improving Nutrient Use Efficiency (NUE) are, development of

multinutrient formulations and other novel controlled release fertilizers to minimize the nutrient losses from soil-plant system, Scheduling nutrient application to match requirements of crops/cropping systems, Germplasm screening for efficient nutrient use, and Recycling of crop residues and other organic wastes etc.

Declining organic matter status

Soil organic matter plays key role in soil fertility sustenance. In soybean-wheat system, without balanced input of nutrients, organic matter status of soil declined over a time in Alfisols of Ranchi. Whereas, balanced fertilization with NPK and NPK+FYM improved the organic matter status in Vertisols under soybean-wheat system at Jabalpur. Thus, assessing soil organic carbon (SOC) accretions/sequestration under intensive cropping with different management practices plays an important role in long-term maintenance of soil quality.

The carbon sequestration research is gaining credence worldwide in the context of sustainable management of land and soil resources and arresting the deterioration of the environment. The emerging field opens up many new avenues of basic and strategic research relevant to Indian conditions for the next 2-3 decades. The future research should take lead in modeling carbon sequestration potential of different soils and land use systems and establishing benchmarks and standards for carbon trading. With large area under wastelands, the Indian farmers are going to derive potential economic benefits out of the new carbon-trading venture.

Potential availability of organic resources

It is estimated that 300, 375 and 16.5 million tonnes of crop residues, livestock dung and human excreta per annum, respectively are available in the country. Of this, around one third of crop residues and half of the livestock dung and 80% of human excreta are available for use in agriculture. The greater use of these materials in agriculture can ensure better soil fertility and sustained high productivity. The availability of these organic sources is likely to increase in future. It is estimated that every million tonne increase in food grain production will produce 1.2-1.5 million tonnes of crop residue and every million increase in cattle population will provide additional 1.2 million tonnes of dry dung per annum. Thus the estimated NPK supply from all the wastes including crop residues is 5.0, 6.25 and 10.25 million tonnes, respectively during 1991, 2011 and 2030. A greater use of organic input has the potential to decrease the expected negative balance since greater availability of alternative fuel such as LPG in rural households in future may make the more organics available for use in agriculture.

Prospects of organic solid waste recycling

Organic solid wastes generated in large quantities by domestic, commercial and industrial activities are often indiscriminately disposed on the soils. In recent survey (2011), it has been estimated that more than 5100 towns and 380 urban agglomerations of India, harboring 27.8% of country's population generate more than 70 million tonnes of municipal solid wastes (MSW). Cities with more than one lakh population contributed 72.5% of the waste generated in the country as compared to other 3955 urban centers that produce only 17.5% of that total waste (MOUD 2005). Considering an average collection efficiency of about 70%, country has the potential of producing about 5 - 14 million tonnes of compost annually from municipal solid wastes depending on the method of composting which is expected to reach about 12 - 35 million tonnes per year by the year 2030 as a result of phenomenal increase in urban population and ever increasing industrialization. This, however, is possible by improving the composting technology of city wastes that is also cost effective. By following the proper

composting techniques, the municipal solid wastes can provide an amount of 1.2 to 2.5 lakhs tonnes of N, P and K that could be increased to about 2.1 to 4.4 lakh tonnes per year by 2030. The currency value of fertilizer savings through MSW compost can be about 367 crores at the current level of solid waste generation and can go up to 653 crores by the year 2030 through the involvement of improved technology in compost making.

Soil scientists and other environmentalists have to play a pivotal role in converting these wastes into valuable manure through proper management. Use of organic manures is effective in stabilizing productivity under low to medium cropping intensity while integrated use of organic and chemical fertilizers provides stability and sustainability to crop production under modern intensive farming. Research is needed on the utilization of MSW composts of varying quality produced through different methods in the integrated nutrient management of crops and cropping systems and in peri-urban agriculture.

Organic farming and establishing quality standards

India has 15% of the world's livestock population and a great opportunity lies ahead for organic farming in the regions where the livestock density is higher. The Indian organic farming industry is estimated at about 900 million rupees (US$ 20 million) and is almost entirely export oriented (www.eximbankindia.com). According to Agricultural and Processed Food Products Export Development Authority (APEDA), a nodal agency involved in promoting Indian organic agriculture, about 6,792 tonnes of organic produces with a worth of 712 million rupees are being exported from India (www.Apeda.com). Ascertaining the scope of organic farming in the country in the context of geographical advantages and export potential of crops, with special reference to annual crops should receive top priority.

Organic agriculture offers trade opportunities for farmers in the developing and developed countries. This market of organic products is expected to grow globally in the coming years and high growth rates over the medium term (from 10-15 to 25-30 %) are expected. Organic farming is being advocated in certain areas and selected crops having export potential. Thus there is an urgent need to devise organic produce protocols and package of practices for different agro-ecoregions by combining existing ITK and modern technological approaches. Working out quality standards for organic produce and economics of organic farming vis-a-vis fertilizers should receive immediate attention.

Characterization and conservation of agro-biodiversity

India is endowed with a wide variety of climates and soils and has a rich biodiversity in both fauna and flora. Much of microbial diversity remains unexplored. It is estimated that although one third of fungal diversity of the globe exists in India, yet only 5% of the fungi have been characterized so far. Similarly only 1% of the bacteria are culturable. The uncultured soil microbial diversity represents a rich reservoir of microorganisms and genes. However, a vast amount of basic research is required for exploitation of vast pool of genes in soils for agricultural, industrial, pharmaceutical and other uses to benefit mankind.

Functioning of terrestrial ecosystems, plant biodiversity, productivity, variability and stability is directly depends on the community diversity of soil biota. Soil biodiversity is an abstract aggregated property of species in the context of communities or ecosystems. Functional diversity rather than taxonomic diversity (community structure) or species richness per se is the major determinant of ecosystem functioning. It may be thus more important to understand the linkages between the actions of a key species or the functional groups and ecological functions of different

ecosystems than to search for the diversity index or the species richness and try to relate the same to ecosystem or community functioning.

Characterization of functional communities of soil organisms (flora and fauna) and soil biological activities under different soil crop situations for enhancing nutrients availability and also characterization of microbial biodiversity and functional communities (particularly N_2- fixers, P&S solubilizers, Ligni-cellulolytic organisms), testing of mixed biofertilizer formulations and diversity of biofertilizers in agriculture should receive top priority.

Since the organic materials are a scarce commodity, biofertilizers particularly plant growth promoting rhizobacteria (PGPR) and mycorrhiza (VAM) are increasingly being deployed and good responses are being obtained showing that increasing the soil microbial diversity through such inoculation is benefiting the soil health in a similar way as addition of organics which also promote the proliferation of native soil health promoting microorganisms. This has led to a surge of interest in biofertilizers and the production of carrier based microbial inoculants increased from around 2000 tonnes/yr in 1991-92 to around 20000 tonnes in 2009-10. About 0.48 million tonnes of N and 0.20 million tonnes of P are being contributed by the 13000 tonnes of biofertilizers. It is expected that the use of biofertilizer will increase to 27000 tonnes by the year 2030 which will contribute substantial amount of N and P.

Microbial inoculation will be a regular feature not only to promote nutrients mobilization including micronutrients but also fight stress conditions like drought and salinity and increasingly, as to control specific diseases and maintain soil health. This will result in big expansion of industries producing biofertilizers and bio-control agents and improvement in biofertilizer technology. Biosensors based on gene chips would be developed and routinely used to monitor the levels of inorganic and organic contaminants in water and soils and monitor soil health. For this, suitable research information in biochemistry would be needed.

Conservation agriculture and zero tillage

Conservation Agriculture having the principle of providing continuous soil cover (by using crop residues, cover crops, agro-forestry etc.), minimum soil disturbance and crop rotations bears a high potential to sustain Indian agriculture by increasing productivity, while protecting natural resources and environment. It is practiced on more than 75 million ha worldwide in more than 50 countries. Adoption of conservation agriculture under the present scenario of global warming due to GHGs evolutions from land use change, and carbon trading potential in India becomes imperative. It is speculated that over the past few years, adoption of zero-tillage has expanded to cover about 2 m ha. The potential of C sequestration in C depleted soils of India is high with adoption of conservation tillage. It is also estimated that most part of the country will receive higher rainfall in 2020, 2050 and 2080 than the current value, so this changing scenario can be converted to suitable opportunities in conserving and sequestering C in Indian soils along with the attendant co-benefits of enhanced soil and water quality, improved soil structure with concomitant reduction of soil erosion and protection of environment. Thus, the future perspectives include the evaluation of conservation tillage practices affecting savings on water, nutrients, energy and time for raising the productivity of farms. Studies on water, nutrient and tillage interactions are desired for improving input use efficiency. There is also a need to look for strategies for zero tillage in dryland farming situations.

Water management

The Indian agriculture is supporting 16.8 % world's humans from 2.42 % world's land and 4% of the world's fresh water with constraints of highly variable rainfall spatially and temporarily. The production in most of the irrigated area has reached plateau and the water use efficiency is likely to be stagnant. With all developments in all water resources, about 50 per cent of the country's agriculture has to depend upon rainfed agriculture. The water demand in other sectors in comparison with irrigation is shooting up and the per capita availability of land and water is declining. For meeting the demand of the country's continuously swelling population, the current irrigated land of 66 M ha has to increase to 76 M ha by 2025 and to 80 M ha by 2030. The areas where ground water recharge potential is low, the use of groundwater for irrigation has to be more balanced and judicious than areas where groundwater recharge potential is high. The choice of increasing groundwater irrigation is warranted, because its irrigation efficiency (65-70 %) is higher than canal (38 %). Under such situation of the country, enhancement in production has to be come from less water and land. Achieving the task of higher productivity in future is likely to be increasingly difficult and challenging. The research and developments in agriculture has to focus on developing practicable tools and strategies to conserve moisture in-situ, recharge groundwater, harvest water in arid and semi arid areas and develop strategies for multiple use of water especially for humid areas.

Most of the breeding programmes, hitherto, have been concentrated to evolve high yielding, disease and pest resistant cultivars. In future, an interdisciplinary effort between mutation breeders and soil and water management specialists is required to identify and evaluate the performance of elite germplasm and to understand mechanisms of stress tolerance.

Acid Soils

Nearly 25 million hectares of cultivated lands with pH less than 5.5 are critically degraded. The productivity of these soils is very low (one tonne/ha) due to deficiencies of P, Ca, Mg, Mo and B and toxicities of Al and Fe. Liming and nutrient management technologies have been developed to ameliorate acid soils and increase their productivity. But economics of liming is questionable because of high lime requirement of most of the acid soils of India and the effect of liming does not persist for long. Therefore, the liming effect of other cheaper materials such as paper mill sludge, pressmud, household wastes-ash and limestone has to be exploited as the alternative. Since the deficiency of micro and secondary nutrients is emerging as the yield limiting factors in addition to inherent problems of these soils, soil tests need to be calibrated on acid soils for recommending fertilizer dose for a whole cropping sequence based on initial soil test values.

Soil Health in relation to Human and Animal Health

Soil is a crucial component of rural and urban environments, and in both places land management is the key to soil quality maintenance. Due to increased anthropogenic activities, soil is the recipient of several pollutants like pesticides, herbicides, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, heavy metals and many inorganic salts. These pollutants have adverse impacts on soil physico-chemical environment, nutrient cycling/transformation processes, soil biodiversity, plant growth, food quality through contamination etc. Large quantity of urban wastes is produced in different cities causing water, air and soil pollution. Mining, manufacturing and the use of synthetic products (eg. Pesticides, paints, batteries, industrial wastes, and land application of city and industrial sludge) can result in heavy metal contamination of urban and agricultural soils.

Excess heavy metal accumulation in soils is toxic to humans and other animals. This leads to introduction of toxic elements in the food chain and might pose a serious threat to animal and human health. The wide spread occurrence of geomedical problems of anemia, goiter, dental caries, coronary artery diseases is directly related to reduced Fe, I, F, and Mg in the food, respectively. Selenosis in animals and fluorosis in human beings caused due to toxic levels of Se and F in food and drinking water.

Prevention is the best method to protect the environment from contamination by heavy metals. For this, regulations governing the maximum loading limits of heavy metals have been developed by a number of developed countries. India does not have any such regulation or guidelines to set heavy metal loading limits for land application of pollutants. Hence, there is an urgent need to formulate heavy metal standards to assess soil quality and develop our own formal guidelines.

Generation of information on atmospheric input of N, S, B, F, I etc helps in understanding nutrient cycling and budgeting in agro eco-systems and geo-medical problems. Micronutrients cycling in soil-plant-animal -human –continuum plays a key role in micronutrient nutrition of animals and human beings. Studying relationship between soil quality and animal and human health in collaboration with medical institutions will be rewarding and will help solve several nutritional problems.

Phyto/Bioremediation of Contaminated Soils

Developed countries are challenged by visible damage to their environment by a multitude of contaminants as a consequence of industrial growth. Remediation measures generally employ physical, chemical or biological means or their combinations. The first two are referred to as engineering strategies, and the latter as bioremediation. In the latter tool, the living organisms are used to reduce or eliminate environmental hazards resulting from accumulation of toxic chemicals and other hazardous wastes. Another new trend in bioremediation is the use of phytoremediation using plants and vegetation as a clean up tool. This method exploits various biogeochemical processes in the rhizosphere including extraction, immobilization, and degradation of contaminants and offers some viable solutions for dealing with mixed wastes.

Database on the extent of soil and water contamination due to heavy metals which needs to be generated. Conventional methods to remediate metal-contaminated soils (hand filling or excavation and extraction) can be used at highly contaminated sites but are not applicable to large areas. These remediation methods require high energy input and expensive machinery. Phytoremediation, the use of plants to clean soils, can be a cost effective in situ alternative for low and medium contamination soils and does not adversely affect soil fertility.

Screening of germplasms of crops and other plants for efficient heavy metal accumulators is highly desired. Also there is an urgent need for working out of phyto/bio-remediation options for waste products/effluents of important industries like paper mills, tanneries, distilleries etc.

Indian Institute of Soil Science

In view of the fast changing scenario of Indian agriculture, and the growing importance of enhancing and sustaining productivity of soil resources, the Indian Institute of Soil Science was established at Bhopal in 1988 by the ICAR with the following mandate.

The Mandate

To provide scientific basis for enhancing and sustaining productivity of soil resources with minimal environmental degradation

The Institute Set-up

The Institute has four divisions viz., Soil Physics, Soil Chemistry and Fertility, Soil Biology and Environmental Soil Science and one section i.e. Statistics & Computer Applications.

Soil Physics

The major emphasis of this division is to carry out research on management of soil physical components to enhance and sustain soil quality and productivity through conservation tillage; to study the interaction of water & nutrient; study solute movement in soils (root zone) under intensive production system; and to develop root simulation models for water and nutrient uptake.

Soil Chemistry and Fertility

The division has been entrusted with the responsibility to conduct the basic and strategic research related to nutrient management and fertility improvement of soils of India, to study the nutrient dynamics to enhance the efficiency of applied nutrient inputs, improve and maintain carbon stocks in soils, develop nutrient models to aid nutrient management decisions for important agro ecosystems, assess soil quality to monitor long term changes in soil fertility under different agro-ecological systems and build up models for predication of changes in soil health.

Soil Biology

The division is entrusted with responsibility to undertake research on management of soil biota, biofertilizes, PSM, VAM, earthworms etc. for the enhancement of nutrient supply, solubilization developing efficient techniques for inoculation and composting; transformation and turnover of microbial biomass and biomass nutrients; recycling of organic wastes and organic matter dynamics.

Environmental Soil Science

The division is entrusted with the responsibility to develop technologies to reduce pollution from city and industrial wastes; nitrate leaching to ground water bodies, nutrient load in run-off and drainage water; evaluate sink capacity of soils for pollutants, decontaminate the soils contaminated with heavy metals using plants (phytoremediation) and microorganism (bioremediation) to minimize emission of green house gases and to study the environmental implications of organic farming.

Further, to help in fulfilling its mandate and to strengthen and to provide a path guiding role in Soil Science Research in the country, three all India Coordinated Research Project (AICRPs) viz., Long Term Fertilizer-Experiment (LTFE), Soil Test Crop Response Correlation (STCR), Micro and Secondary Nutrients and Pollutants Elements in Soils and Plants (Micronutrients) and a Network Project on Biofertilizers are functioning at the Institute.

Infrastructure Facilities

Analytical Instruments: The Institute has advanced analytical instruments such as Inductively coupled plasma (ICP), NIR Spectrophotometer, FTIR, CHNS Analyzer, Gas Liquid Chromatograph, Atomic Emission Spectrophotometer, Atomic Absorption spectrophotometer (AAS), Ion Chromatograph, Pressure Plate, Neutron Moisture Meter, Guelph Permeameter, Penetrometer, Vane Shear Apparatus, K-Permeameter, Rainfall Simulator, IR Thermometer, Air Permeameter, Image Analysis System, Kjeltech System, Microwave Digestion Unit, Autotitrator, Flame Photometer, Nephalometer, HPLC, UV-Visible Spectrophotometer, Water Analyzer, Flow Injection Analyzer, Freeze Drier etc.

Experimental Farm: The Institute developed its campus and experimental farm on a consolidated block of 50 hectares in area situated between 23°18'14" and 23°18'48" N latitude and 77°24'17" and 77°24'58" E longitude on Vindhyan plateau of western Madhya Pradesh. The institute developed four run off water collection ponds for water harvesting and its efficient use on the farm.

Library, Information and Documentation Services: The Institute Library has collection of core books and journals mainly in the field of soil science, and the collection contains 2310 books, 1618 bound journals and 891 Annual Reports. It subscribes 74 journals, out of which 30 are international journals. Collection of the Library has been computerized with the UNESCO's software CDS/ISIS (3.07) and is having up-to-date databases on books, annual reports and journals. The Library has got a separate section for the CD-ROM search for research abstracts published in various journals world wide with two major databases, i.e., SOIL-CD and AGRIS-CD.

GIS Facility: Institute has established GIS facility for soil fertility mapping with GIS, GPS and Remote Sensing Tools. This facility has three GIS workstations, Digitizer, A0 Scanner and Plotter, GPS etc.

Conference Hall: The Institute has a well-furnished, air-conditioned and well-equipped conference room with a sitting capacity of 120 persons for organizing seminars and inaugural and valedictory functions of training programmes.

Training Hostel-cum-Guest House: The Institute has developed its training hostel-cum- guesthouse in its premises to provide boarding and lodging facilities to trainees and other officials. The training hostel cum guesthouse has four VIP rooms for visiting faculty.

Committee Room : A well furnished and air conditioned committee room equipped with audio system and detachable cable mounted microphones, audio-visual projection system with multimedia projector has sitting capacity of 65 persons.

Major Basic Research Achievements

- Understanding soil chemical, physical and biological processes under long-term cropping, manure and fertilizer use.
- Quantification of N_2 fixation and annual N benefit from biological fixation in soybean-wheat system.
- Developed malachite green method for the estimation of minute quantities of P in various soil extracts.
- Mineralization kinetics and transformations of S under long-term use of fertilizers and manures.
- Mobilization and utilization of P from low-grade rock phosphate using soybean leaf litter.
- Determination of soil potassium stocks in Indian semi-arid tropics in terms of biotite content.
- Zinc dynamics in major benchmark soils of India.

- Soil test maintenance P requirement of soybean-wheat system.
- Impact of long-term tillage, residue, water and fertilizer management on soil health and crop productivity assessed.
- Climate change and soil organic carbon dynamics.
- Carbon sequestration under low, medium and high management systems in different regions.
- Assessing soil biological quality under INM.
- Soil and produce quality under organic farming.
- Developed quality standards for urban solid waste composts.
- Developed maturity indices for composts.
- Impact of polluted irrigation water as soil quality assessed in Ratlam-Nagda industrial area and suggested the remedial measures.
- Sink capacity of soils for metal pollutants.

Major Technologies Developed

- Integrated and balanced nutrient management technologies for soybean-wheat system, cotton, pulses, oilseed crops and soybean/maize-wheat intercropping system.
- Residual P management in soybean-wheat system.
- Integrated N management in rice-wheat system.
- Wheat residue management technology in soybean-wheat system.
- On-line fertilizer recommendation system for different cropping systems.
- GIS based district-wise and tehsil-wise soil fertility maps of major states.
- Evaluated new fertilizer material viz., bentonite sulphur pastilles as source of sulphur.
- Identified alternate cropping systems in deep Vertisols of M.P.

- Conservation tillage practices for soybean-wheat system.
- Sub-soiling technology for soybean- pigeon pea intercropping
- Technology for efficient use of limited water supply in soybean-wheat and maize-gram systems.
- Vermi-composting technology
- Technology for production of enriched compost.
- Safe prescription limits for use of distillery effluents.
- Screened different flowering plant species for phyto-remediation
- Organic farming practices for soybean, wheat, isabgol, pigeon pea etc.
- Developed mixed biofertilizers and liquid biofertilizer formulations and techniques for their efficient use in improved nutrient management.
- Developed district-wise soil test crop correlation (STCR) based site-specific balanced fertilizer and integrated nutrient management recommendations for different crops of the country.

IISS 2030

The Institute was started on 16th April 1988 at Bhopal, Madhya Pradesh, Central India. It is located in Nabibagh village which is about 7 km and 11 km away from Railway Station and Air Port, respectively. Since then The Indian Institute of Soil Science is marching ahead with vigour of young scientists to face complex challenges of soil health and crop productivity issues and to harness domestic and global opportunities to overcome these for the welfare of the farmers, consumers and other stake-holders in the food-supply chain. Sincere efforts are being made to become a leading organization in the world in the field of soil science, which is vibrant, responsive and sensitive to the needs of stakeholders.

Vision

Sustaining Higher Crop Productivity and Better Soil Health through Basic Research and Technological Interventions

Mission

Enhancing Soil Productivity with Minimum Environmental Degradation

Focus

To accomplish the vision and mandate of the IISS, Bhopal – it gives the highest priority to soil health issues faced by farmers and other stakeholders and entire strategy is based on "Farmers' First". It would concentrate on the following key areas.

1. To carry out basic and strategic research on soils especially physical, chemical and biological processes related to management of nutrients, water and energy.
2. To develop advanced technology for sustainable systems of

input management that is most efficient and least environmental polluting.

3. To develop database repository of information on soils in relation to quality and productivity.

4. To develop expertise and backstop other organizations engaged in research on agriculture, forestry, fishery and various environmental concerns.

5. To exchange information with scientists engaged in similar pursuits through group discussions, symposia, conferences and publications.

6. To collaborate with State Agricultural Universities, National, International and other Research Organizations in the fulfillment of the above objectives.

Focus

The impaired soil quality, as a sequel to certain amount of deterioration in soil physical and chemical conditions, falling organic matter levels and consequent biological condition and emergence of some nutrient deficiencies, is being ascribed as one of the reasons for decline in factor productivity of major crops. Need to have a workable index of soil quality assessment imbibing influence of different physical, chemical and biological soil attributes.

The carbon sequestration research is gaining credence worldwide in the context of sustainable management of land and soil resources and conserving deteriorating environment.

Organic farming is being advocated in certain areas and selected crops having export potential. Urgent need to devise organic produce protocols and package of practices for

different agro-ecoregions by combining existing ITK and modern technological approaches.

Improving applied nutrient and water use efficiency in different production systems.

The conservation tillage practices affecting savings on water, nutrients, energy and time should be evaluated for raising the productivity of farms.

Gainful utilization of urban solid wastes generated by rapidly increasing urban population by converting them to value added composts. Develop cost-effective and eco-friendly composting and water treatment technologies for effective utilization of the solid and liquid wastes.

Characterization and prospecting of large soil bio-diversity still remains a challenging and rewarding area of research.

Need to have an ostensible understanding about the cause and effect relationship in soil and food contamination with heavy metals and pesticides to suggest mitigating options.

Nanotechnology may play an important role in future soil science research particularly in improving the input use efficiency and decontamination of polluted soils.

Basic and strategic research to develop adequate quality standards of composts suiting to Indian conditions for enforcing quality control.

India does not have any regulation or guidelines to set heavy metal loading limits for land application of pollutants and there is an urgent need to work in this direction

Harnessing Science

The Indian Institute of Soil Science would strive hard to harness the power of soil science and other related disciplines in increasing productivity, enhancing nutrient and water use efficiency, minimizing soil and environmental pollution, improving soil and produce quality, recycling organic wastes, maintaining biodiversity etc through improved and conventional techniques. The institute would develop innovative techniques to protect soil health for better livelihood through basic and strategic research.

In the present context, technological challenges are becoming more and more complex than before as demand for food is increasing and soil resources are declining. The per capita arable land decreased from 0.34 ha in 1950-51 to 0.15 ha in 2000-01 and is expected to shrink to 0.07 ha in 2030. Despite significant growth in agriculture during the last four decades, most of our important soil based production systems are showing the signs of fatigue. As a result, the crop yields stagnated and the total factor productivity of fertilizers has been declining in intensive cropping systems. The decline in factor productivity and compound growth rates of major crops under intensive cropping systems and low nutrient use efficiency are results of deterioration of chemical, physical and biological quality of the soils and imbalanced and inadequate supply of plant nutrients to the soils. Incidentally, science is also changing rapidly with availability of new tools, techniques, approaches that promise technological breakthroughs to accomplish the mission.

Enhancing Nutrient and Water Use Efficiency

As discussed in the scenario, the current nutrient use efficiencies of applied nutrients is very low in different crops/cropping systems. The institute has been working hard to

develop efficient nutrient management strategies and evaluating new fertilizer materials for achieving higher efficiency. The country has now realized the absolute necessity of integrated plant nutrient management systems involving a sensible blend of chemical fertilizers along with composts, vermi-composts, green manures, biofertilizers, non toxic organic wastes, biopesticides, etc. which are now almost universally advocated along with recommendations on judicious use of irrigation water. Integrated and balanced nutrient management technologies were developed for soybean-wheat system, cotton, pulses, oilseed crops and soybean/maize-wheat intercropping systems. The institute has developed/evaluated newer fertilizer materials such as nano-phos from low grade phosphate rocks, bentonite sulphur pastilles, urease and nitrification inhibitor coated urea fertilizers, granubor etc.

The future research activities in the domain of nutrient management and fertility improvement need to address four crucial issues: (i) assessment of nutrient substitution rates or fertilizer equivalent value of diverse organic materials having potential for use as soil fertility restorer inputs, (ii) developing newer fertilizer products using low-cost and locally available minerals and assessing the potential of such modified materials to minimize losses and improve use efficiency of nutrients, (iii) developing precision agriculture tools involving precise fertilizer application based on soil tests, (iv) customized fertilizers through fortification, nano-fertilizer materials needs much attention in future.

Water resources will come under increasing pressure in the Indian subcontinent due to the changing climate. It is projected that most irrigated areas in India would require more water around 2030 and global net irrigation requirements would increase relative to the situation without climate change by 3.5–5% by 2025, and 6–8% by 2075. The quantity of water required for agriculture has increased progressively through the years as more and more areas were brought under irrigation. According to available estimates, due to judicious utilization, the demand on water in this sector is projected to decrease to about 68% by the year 2050, though agriculture will still remain the largest consumer.

Under such circumstances, improving water productivity (WP) is one option for coping with water scarcity. Traditionally, the discussion of crop water–yield relationship is mainly addressed at crop plant and field level. The advent of a paradigm shift in agricultural water management has directed growing efforts to addressing crop water and yield interrelationships beyond the crop and field levels, i.e. irrigation scheme, catchments and basin, and national and global scale.

The future focus would be on (i) assessment of region specific limitations of water availability; spatial variation of climatic water balance, probabilistic rainfall and soil moisture potential, (ii) evaluation of crop water productivity (CWP) and crop-associated blue and green water consumption patterns based on GIS, crop growth models, soil water and atmosphere models and hydrological modeling approach, (iii) developing region and source specific conservation methods; devising precise methods of water application and the frequencies of water application, use of zeolites and polymers in soils to increase WHC and (iv) valuation of various parameters of WP in order to ascertain best management practices.

Sustaining Better Soil Health and Produce Quality

Declining soil health year after year has been the one of the major reasons responsible for reduced response of crops to applied nutrients and lower profits to farmers. Sincere efforts have been made by the institute scientists to assess soil quality and develop strategies to improve soil quality. Systematic studies have been conducted in on-going long-term experiments in different regions of

the country to understood the soil fertility dynamics as influenced by intensive cropping with different fertilizer and manure inputs. We identified minimum data set (MDS) of soil quality parameters suitable for different groups of soils for periodic evaluation of soil quality under different production systems. GIS based tehsil-wise/district-wise soil fertility maps of different states have been generated and on-line fertilizer recommendation system based on soil test crop correlation fertilizer prescription equations has been developed to improve or maintain soil quality. The efforts are being made for linking of GPS-GIS based soil fertility maps with precise fertilizer recommendation. Despite, future research focus should be on developing a workable index of soil quality assessment imbibing influence of different physical, chemical and biological soil attributes and developing strategies for resilience of degraded soils.

Organic agriculture offers trade opportunities for farmers in the developing and developed countries. The Indian organic farming industry is estimated at about 900 million rupees (US$ 20 million) and is almost entirely export oriented (www.eximbankindia.com). This market of organic products is expected to grow globally in the coming years and high growth rates over the medium term (from 10-15 to 25-30 %) are expected. Sustained efforts have been made during the last 5 -6 years to assess the food quality as influenced by different nutrient management practices. Organic farming practices for soybean, wheat, isabgol, pigeon pea, pomegranate etc have been developed. Organic farming and integrated nutrient management practices produced the similar quality food grains as that of chemical fertilizers but former were found economical. Attempts are being made to integrate indigenous wisdom such as panchagavya, agnihotra etc with the scientific nutrient management techniques such as integrated and balanced nutrient management. Future emphasis would be on assessing the produce quality as influenced by long-term application of manures and fertilizers in different crops grown on major groups of soils.

Bio-fortification

Now when the target for food security (adequate calories) has nearly been achieved, emphasis has also to be given for safely eliminating micronutrient malnutrition among people which is now appearing due to less dietary intake, especially of iron, iodine and zinc. Introduction of intensive green revolution cropping systems (cereal based) by displacing traditional micronutrient rich crops of pulses, vegetables and fruits has been found responsible for such emerging malnutrition which now afflicts more than 40% of the world population, particularly of developing countries like India. Indian agricultural research must address this issue of micronutrient malnutrition that affects human health and productivity. Indian Institute of Soil Science has identified the bio-fortification as major thrust area and initiated research projects.

Maintaining Soil Biodiversity and Genomics

There is a need to characterize the vast amount of biodiversity of fauna and flora present in India. Various challengeable research areas where the microbial community plays a critical role are recycling of nutrients in bio-solids and manures, removal of environmental contaminants, reclamation strategies of degraded soils, improvement in soil physical conditions by enhancing aggregation and C sequestration. Each one has to be tackled in future through a concerted efforts on (i) Characterization and prospecting of large soil bio-diversity (ii) Characterization of functional communities of soil organisms, (iii) Testing of mixed biofertilizer formulations etc.

Conservation Agriculture, Carbon Sequestration, Nutrient Acquisition and Loss vis-a-vis Climate Change

It is well known that the carbon dioxide (CO_2) concentration

of the global atmosphere has increased during the last few decades, mainly due to energy consumption from fossil fuels. Since the start of the industrial evolution, the atmospheric CO_2 level has increased from 280 ppm to around 385 ppm, and continues to rise at approximately 1.8 ppm per year. It is expected that the CO_2 level might reach a concentration of 600–1000 ppm by the end of this century. It appears more likely that greenhouse gases from human activities were the dominant drivers of these global-average temperature changes during the 20th century. Due to the increase of the CO_2 level, it is expected that the maximum, minimum and mean global temperatures will also change by 3–4°C. The Inter-governmental Panel on Climate Change (IPCC) expects a global surface temperature increase, ranging from 1.0 to 3.5 ◦C by 2100 based on the predictions of the general circulation models (GCM), such as GISS, UKMO, OSU and GFDL-R30 (IPCC, 2001). The interactive effects of global warming and increasing CO_2 levels could especially impact agriculture, affecting both growth and development of crops and ultimately impacting yield and food production. There are still many questions about the interactive effects of increasing temperatures and CO_2 concentrations on plant growth and development. Hence future research strategies would be (i) Assessing the effect of CO_2 on growth and development of soybean-wheat and the other prevalent cropping systems under different temperature regimes, (ii) Development of mitigation strategies, (iii) Modeling the interactive effect of CO_2 and temperature on SOC dynamics.

Some attempts have been made to identify management systems and carbon pools which are potential sinks for carbon sequestration in soil. Soil organic carbon in forest soils under teak and sal with low management was two times higher than that of the corresponding cropped soils. The active pools of soil microbial biomass carbon comprised 3.2 to 5.6 % of SOC in Vertisols and 1.2 to

5.7 % of SOC in Alfisols. Water soluble (WS) carbon ranged from 0.80 to14.1 % of SOC in Vertisols and 1.5 to 4.9 % of SOC in Alfisols. WS Carbohydrates comprised 15-40.3 % of SOC in Vertisols and 10.5 to 25 % of SOC in Alfisols. Vertisol sequestered greater amount of carbon followed by Inceptisol and Alfisol under long-term fertilizer and manure application.

Agricultural demand for irrigation water being a major share of total water demand of the country, is considered more sensitive to climate change. A change in field-level climate may alter the need and timing of irrigation. Increased dryness may lead to increased demand, but demand could be reduced if soil moisture is properly conserved and_managed at critical times of the year. The conservation tillage practices affecting savings on water, nutrients, energy and time should be evaluated for raising the productivity of farms.

Minimizing Soil and Environmental Pollution

Although food security and safety is a continuing global concern, environmental quality, appropriate land use, and protection of natural resources are equally important issues. The environmental and agricultural issues dealing with land use and management are likely to be increasingly studied in future by large interdisciplinary groups of ecologists, biologists, environmentalists, engineers, and social scientists.

Prevention is the best method to protect the environment from contamination by heavy metals. Preventing heavy metal pollution is critical because cleaning contaminated soils is extremely expensive and difficult. Various approaches are used in different countries to assess the level of heavy metals in contaminated soils. There is an urgent need to formulate heavy metal standards to assess soil quality with respect to background level, maximum allowable level and intervention level to support the decisions in assessing and monitoring sites, and to develop our own formal guidelines that set

heavy metal loading limits for land application of many solid and liquid wastes.

Institute has made significant contributions in phytoremediation and recycling of municipal solid wastes and industrial wastes in agriculture. Un-tired research efforts led to the development of safe prescription limits for use of distillery effluents and quality standards for municipal solid waste composts which are included in Bureau of Indian Standards. Identified different flowering plant species for phyto-remediation of contaminated soils which needs to be tested under field conditions in polluted areas of the country.

Liquid and solid wastes recycling

In order to minimize the entry of heavy metals and other organic pollutants through solid and liquid wastes into agricultural land, several countries have formulated regulatory mechanisms, like maximum cumulative loading limit, maximum annual loading limit, maximum concentration limit of metal in soil to receive further input, maximum concentration in soil amendment materials. The different approaches for such formulations have resulted widely differing numerical limits for the same metal. India has not put forward any soil protection policy to restrict heavy metal build up during their inadvertent addition through different amendments. Future researches should focus on following important areas in order to protect our soil resources from metal contamination.

(a) Determination of baseline concentration of heavy metals in different soil types:

Soils contain variable concentrations of heavy metals depending on the climate, parent material as well as different properties like texture, contents of oxides, organic matter etc. Hence, unless a known severe pollution occurs, it is not possible to identify through mere soil testing whether a soil has been contaminated or not due to anthropogenic activity. Knowledge on baseline concentration of heavy metals in different soil types under major agroecological zone will help in estimating the probability of metal contaminations by intentional as well as inadvertent use of polluted effluents, waste derived amendment materials, atmospheric deposition etc. Information on upper limit of baseline concentration is essential for taking policy decisions in respect of unavoidable additions of heavy metal pollutants in croplands.

(b) Determination of maximum concentration limits of heavy metals in major soil groups:

Knowledge on this parameter will help administrator/land-user in assessing level of contamination and possible impact of the contamination level on different component of environment and will also help in determining appropriate action plan with respect to remediation. It will also help in determining the suitability of an area for non-agricultural purposes like establishment of industrial area etc.

(c) Environmental risk and impact assessment on use of solid and liquid wastes on agro-ecosystems of the country

Applications of Nanotechnology in Soil Science

Nano-Science and technology is the confluence of many sciences like Physics, Chemistry, Biology, Material Science and engineering and it underlies a new unity in science where a technological or scientific advance in one field can create extraordinary opportunities in another. Vast deposits of minerals, which are not suitable for industrial use, can be made useful as sources of plant nutrients for the crop production. Currently most of the chemicals, which are used as fertilizers, are made water soluble so as to provide easy supply of nutrient to the growing plants. In contrast, non-

soluble minerals can be converted to nano-size through top-down approach as a source of plant nutrients.

Preliminary investigations at the institute clearly indicated that low grade rock phosphates, can easily be made as a source of P to the plant when they are converted to nano-size (<100 nm). Similarly, vast deposits of glauconite/waste mica can be successfully utilized as source of K to plants by converting them to nano-size level. In a similar manner other natural mineral deposits like dolomite and magnetite (as source of Ca & Mg), pyrite (as source of Fe and S), can be made useful for agriculture use with a reduced cost and without impairing damage to environment. We need to create a strong knowledge base to explain the transport of nano-particles from soil solution to plant. In spite of several benefits, the handling of different nano-particles requires some sort of safety for health hazards and risks for the environment. The toxic effects of nano-materials are very specific and depends the size, shape and type of base materials. The ultra fine particles as nano-particles (<100 nm) are more toxic than the particulates (<2.5 m) of the same material on a mass basis. The very limited research conducted indicated that the nano materials such as hydroxyapatites have good potential to decontaminate the heavy metal polluted soils.

Some researchable issues in agriculture pertinent to nanotechnology are (i) development of nano-sensors to monitor soil quality, (ii) development of nano-magnets for soil contaminant retrieval, (iii) development of nano-membranes for water treatment/ purification, (iv) fertilization and herbicide application through nano-products (NPs), (v) synthesis of nano fertilizers for soil and plant application, (vi) solubility and degradability of engineered NPs in soils and waters, and (vii) establishment of baseline information on safety, toxicity and adaptation of NPs in soil and adequate life.

Strategy and Framework

A 5- Point following strategy would be adopted to accomplish the vision and the goals of the Indian Institute of Soil Science, Bhopal and to enhance the efficiency of soil, water and plant nutrients (Annexure – 1).

1. Enhancing Nutrient and Water Use Efficiency

- Increasing inputs use efficiency through
- Precision agriculture
- Nano-technology
- Fertilizer fortification
- Integrated nutrient management: Indigenous mineral and by-product sources

2. Sustaining Soil and Produce Quality

- Efficient composting techniques and integrated plant nutrient supply systems
- Bio-fortification of food grains
- Organic farming and produce quality characterization
- Improving soil quality through organic matter additions and correcting nutrient imbalances
- Development of a workable index of soil quality assessment imbibing influence of different physical, chemical and biological soil attributes
- Understanding resilience of degraded soils and restoration of their productivity

3. Soil Biodiversity and Genomics

- Characterization and prospecting of large soil bio-diversity
- Characterization of functional communities of soil organisms.
- Testing of mixed biofertilizer formulations

4. Climate change and carbon sequestration

- The carbon sequestration research in the context of sustainable management of land and soil resources and conserving deteriorating environment
- Conservation agriculture and carbon sequestration especially in semi-arid and sub-humid regions.
- Tillage and nutrient interaction in soil
- Crop simulation modeling and remote sensing in climate change research
- Crop adaptation to climate change-rhizospheric studies

5. Minimizing Soil Pollution

- Bio-remediation/phyto-remediation of contaminated soils
- Quality compost production and establishing quality standards
- Soild wastes and waste waters – quality assessment and recycling

Epilogue

The Indian Institute of Soil Science (IISS) is well equipped to take up the emerging challenges of food security and safety, soil and water quality, organic waste recycling, global climate change, environmental protection etc by reorienting it research pursuits addressing the emerging issues viz., Enhancing Nutrient and Water Use Efficiency, Sustaining Soil and Produce Quality, Soil Biodiversity and Genomics, Climate change and carbon sequestration etc. Water resources will come under increasing pressure in the Indian subcontinent due to the changing climate.

Some research areas that need urgent attention for improving Nutrient Use Efficiency (NUE) are, development of multinutrient formulations and other novel controlled release fertilizers to minimize the nutrient losses from soil-plant system, Scheduling nutrient application to match requirements of crops/cropping systems, Germplasm screening for efficient nutrient use, and Recycling of crop residues and other organic wastes etc.

Microbial inoculation will be a regular feature not only to promote nutrients mobilization including micronutrients but also fight stress conditions like drought and salinity and increasingly, as to control specific diseases and maintain soil health. This will result in big expansion of industries producing biofertilizers and bio-control agents and improvement in beiofertilizer technology. Biosensors based on gene chips would be developed and routinely used to monitor the levels of inorganic and organic contaminants in water and soils and monitor soil health. For this, suitable research information in biochemistry would be needed.

The emphasis would be on safely eliminating micronutrient malnutrition among people which is now appearing due to less dietary intake, especially of iron, iodine and zinc. Efficient recycling of wastes in agriculture and minimizing soil and environmental pollution is another challenge which could be overcome by developing suitable bio-remediation/phyto-remediation and other techniques and production of quality composts from wastes and establishing quality standards.

Concerned efforts would be made to address the food security challenge by transforming the basic soil science research achievements into affordable implementable technologies at farmers' level.

References

Ghosh, A.B. and Hasan, R. (1980) Fert. News, 15(11), 19-24.

Motsara, M.R. (2002) Fertiliser News 47(8):15-21.

MOUD (2005) Annual Report of Ministry of Urban Development, Govt. of India, New Delhi.

Muralidharudu, Y., Sammi Reddy, KI., Mandal, B.N., Subba Rao, A., Singh, K.N. and Sonekar, Shailendra. 2011. GIS based soil fertility maps of different states of India. All India Coordinated Project on Soil Test Crop Response Correlation, Indian Institute of Soil Science, Bhopal. pp. 1-224.

Ramamurthy, B. and Bajaj, J.C., (1969) Fert, News 14(8), 1.

Annexure 1: Strategic framework

Goal	Approach	Performance Measure
Enhancing Nutrient Use Efficiency	Soil fertility evaluation, monitoring and precise fertilizer recommendations. Efficient utilization of organic wastes, indigenous minerals and industrial byproducts in agriculture. Development of fortified fertilizers and other controlled released fertilizers. Exploitation of role of nano -science and technology	Improved nutrient use efficiencies Developed novel fertilizer materials
Enhancing Water Use Efficiency	Rainwater harvesting, conservation and use efficiently for irrigation. Studies on water, nutrient and tillage interactions for improving input use efficiency. Studies on water and nutrient dynamics considering soil -plant-atmosphere-continuum (SPAC).	Improved water productivity
Enhancing and Sustaining Soil and Produce Quality	Development of soil quality indicators and methodology to assess soil quality.	Developed minimum data set
	Monitoring long term changes in soil fertility periodically and evolve strategies for improved soil fertility. Developing improved nutrient management practices Mineral enrichment in food grains through bio-fortification Optimization of tillage requirements for different production systems of different regions.	Mineral enriched foods Technologies and management practices for better soil health.
Soil Biodiversity and Genomics	Characterization of functional communities of soil organisms (flora and fauna) and soil biological activities under different soil crop situations for enhancing nutrients availability.	Developed efficient microbes for higher nutrient use efficiency.
	Characterization of microbial biodiversity and functional communities (particularly N_2-fixers, P & S solubilizers, Ligno-cellulolytic organisms), testing of mixed biofertilizer formulations and diversity of biofertilizers in agriculture. Basic studies on maintaining agro-biodiversity.	
Climate change and carbon sequestration	Developing and popularizing of conservation agriculture techniques in different production systems. Use of crop simulation models and remote sensing in developing mitigation techniques. Identification of carbon sequestered, analyze factors conducive for carbon sequestration and develop management practices for higher sequestration. Screening of efficient crop varieties. Assessing and minimizing green house gas emissions from major production systems.	Enhanced carbon sequestration and carbon credit gained Developed conservation agriculture techniques Identified sinks for carbon in soils Identified better crop varieties Reduce green house gas emissions
Minimizing Soil Pollution	Rational use of organic wastes and organic farming. Monitoring soil health due to continuous loading of wastes and waste water into the soil under conventional and organic farming systems. Developing safe prescriptions/ guidelines for recycling of different wastes into agricultural soils. Evaluation of sink capacity of soils to make guidelines for loading of heavy metal contaminated wastes into soils. Techniques for remediation of contaminated soils.	Developed quality composts Environment with clean air and water