भाकृअनुप
ICAR

REPORT OF THE QUINQUENNIL REVIEW TEAM

ICAR- Indian Institute of Soil Science
&
AICRP on Long Term Fertilizer Experiments,
AICRP on Soil Test Crop Response,
AICRP on Micro-and Secondary - Nutrients and Pollutant Elements in Soils and Plants,
AINP on Soil Biodiversity - Biofertilizers

2012-2017

ICAR- INDIAN INSTITUTE OF SOIL SCIENCE

Nabibagh, Berasia Road, Bhopal-462038 (M.P.)

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PREFACE

A Quingennial Review Team (QRT) was constituted by the Secretary, DARE (Gol) & Director General, ICAR vide office order F.No. NRM/12-02-17-IA-11 dated May 29th 2017 to review the work done by the ICAR-Indian Institute of Soil Science (ICAR-IISS), Bhopal as well as AICRPs on Long Term Fertilizer Experiments, Micro- and Secondary- Nutrients and Pollutant Elements in Soils and Plants, Soil Test Crop Response and AINP on Soil Biodiversity-Biofcrtilizers for the period 2012-2017.

The Chairman QRT had its initial meeting with Assistant Director General (SWM), NRM for planning the work on April 13, 2017. The team had its first meeting with the Director, PCs, HoDs and other scientists of the Institute on September 19-20, 2017 at the Indian Institute of Soil Science to review the work. The schedule of interaction with the scientists of various centres of AICRPs located in different parts of the country was finalized in the meeting. The review meetings with different AICRPs and AINP centres were held during October 2017 to March 2018 at NASC New Delhi (North zone), UAS Bengaluru (South zone), AAU Anand (West zone) and OUAT Bhubaneswar (East zone), where scientists of respective zones participated. The team met Vice Chancellors, Directors of Research, staff of the projects and other stakeholders to ascertain their views. The final meeting of the QRT was held at ICAR-HSS, Bhopal during June 23-25, 2018 to prepare the draft report and finalize the recommendations.

The Chairman and team members are grateful to Dr. Trilochan Mohapatra, Secretary, DARE (Gol) & Director General, ICAR for the confidence imposed in the team to carry out this important task of scientific review. The team is thankful to Dr. K. Alagusundaram, Deputy Director General (NRM) and Dr. S. K. Chaudhari, Assistant Director General (SWM) for providing necessary guidelines. They are also thankful to Dr. A.K. Patra, Director, IISS Bhopal for his kind help and cooperation in this endeavour. The team expresses it's appreciation to the Project Coordinators (Dr. Muneswar Singh, Dr. Pradip Dey, Dr.A.K. Shukla, Dr. S.R. Mohanty) and the Heads of the Division (Dr. J.K. Saha, Dr. M.C. Manna, Dr. A.K. Biswas and Dr. R.S. Chaudhary) and all the scientists of ICAR-IISS for the help rendered and inputs to accomplish this assignment. The help and support rendered by the staff of administration, finance and other units of the Institute is sincerely acknowledged. The Chairman and members of the team express their appreciation and special thanks to Dr. J.K. Saha, Member Secretary for his sincere and untiring efforts in organizing the visits, collecting and collating the information, and providing logistic support to conduct the review and bring out this report.

(V. S. Tomar)
Chairman

(Masood Ali)
Member

(H. K. Senapati)
Member

(Biswapati Mandal)
Member

(M. Chinnadurai)
Member

(A. L. Pharande)
Member

(J.K. Saha)
Member-Secretary

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Executive Summary

The Indian Institute of Soil Science (IISS) was established by ICAR in 1988 at Bhopal (M.P.) to carry out fundamental research on all aspects of soils for enhancing and sustaining productivity of soil resources with minimal environmental degradation. The 5th Quinquennial Review Team (QRT) was constituted by the I.C.A.R. to conduct external review of the programmes of IISS, Bhopal and three AICRPs (AICRP on Long Term Fertilizer Experiments, Micro- and Secondary- Nutrients and Pollutant Elements in Soils and Plants, Soil Test Crop Response) and one AINP on Soil Biodiversity-Biofertilizers during the period April 2012- March 2017 vide letter Office Order F.No. NRM/12-02-17-IA-II dated May 29th2017. The composition of the team was:

Chairman:	Dr. V.S. Tomar
Members:	Dr. Masood Ali
	Dr. H.K. Senapati
	Dr. Biswapati Mandal
	Dr. A.L. Pharande
	Dr. K. Chinnadurai
	Dr. J.K. Saha (Member Secretary)

The Chairman of QRT Dr. V.S. Tomar had a meeting with Dr. S.K. Chaudhari, Assistant Director General (SWM) on April 13, 2017 at Delhi to plan the review process. The QRT had its first meeting with the Director, Project Coordinators (PCs), Head of Divisions (HODs) and other scientists of the Institute on September19-20, 2017 at the Indian Institute of Soil Science. Action taken on previous QRT recommendations and performance of the Institute, AICRPs and AINP were reviewed. The team decided the modus operandi and the schedules for review of AICRP/AINP centres. Subsequent QRT meetings were held at National Agricultural Science Complex, New Delhi (October 24-25, 2017) for north zone, University of Agricultural Sciences, Bengaluru (December 19-21, 2017) for south zone, Anand Agricultural University, Anand (February 5-7, 2018) for west zone and Orissa University of Agriculture & Technology, Bhubaneswar (March 6-9, 2018) for east zone. The QRT members also visited field experiments & laboratory facilities and interacted with the scientists, other staff and stakeholders at selected AICRP & AINP centres. This was followed by a final meeting of the members at IISS, Bhopal on June 23-25, 2018 to finalize the report.

The Institute, during the period under review, carried out research activities under four major flagship programmes viz., (1) Soil Health and Input Use Efficiency, (2) Conservation Agriculture and Carbon Sequestration vis-à-vis Climate Change, (3) Microbial Diversity and Genomics and (4) Soil Pollution, Remediation and Environmental Security. These flagship research programmes are being executed by Divisions of Soil Chemistry &

Fertility, Soil Physics, Soil Biology, and Environmental Soil Science, respectively. However, some of the major projects were not placed in the relevant divisions, which need to be corrected. The research activities undertaken are in consonance with the mandate and objectives of the Institute. The QRT was appreciative of the good strides made by the Institute during the period under review in research and development of linkages and infrastructure in spite of paucity of technical staff and funds. The Institute has implemented 83 research projects of which 44 were in-house, 24 externally funded and 15 contractual.

The major outcome of the programmes carried out during the review period were: Development and commercialization of a mini-laboratory 'Mridaparikshak' for quantitative and rapid soil testing for chemical and fertility parameters in September 2015; standardization of Mid-Infrared Spectroscopy for rapid quantitative analysis of pH, clay and organic carbon in soil; development of farmer friendly, low-cost, in-situ soil physical health assessment techniques; development of nano-P fertilizer using low-grade rock-phosphate that has potential to reduce import of P; soil biodiversity characterization in Mollisol and Alfisol by molecular techniques indicating influence of nutrient management practices on distribution of predominant microbial community; determination of critical limits of Pb and Cr in Vertisol, Alfisol and Inceptisol for identifying polluted soils that can contaminate food crop; technique for reducing heavy metals from composts through physical and chemical fractionation method; technique for mitigating green house gases (GHG) emission from composting system; quantifying net green-house gases emission potential under different nutrient management system in soybean-wheat cropping system of central India. In totality, Institute has delivered very good outcome in tune with the assigned objectives.

In spite of the impressive progress made by the Institute, the QRT feels that it has to make more headway in emerging areas and frontiers of soil science in the face of national requirements and global competitiveness. Increasing food productivity from limited land resources while protecting it from degrading forces is the major challenge demanding newer technological innovations and interventions. In commensuration of National Policy for Farmers 2007, the institute should focus on developing technologies for enhancing profitability in agriculture and also fulfilling the objectives of National mission of Doubling the income of farmers' by the year 2022. The QRT recommends that concerted efforts should be made (1) to enhance fertilizer use efficiency and to reduce dependence on imported fertilizers. (2) In order to combat the impending influence of climate change, the institute should undertake basic research on its impact on various chemical and biological processes in soil for developing appropriate technologies to manage soil health. (3) Sequestration of carbon (C) in soil is considered an important strategy for mitigating global warming and improving soil health. Concerted effort may be undertaken by the institute to determine the critical C input value that is to be added in soil to maintain its organic C in different agro climatic zones of the country. Efforts on increasing stabilization of organic carbon in soils may also be explored. (4) In order to cut-down import expenditure of fertilizer nutrients, institute should also focus its research on utilizing indigenous minerals using nanotechnology. (5) Research on conservation agriculture at the institute should be conducted in collaboration with other organizations to provide a complete package of practices under different soil and climatic zones with a focus on farmers' acceptability and prevention of crop residue burning. (6) To reduce burden on scarce dumping ground of cities, municipal solid wastes are required to be composted by shortest possible time. The institute in collaboration with expert organizations should develop appropriate technology to this end. (7) Recognizing the importance of 'Swachh Bharat Mission', the QRT feels strongly that IISS should initiate research for safe use of sewage sludge, and city/industrial wastes in agriculture. (8) There is a need to formulate heavy metal standards to assess soil quality and formulate guidelines on safe land application of various solid and liquid industrial and municipal wastes through comprehensive research. (9) Strategic research on phytoremediation should address the magnitude of soil pollution in agricultural lands observed in the country and should include appropriate soil management to enhance its remediation.(10) The country needs a centre of excellence for advanced research and training on "Soil pollution and remediation". IISS has the requisite expertise in various disciplines, and with the advanced laboratories this institute will be a suitable place for such centre of excellence.

Being engaged primarily in chemical analysis, laboratories in the Institute building have passed through 20 years of corrosive acidic environment and have become worn-out/shabby. IISS, Bhopal may be granted one time renewal grant of Rs. 25 crore for repairing/overhauling of laboratories, residential & Institute buildings and replacing old outlived and condemned instruments with new ones. The institute does not have qualified human resources to undertake social, economic and environmental impact assessment of the technologies. The QRT recommends for the creation of a 'Unit of Impact Assessment and Technology Transfer'. The cadre strength of the administrative section is inadequate. In view of increased research and extension activities in the Institute, QRT recommends that these vacant positions should be filled up for improving efficiency of the administrative section.
The IISS should continue to concentrate on basic and strategic research on soil and act as the torch bearer for other institutes and SAUs. It has the advantage of housing four AICRPs which ensures the institute to have a footprint all over the country. The institute should capitalize this opportunity and address the major soil related problem in the country. The QRT felt that there is a need for greater complementarities in research among the Divisions of IISS as well as between the Divisions and the AICRPs. The PCs of the AICRPs should play a role of national leader of their domain and help fellow researchers/scholars at distant places.

In addition to generation of primary and secondary data related to soil fertility during 2012-17, the AICRP on Long Term Fertilizer Experiments (LTFE) has made an attempt to identify key indicators of soil quality, determine critical C input values for maintaining its status and suggest management strategies to counter the impact of climate change in a few agro-ecological regions. The project has developed technique to save P fertilizer by applying half dose of P in both rabi and kharif crops or only in rabi crop and no P in Kharif crop in Indo-Gangetic alluvial belt, Alfisols of Karnataka and in Vertisols of Jabalpur.FYM @ 5 t/ha/year has been found a better option than lime @ 2-3 t/ha/year for ameliorating acidic Alfisols of Ranchi, Palampur and Bangalore for improving and sustaining crop productivity.

In Vertisols in-spite of high status of non-exchangeable K and lattice K, crops need external supply of K through fertilizer for sustainable productivity. Outcome of researches from the project has opened new avenues of saving fertilizers and improving crop productivity in the country. There is a need to carry out in-depth analysis of experimental soils for various soil quality parameters to understand the basic causes for aggradation and degradation of health of different soil types. Assessment may also be made for resilience capacity of different soils to degrading forces. Impact of pesticide residue build-up on soil biodiversity and soil productivity may also be investigated. If required, some of these issues may be addressed collaborating with competent institutes/scientists.

The AICRP on Soil Test Crop Response (STCR) has continued to develop targeted yield based fertilizer prescription equations for several crops and few cropping systems and indicated that considerable amount of fertilizers can be saved if fertilizers are applied based on soil test and yield target using those equations. Online recommendation system (including mobile based App for Maharastra state) has been developed for ease of adoptability by soil testing laboratories (STLs). Portable Soil Testing Kit for Agricultural and Horticultural Crops has also been developed by IGKV, Raipur centre of AICRP (STCR) for rapid soil test based recommendation. The project has developed integrated plant nutrition package involving bioremediation strategies for iron toxicity in lowland rice ecosystem of Assam. For the first time, STCR equation was developed under drip fertigation system to address dry land conditions and STCR recommendation system was developed integrating secondary nutrients at some places. In order to be more acceptable to stakeholders, AICRP on STCR should make an attempt to recommend fertilization on whole cropping system basis as well as under widely differing water availability/management scenario. In order to speed-up soil testing complying with the present policies of central government, the unit should also develop multi-nutrient extractant based soil test and prescription methods for different soils and crops. Using the data generated under the project, the recommended doses of fertilizers (RDF) for different crops needs to be revisited for use by the soil testing laboratories (STLs). The project should develop fertilizer prescription equations for different application methods, indicating saving in cost of nutrient management.

The AICRP on Micro and Secondary Nutrients and Pollutant Elements (MSNPE) has delineated areas of micro- and secondary nutrients deficiencies, catalogued visible micronutrient deficiency symptoms for some crops; attempted to established their critical limits at different levels of production; recommended their appropriate doses for different annual and horticultural crops; and developed agronomic strategies for micronutrients enrichment in major cereals and pulse crops. A slow-release Zn fertilizer was developed for further evaluation through synthesis of nano clay polymer composites to enhance use efficiency of Zn in agriculture. AB-DTPA was found as good extractant for available micronutrients as DTPA for different soil types indicating its potential for universal extractant. The AICRP should focus on enhancing use efficiency of micronutrient fertilizers by crops either through modifications in application/soil management methods or through development of new products/fertilizer materials. Refinement of critical limits based on field experiments may be continued as per the need. Attempts may be made to predict micronutrient availability in soils and to plants developing predictive models using analyzed soil properties in uncovered/unexplored areas. Study on biofortification of cereal grains with Zn and Fe may be continued with robust methodology considering changes in other associated factors (antinutrients/promoters) influencing their bioaccumulation along with economics.

The AINP on Soil Biodiversity-Biofertilizers (SBB) has done considerable researches on microbial diversity especially on rhizobial diversity and soil metagenomics and also on developing biofertilizers. Mixed microbial consortia have been developed for groundnut at Junagarh (Gujarat), wheat in Vertisols at Jabalpur (M.P.), and black gram in rice-fallow at Amravati (A.P.), rice in Eastern India. The effective strains of plant growth promoting bacteria and rhizobia have been deployed for biofertilizer production and demonstrated in tribal and remote areas, which have shown to increase crop yields considerably. Liquid inoculants have been formulated for Rhizobium, Azospirillum and Bacillus strains which enhanced its shelf life up to 12 months with high cell counts. Repeated application of DAPG-producing fluorescent pseudomonas has been found to make the soil naturally suppressive to soil-borne fungal pathogens. The AINP should strengthen its research activities on characterization and exploitation of soil microbial biodiversity; developing region/crop specific biofertilizer formulations for the whole country in time-bound manner; increasing shelf life of biofertilizers; biofertilizers for mobilization of huge amount of residual soil phosphate in the intensively cultivated Indo-Gangetic plains; and also developing bioremediation technology for different organically polluted areas. The AINP should develop simple methodology for testing quality of marketed biofertilizers.

The IISS and the coordinated projects have as a whole accomplished most of the objectives to a large extent and require continuous endeavors with emphasis on basic and strategic research to devise technologies for emerging problems related to soil health deterioration due to pollution and heavy pressure to produce more with limited inputs. In order to excel in their research endeavour, IISS and AICRPs/AINP are required to be supported with additional fund for operational as well as for creating instrumental facilities.

A. INTRODUCTION

The fifth Quinquennial Review Team (QRT) of the Indian Institute of Soil Science (IISS),three AICRPs on viz., Long Term Fertilizer Experiments (LTFE); Micro- and Secondary- Nutrients and Pollutant Elements in Soils and Plants (MSNPE); Soil Test Crop Response (STCR) and one AINP on Soil Biodiversity-Biofertilizers (SBB) was constituted by the ICAR vide office order F No. NRM/12-02-17-IA-II dated May 29, 2017 to conduct an external review of the achievements for the period 2012-17.
The constitution of the team is as under:

1.	Dr. V.S. Tomar, Former Vice Chancellor, JNKVV, Jabalpur & RVSKVV, Gwalior	Chairman
2.	Dr. Masood Ali, Ex-Director, IIPR, Kanpur	Member
3.	Dr. H.K. Senapati, Ex-Dean PG, OUAT, Bhubaneswar	Member
4.	Dr. Biswapati Mandal, Professor & Director of Research, BCKV, Kalyani	Member
5.	Dr. A.L. Pharande, Dean, MPKV, Rahuri	Member
6.	Dr. M. Chinnadurai, Director, CARDS, TNAU, Coimbatore	Member
7.	Dr. J.K. Saha, Principal Scientist & Head, IISS, Bhopal	Member-Secretary

Terms of Reference

1. To critically examine and identify research achievements and impact.

2. To examine objectives, scope and relevance of research programmes and budget allocation.

3. To evaluate relation/collaboration with SAUs and other stake holders.

4. To examine the kind of linkages with clients/end users.

5. To suggest changes in organization, programmes and budget.

6. To examine constraints hindering the institute in achieving objectives and recommend.

7. To suggest for future program development, research prioritization and management changes.

B. THE REVIEW PROCESS

The Chairman QRT had its initial meeting with Assistant Director General (SWM), NRM on April 13, 2017 for planning the review process of taking stock of the work done in the last five years and suggesting future requirements of the work in 12th plan (2012-17). The QRT had its first meeting with the Director, PCs, HoDs and other scientists of the Institute on September 19-20, 2017 at the Indian Institute of Soil Science to review the work. Dr. A.K. Patra, Director, IISS presented overview of the research programmes of the IISS and 4 AICRPs and the salient achievements during the 12th plan. Member-secretary QRT presented on the action taken on the recommendations of the previous QRT. Heads of Division of Soil Chemistry and Fertility, Soil Physics, Soil Biology and Environmental Soil Science as well as all the four Project Coordinators/Network Coordinator (LTFE, STCR, MSNPE and SBB) made presentations of the progress in 12th plan and suggested programmes for future. The QRT members prepared an interim recommendation for IISS after this meeting and finalized the actual schedules for review of the AICRP centres all over the country to be carried out during November 2017 – April 2018. It was decided that there will be review cum interaction meeting of the QRT members at New Delhi (N. Zone), Bengaluru (South Zone), Anand (West Zone) and Bhubaneswar (East Zone) where the AICRPs in those respective zones will be reviewed followed by a wrap-up meeting at IISS, Bhopal for report writing.Before conducting review meetings, brief reports on achievements by all the centres were obtained through Project Coordinators and Network Coordinator.Subsequently, QRT meetings were held at National Agricultural Science Complex, New Delhi (October 24-25, 2017), University of Agricultural Sciences, Bengaluru (December 19-21, 2017), Anand Agricultural University, Anand (February 5-7, 2018) and Orissa University of Agriculture & Technology, Bhubaneswar (March 6-9, 2018). Beside these meetings, Chairman and QRT members also visited selected field experiments & laboratory facilities and interacted with the scientific and other staff and other stakeholders at selected AICRP & AINP centres. This was followed by a final meeting of the members at IISS, Bhopal on June 23-25, 2018 to finalize the report for submission to the ICAR. Besides the discussions during and after the meetings at each venue, the QRT members were also in communication through e-mail and exchanged draft recommendations after each meeting leading up to the final meeting.

C. REVIEW REPORT OF INDIAN INSTITUTE OF SOIL SCIENCE

(i) Brief History

The setting up of the Indian Institute of Soil Science was a follow up of the recommendations of a Working Group of the ICAR and a Task Force Committee comprising eminent scientists and a representative of the Planning Commission which felt that fundamental research *per se* in many aspects of the soil was not being taken up by any of the then ICAR institutes and unless this lacuna was filled up, applied research relating to soil and hence to agriculture was likely to suffer. Healthy and complementary linkages amongst existing ICAR institutes were envisaged whereby the research results of basic nature emanating from the proposed Institute (IISS) would find meaningful testing grounds in the existing institutes. The same point of view was made applicable to the existing All India Coordinated Research Projects (ICAR-AICRP) concerned with soil and nutrient management and it was felt that they would continue to test, if necessary, some of the basic findings emanating from the proposed Institute. The Task Force envisaged that the proposed institute (IISS) itself should have some opportunities of testing its findings or applying them to productive purpose on its own farm.

The Institute came into existence at Bhopal, Madhya Pradesh as per the recommendation of the site selection committee constituted by the ICAR. The institute falls in agro-ecological sub-region no. 10 which covers central highlands of Malwa and Bundelkhand and represents one of the dominant soil groups of the country occupying 8.2 million ha of medium and deep clayey black soils (Chromusterts, Ustochrepts and Ustorthents)with medium and high water holding capacity, average precipitation of 1000-1500 mm and potential evapotranspiration of 1300-1500 mm. Soybean, wheat, pulses and millets are the predominant crops and the region has been identified for its high potential for agricultural production under watershed management.

The Institute formally started functioning since 16th April 1988, from the seminar room of another ICAR Institute (CIAE, Bhopal) then located at G.T.B. Complex, T.T. Nagar, Bhopal. Later, the Institute shifted to a rented building at M.P. Nagar, Bhopal and then on to its own campusat Nabibagh on Berasia Road in 1995.

The institute has four programmes listed below.

Programme No.	Title
Programme-I	Soil Health and Input Use Efficiency
Programme-II	Conservation Agriculture and Carbon Sequestration vis-à-vis Climate Change
Programme-III	Microbial Diversity and Genomics
Programme-IV	Soil Pollution, Remediation and Environmental Security


IISS

These programmes were carried through inter-disciplinary researches in the following four divisions in the Institute. They are:

- Soil Physics,
- Soil Chemistry & Fertility
- Soil Biology
- Environmental Soil Science.

In addition the institute has three sections namely `Remote Sensing & GIS', 'Farm section' and 'Administrative section' to assist the researchers. In order to manage and disseminate knowledge pools, Institute constituted eight technical units/cells viz., (i) Prioritization, Monitoring and Evaluation Cell (PME), Agriculture Knowledge Management Unit (AKMU), Institute Technology Management Unit (ITMU), Library, Information and Documentation Unit, Right to Information (RTI), Results, Framework & Documentation (RFD), Consultancy Processing Cell (CPC) and Official Language Cell (Hindi Cell).

The ICAR also shifted the Project Coordinating units of six AICRPs concerned with soil and nutrient management to IISS, Bhopal, in order to strengthen its activities further in the national perspective and to enlarge its linkages with the national agricultural research system. Two AICRPs were phased out and one was converted into a network Project in the Tenth Five Year Plan.

Sl. No	Name of AICRP/AINP	Place from where shifted	Year of shifting	Year of phasing out
1.	Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants (MN)	PAU, Ludhiana	1988	Continuing
2.	Soil Test Crop Response Correlation (STCR)	CRIDA, Hyderabad	1996	Continuing
3	Long Term Fertilizer Experiments (LTFE)	IARI, New Delhi	1997	Continuing
4	Biological Nitrogen Fixation (BNF)	IARI, New Delhi	1997	Reframed as AINP on Soil Biology and Biofertilizers
5	Microbiological Decomposition and Waste Recycling (MD)	HPKV, Palampur	1997	2002
6.	Soil Physical Constraints and their Amelioration for Sustainable Crop Production (SPC)	IARI, New Delhi	1997	2002

(ii) Mandate of the Institute

During April 2012 to May 2016, the institute had the mandate "TO PROVIDE SCIENTIFIC BASIS FOR ENHANCING AND SUSTAINING PRODUCTIVITY OF SOIL RESOURCES WITH MINIMAL ENVIRONMENTAL DEGRADATION"

…with the following specific objectives:

- To carry out basic and strategic research on soils especially physical, chemical and biological processes related to management of nutrients, water and energy.
- To develop advanced technology for sustainable systems of input management that is most efficient and least environmental polluting.
- To develop database repository of information on soils in relation to quality and productivity.
- To develop expertise and backstop other organizations engaged in research on agriculture, forestry, fishery and various environmental concerns.
- To exchange information with scientists engaged in similar pursuits through group discussions, symposia, conferences and publications.
- To collaborate with State Agricultural Universities, National, International and other Research Organizations in the fulfillment of the above objectives.

Vide Notification dated 20th May, 2016 from DARE, mandate of IISS, Bhopal has been amended with effect from 16/05/17. Presently, Institute has the vision of "**Providing scientific basis for Enhancing and sustaining productivity of soil resources with minimal environmental degradation**" with following mandates:

a) Basic and strategic research on physical, chemical and biological processes in soils related to management of nutrients, water and energy
b) Advanced technologies for sustainable soil health and quality
c) Coordinate the network research with State Agricultural Universities, National, International and other Research Organizations

(iii)Institute Vision

The institute has developed its vision for the future in a focused way centering on following goals along with strategies to accomplish the goals.

1. **Providing Food and Nutritional Security by Improving Nutrient and Water Use Efficiencies**

- Developing technologies for efficient use of nutrients through efficient delivery employing precision agriculture tools, nanotechnology, and fertilizer Fortification.
- Mineral enrichment in food crops through efficient bio-fortification technologies.
- Developing dynamic expert systems of precise and timely input supply under varying soil- crop-climate and resource situations.

- Developing micro irrigation based efficient nutrient delivery technologies under water limited environments.
- Developing consortia based efficient microbial formulations for mobilization of soil nutrients/fixation of nutrients in biological systems.
- Engineering of nutrient efficient crops and varieties utilizing molecular biology and biotechnological tools.

2. Harnessing Biodiversity and Utilizing Genomics for Efficient Agriculture and Maintaining Ecological Balance

- Prospecting of large soil bio-diversity including characterization and testing of functional communities of soil micro-organisms
- Impact assessment of soil management practices on functional diversity of microorganisms involved in key microbial functions and soil health using genomics tools
- Development of a new generation of small, robust sensors using nanotechnology.
- Identify microbial plant interaction processes in the rhizosphere under different stress situations.

3. Self Sufficiency in Plant Nutrient Supply Through Utilization of Indigenous Mineral Resources

- Developing new plant nutrient products from indigenous mineral resources using nanotechnology.
- Beneficiation of minerals and byproducts though microbial, chemical and thermal interventions

4. Clean and safe soil environment through waste recycling

- Establishing quality standards for waste products and quality compost Production
- Development of faster microbial based technologies to manage agro/ industrial/ municipal waste for nutrient supply and recovery
- Quality assessment of waste waters and its recycling through biologically mediated/ chemical processes.

5. Soil Quality/health Management for Sustainable Agriculture

- Developing a workable index of soil quality assessment factoring the influence of different physical, chemical and biological soil attributes and developing strategies for restoring resilience of degraded soils.
- Database of threshold values of key indicators of soil quality/health and resilience for identification of degraded and likely to degraded lands due to natural as well as anthropogenic activity.

- Formulating standards with respect to heavy metals for background level, maximum allowable level and intervention level to generation of information on atmospheric inputs.
- Microbial bioremediation/ phyto-remediation strategies for soils contaminated with heavy metals and agrochemicals

6. Developing Strategies for Energy Efficient and Climate Resilient Agriculture

- Development of conservation agriculture practices for different farming situations
- Assessment and modeling carbon sequestration potentials of different soils and land use systems and development of standards for carbon trading in agro-ecosystems.
- Monitoring long-term changes in soil quality and carbon sequestration under conservation agriculture/organic farming.

On some issues mentioned in the previous QRT report of 2007-12 on a) developing rapid soil testing methodology; b) enhancing nutrient use efficiency through development of modified fertilizers; c) creation of a databank on important soil properties for agro sub- ecological regions and host its web site; d) developing a workable index along with simple, cheap and robust methods for evaluating the key indicators, it is encouraging to see that valuable initiatives have been taken to build up competence and facilities and these initiatives have started showing results. Some of these initiatives need to be continued in future also.

(iv) Priorities, Programmes and Projects

A major thrust of the institute is to carry out basic and strategic research for enhancing and sustaining productivity of soil resources with minimal environmental degradation. The scientific management of soil &water resources as well as plant nutrient supply, on which agricultural productiondepends, is of critical importance in ensuring the food security of our nation. Appropriate land use, management &protection of natural resources, irrigation water quality are recycling of farm wastes are critical issues related to ensuring sustainable production. Environmental and agricultural issues dealing with biodiversity and other natural resources have to be tackled by large interdisciplinary groups of soil scientists, ecologists, biologists, environmentalists, engineers, and social scientists.

The vast area of soils in India is generally poor in soil organic matter and is beset with multiple nutrient deficiencies or toxicities. Therefore, the nutrient management &soil fertility improvement, conservation and management of soil organic matter are the mainstay of the institute programs. The country has now realized the absolute necessity of integrated plant nutrient management systems involving a sensible blend of chemical fertilizers and soil amendments along with composts, vermi-composts, green manures, biofertilizers, non toxic organic wastes, biopesticides, etc. and are now being invariably advocated along with recommendations on judicious useof irrigation water. In view of dwindling natural resources related to agricultural inputs, several industrial and city wastes are required to be explored as alternative for enhancing and sustaining crop productivity.

The institute has therefore rightly concentrated in the last five years on addressing the issues of soil quality assessment,developing integrated nutrient management technologies,increasing use efficiency of plant nutrients through formulation of new product and using nanotechnology, impact assessment of conservation agriculture, dynamics of soil carbon sequestration under different nutrient management systems and impact of climate change on it, nutrient management in organic farming system, soil microbial diversity under long-term fertilizer experiment and its role in mitigating climate change, rapid composting of organic wastes, metal removal from MSW composts, heavy metal toxicity assessment, safe use of city wastes, remediation of polluted soil, mitigation of GHG emission etc.

The institute is also taking 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 research projects of the Institute for the period under review (20012-17) are as follows:

Sl. N.	Title of the project	Duration	Year				
			2012 -13	2013 -14	2014 -15	2015 -16	2016 -17
Programme 1: Soil Health and Input Use Efficiency							
1.	Long-term Evaluation of Integrated Plant Nutrient Supply Modules for sustainable productivity in Vertisol.	April, 2002 to long term	√	√	√	√	√
2.	Network Project on organic farming (External funded)	Kharif 2004 to 2017	√	√	√	√	√
3.	Quality assessment of crops under different nutrient management system in long term experiment	May 2008 to May 2013	√	√			
4.	Nano-technology for Enhanced Utilization of Native-Phosphorus by Plants and Higher Moisture Retention in Arid Soils (NAIP Project) (External funded)	18th July, 2008 to 31 March 2014	√	√			

5.	Understanding the mechanism of variation in status of a few nutritionally important micronutrients in some important food crops and the mechanism of micronutrient enrichment in plant parts. (NAIP) (External funded)	February, 2009 to March, 2014	√	√			
6.	Evaluation of Allwin wonder and allowin top for their effects on maize productivity and soil fertility (Contractual Research Project)	April, 2009 to April, 2012	√				
7.	Efficacy of soil sampling strategies for describing spatial variability of soil attributes	14 October, 2009 to July 2012	√				
8.	Study on nanoporous zeolites for soil and crop management	March 2010 to March 2014	√	√			
9.	Bio-fortification of grain sorghum and finger millet varieties with zinc through agronomic measures.	Kharif 2010 to Kharif 2013	√	√			
10.	Participatory assessment of qualitative parameters for categorizing different degrees of soil quality to enhance the soil health and productivity.	March 2010 to Sept. 2013	√	√			
11.	Participatory integrated nutrient management for improving the productivity and fertility of soils of Nagaland.	May 2010 to April 2013	√	√			
12.	GPS and GIS based model soil fertility maps for selected districts for precise fertilizer recommendations to the farmers of India. (External funded)	June 2010 to December 2012	√				
13.	Studies on soil resilience in relation to soil organic matter in selected soils.	July 2010 to June 2015	√	√	√	√	
14.	Soil Resilience and its Indicators under Some Major Soil Orders of India.	March 2011 to February 2014	√	√			
15.	Soil quality assessment for enhancing crop productivity some tribal districts of Madhya Pradesh	July 2011 to June 2016	√	√	√	√	√

16.	Biochar on soil properties and crop performance	January 2012 to January 2017	√	√	√	√	√
17.	Development of phosphorus saturation indices for selected Indian soils	April 2011 to April 2014	√	√	√		
18.	Standardization of foliar feeding of zinc for correcting its deficiency and grain enrichment in wheat	October 2014 – June 2017			√	√	√
19.	Use of nano sensors network for field detection of temperature and moisture stress in plant and soil. (External funded)	April 2015 to March 2016				√	
20.	Conversion of naturally occurring plant nutrient containing minerals into nano form by top down approach to enhance the availability of plant nutrients in soil and faster reclamation of problem soils (External funded)	April 2015 to March 2016				√	
21.	Evaluation of efficacy of sulphur and zinc containing complex fertilizers for maximizing yield through balanced nutrition of different crops in India (Funded by Zuari Agro Chemicals Limited)	10 April 2015 to June 2017				√	√
22.	Evaluation of efficacy of zinc metalosate and boron metalosate foliar supplements for maximizing yield through balanced nutrition of important crops grown in India (Funded by Indofil Industries Limited)	22 June 2015 to June 2017				√	√
23.	Integrated assessment of some IISS Technologies in Enhancing Agro-Ecosystems productivity and livelihood sustainability	January 2013 to July 2016	√	√	√	√	√
24.	Nano-particle delivery and internalization in plant systems for improving nutrient use efficiency	July 2013 to June 2015		√	√	√	
25.	Evaluation of plant nutrition product (NP-1) for nutrient use efficiency in cereal crops (Sponsored by Nagarjuna Fertilizers and Chemicals Pvt. Ltd., Hyderabad)	December 2012 to June 2015	√	√	√	√	

26.	Effect of urea pastilles productivity and nutrient use efficiency in some soils of India Sandvik India Pvt. India (Contractual /Consultancy Project)	November, 2012 to November 2014	√	√	√		
27.	Evaluating rock phosphates for their suitability for direct application	October 2013 to May 2017		√	√	√	√
28.	Evaluation of modified urea materials and agronomic interventions for enhancing nitrogen use efficiency and sustaining crop productivity	October 2013 September 2017		√	√	√	√
29.	Testing a new slow release 14-7-14 NPK fertilizer for its efficiency under field conditions (Contractual)	July 2013 to June 2014		√	√		
30.	Evaluation of efficacy of polysulphate on oil seed crops (soybean-mustard)	July 2014 to June 2015			√	√	
31.	Evaluation of urease inhibitor product (limus) for nutrient use efficiency in cereal crops (Consultancy/Contract research project)	July 2014 to June 2016			√	√	√
32.	Evaluation of nano-nutrients product (NUALGI) for improving nutrient use efficiency of crops	July 2014 to June 2015			√	√	
33.	A Rapid Soil Test Kit for making soil test based fertilizer recommendations and preparing soil health card with respect to soil fertility parameters (Contractual/Consultancy)	Nov. 2014 to Feb 2015			√		
34.	Assessment of important soil properties of India using mid-infrared spectroscopy	May 2015 to June 2018				√	√
35.	Enhancing Resource Use Efficiency in Pulse Based Cropping System in Central India (Collaborative project from ICAR-IIPR, Kanpur) (External funded)	July 2014 to June 2017			√	√	√
36.	Upgrading Mridaparikshak mini lab Technology-Addition of five parameters viz. available Copper, Manganese. Lime requirement,	Dec 2015 to April 2016				√	√

	Gypsum and Calcareousness in mridaparikshak (M/s Nagarjuna Agro Chemicals Pvt. Ltd. Hyderabad) (External funded)						
37.	Soil quality assessment and developing indices for major soil and production regions of India. (funded by ICAR Extramural)	April 2015 to March 2017				√	√
38.	Response of crop to applied Potassium in Vertisols of India. (Sponsored project PRII Gurgaon)	June 2015 to May 2017				√	√
39.	Development of customized fertilizer solutions to promote balance fertilization in selective agriculturally important states of India towards crop productivity and farm profitability	May 2015 to April 2016				√	√
40.	Hyper-spectral remote sensing approaches to evaluate soil quality and crop productivity of central India under DST sponsored Network Project on Hyper-spectral Big Data Analytics. (External funded)	April 2016 to March 2019					√
41.	The Äquasorb" project Effect of aquasorb on water and nutrient use efficiency & crop productivity of soybean & tomato in selected soils of India (Funded by SNF India Pvt. Ltd. Vishakhapatanam	13 July 2016 to June 2018					√
Programme 2: Conservation Agriculture and Carbon Sequestration vis-à-vis Climate Change							
42.	Tillage and manure interactive effects on soil aggregate dynamics, soil organic carbon accumulation and by pass flow in vertisols (External funded)	June 2008 to March 2015	√	√	√		
43.	Detection of water and nitrogen stress and prediction of yield of soybean and maize using hyper-spectral reflectance and vegetation indices. (External funded)	June 2009 to July 2013	√	√			

44.	Tillage effects on weed dynamics in soybean-wheat system on Vertisol.	1st June 2009 - June 2012	√					
45.	Soil carbon saturation and stabilization in some soils in India.	July 2010 to March 2014	√	√				
46.	Evaluating Conservation tillage on various cropping sequences/rotations for stabilizing crops productivity under erratic Climatic Conditions in Black Soils of Central India.	March 2010 to June 2016	√	√	√	√	√	
47.	Impact of crop covers on soil and nutrient losses through runoff in Vertisol.	June 2010 to May 2014	√	√	√			
48.	Changing climatic factors' influence on the nutrient acquisition, utilization and recovery by soybean and wheat/gram germplasm lines/ genotypes on black soils of central India	June 2010 to June 2013	√	√				
49.	Assessing impacts of climate change on different cropping systems in Central India and evaluating adaptation studies through crop simulation models	June 2011 to May 2016	√	√	√	√	√	
50.	Characterizing rooting behaviours, soil water patterns and nutrient uptake of soybean – chickpea under different tillage and water regimes in Vertisols.	June 2011 to December, 2014	√	√	√			
51.	Evaluating Conservation Agriculture for Stabilizing Crop Productivity and Carbon Sequestration by Resilient Cropping Systems/Sequences under aberrant Climatic Conditions in Black Soils of Central India (NICRA) (External funded)	September 2011-14	√	√	√			
52.	Integrated assessment of soil and crops for enhancing productivity and C-sequestration potential of Vertisols of central India under changing climate scenarios (NICRA) (External funded)	Feb 2015 to March 2018				√	√	
53.	Weed Management for major cropping systems under conservation agriculture in Vertisols	June 2014 to May 2017			√	√	√	

54.	Simulating the effect of elevated CO_2 and temperature on water productivity and nutrient use in soybean-wheat cropping system. (External funded)	22 June 2015 to June 2018				√	√
55.	Consortium Research Platform on Conservation Agriculture (CRP on CA) (External funded)	April 2015 to March 2017				√	√
56.	Ensuring food security, sustainability and soil health through resource conservation based farmer FIRST approach in central India	2016 to 2018					√
Programme 3: Microbial Diversity and Genomics							
57.	Structural and functional diversity of microbes in soil and rhizosphere	January 2010 to January 2014	√	√			
58.	Actinomycetes diversity in Daccan plateau, hot, arid region and semi arid eco-sub-region (AER 3 and 6) and evaluation of their PGPR activity.	August 2010 - April 2014	√	√	√		
59.	Developing technique for acceleration of decomposition process using thermophilic organisms	September 2011 to December 2015	√	√	√	√	
60.	Consequences of transgenic cotton on soil microbial diversity	March 2011 - March 2014	√	√			
61.	Chemical and Microbiological Evaluation of Biodynamic and Organic Preparations.	June 2011 - June 2014	√	√	√		
62.	Metagenomic characterization and spatio-temporal changes in the prevalence of microbes involved in nutrient cycling in the rhizoplane of bioenergy crops. (External funded)	November 2011 to November 2014	√	√	√		
63.	Archaea and Actinobacteria in Vertisols of Central India-Assessment of Diversity, Bigeochemical Processes and Bioinoculant Potential (Externally funded project from AMAAS) (External funded)	July, 2014 to March 2017			√	√	√

64.	Metagenomic mapping of microbial diversity in rhizosphere of major crops of India and Argentina offsetting production potential. (External funded)	May 2015 to May 2018				√	√
65.	Isolation and characterization of heavy metal resistant bacteria & evaluation for their use in agriculture (Collaborative project from ICAR- NBAIM, MAU) (External funded)	May 2014 to March 2017			√	√	√
66.	In-situ residue decomposition of rice-wheat and sugarcane for enhancing crop productivity and soil health (ICAR-Extra Mural Project) (External funded)	Jan 2016 to March 2018				√	√
67.	India-UK nitrogen Fixation Centre ((IUNFC)	June 2016 to June 2019					√
	Programme 4: Soil Pollution, Remediation and Environmental Security						
68.	Non point sources of phosphorus loading to upper lake, Bhopal.	April 2011 to March 2014	√	√			
69.	Phyto extraction of Cr by some floriculture plants	June 2009 to May 2013	√	√			
70.	Impact assessment of continuous fertilization on heavy metals and microbial diversity in soils under long term fertilizer experiment (External funded)	August 2010 - December 2012	√				
71.	Greenhouse gas emission from composting system and characterization of green house gas regulating microbes.	June 2012 - June 2016	√	√	√	√	√
72.	Novel Bio-filtration method using selected mesophilic fungi for of heavy metals from municipal solid waste in M.P. (External funded)	July 2012 to July 2014	√	√	√		
73.	Quantifying Green House Gas (GHGs) emission in soybean wheat system of Madhya Pradesh	31/3/2011 to 31 December 2016	√	√	√	√	√
74.	Interactions among tannery effluents constituents on heavy metals uptake by spinach	January 2012 to December 2016	√	√	√	√	√

75.	Investigations on the safe use of sludge in agriculture land generated from effluent from plant of a soft drink. (Contractual /Consultancy Project)	June 2013 – May 2014	√	√	√		
76.	Impact of Long Term Use of Sewage Water Irrigation on Soil and Crop Quality in Bhopal region of Madhya Pradesh	August 2013 to July 2016		√	√	√	√
77.	Biodegradation of pesticides under changing climate and metagenomic profiling of functional microbes. (External funded)	December 2013- December 2016		√	√	√	√
78.	Determination of Baseline Concentration for Delineating Contaminated Areas in Black Soils of central India	May 2014 to May 2017			√	√	√
79.	Critical limits of Cd for major soil orders of India	July 2015 June 2018				√	√
80.	Assessment of Cotton for the remediation of soils contaminated with heavy metals	June 2015 to May 2018				√	√
81.	Determination of critical limits for identifying heavy metals contamination and their threats in major soil types of India (ICAR-Extra Mural Project) (External funded)	Jan 2016 March 2017				√	√
82.	Reclamation and rehabilitation of coper mining affected land in Malanjkhand area of Madhya Pradesh (Hindustan Copper Limited)	April 2016 to March 2021					√
83.	Management of Municipal Solid Waste (MSW) contaminated landfill area of Bhanpur, Bhopal	November 2016 to October 2018					√

(v) Significant Major Research Achievements of IISS, Bhopal in brief

<u>Programme 1: Soil Health and Input Use Efficiency</u>

I. Soil health assessment methods and protocol

Mini Soil Lab –Mridaparikshak: Rapid soil testing instrument

It is an economic and rapid soil testing instrument developed in September, 2015 to assess soil health parameters and prepare soil health cards for the large farming community of our country. It is also referred as a digital mobile quantitative mini lab to provide soil testing service at farmers' doorsteps. It determines all the important 15 soil parameters i.e. soil pH, EC, organic carbon, available nitrogen, phosphorus, potassium, sulphur and micronutrients including boron, iron, manganese, zinc, copper, calcareousness, gypsum requirement and lime requirement. It is a user friendly instrument which can be easily operated by a young educated farmer (11^{th}-12^{th}Pass) with 2-3 days of training. *Mridaparikshak* is also capable of providing crop and soil specific (alluvial soils, red soils and black soils) fertilizer recommendations based on the targeted yield equations directly to farmer's mobile. Applications for its patent and trademark are pending, and the technology has been commercialized.

*[**Comment of QRT**: Institute should conduct impact assessment study on this instrument after receiving feedback from each of the user.]*

Mid-Infrared Spectroscopy for quantitative analysis of soil

Obtaining quantitative soil information data by systematic sampling using conventional survey and laboratory analyses is time consuming and prohibitively expensive. Diffuse reflectance spectroscopy in the middle infrared region provides an alternative to conventional methods of soil analysis and can potentially be used to analyze a number of soil properties simultaneously. Using soil quality parameters for soils from different places of the country, different prediction models of soil properties were developed using partial least square (PLS) regression and random forest regression technique. Soil properties like pH, clay content, soil organic carbon, pH, total potassium content etc. for Vertisols were predicted with reasonable accuracy using the chemometric models developed. However, predictability of available phosphorus, available nitrogen, and moisture retention at field capacity was quite low as evident from low coefficient of determination values and high RMSE values for these properties.

*[**Comment of QRT**: Use of MIR for rapid soil testing appears promising; however robust scientific explanation is required to be worked upon. The work should be completed at the earliest for its potential to fulfill the objective.]*

Prediction of nitrogen stress, yield and biophysical parameters of maize and wheat through hyperspectral remote sensing:

Field experiment was conducted on a Vertisol to evaluate the effects of nitrogen stress on spectral reflectance characteristics and vegetation indices of maize and wheat. The results showed that the crop biophysical parameters like, leaf area index and biomass growth could be estimated from the broadband vegetation indices like normalized difference vegetation index (NDVI), green-NDVI, and narrow-band vegetation indices viz. normalized difference red edge (NDRE). However the prediction could be improved by using soil adjusted transformed vegetation index (TSAVI) using correction factors from the soil reflectance line developed for Vertisols. Nitrogen stress in maize and wheat crop was earlier predicted with two hyper-spectral vegetations indices namely, Red Edge Position (REP) and Slope of the REP data. However to improve upon the predictability of nitrogen content two new indices namely Combined Index and Double-peak Canopy Nitrogen Index (DCNI) were tested. Both the index could able to predict more than 60% variability of the nitrogen content in maize leaf. DCNI predicted 71% variability of nitrogen content in maize leaf under our controlled experimental condition. It is concluded that DCNI could be used for prediction of nitrogen stress in maize and wheat crops.

*[**Comment of QRT**: IISS may review the researches of other organizations in order to avoid any duplication of work. Institute should also collaborate with other organizations like NRSA so that robust technologies can be developed.]*

Soil Quality Assessment for Enhancing Crop productivity in Some Tribal Districts of Madhya Pradesh

Soil fertility maps for tribal dominated Jhabua, Alirajpur and Dhar districts of Madhya Pradesh were prepared. More than 50% of the soils in the region are at least deficient in three plant available nutrients namely Available N, S and P or Zn. A simple methodology was developed to work out the soil quality index (RSQI) using 15 parameters (physical, chemical and biological indicators) with uniform weight-age and scoring value. Based on the RSQI values, soil quality status of the study area is largely poor i.e. 77.22%, 85.37% and 67.18% soil samples in Jhabua, Alirajpur and Dhar districts, respectively. Frontline demonstration trials in farmers' fields indicated that response to nutrient management interventions were higher in moderately poor quality soils followed by medium and poor quality soils.

*[**Comment of QRT**: Soil quality evaluation based on RSQI approach is altogether different from soil quality evaluation based on principal component analysis. Institute should clearly recommend the right approach of soil quality evaluation and make an effort to use the information].*

Studies on soil resilience in relation to soil organic matter in selected soils of India

Under screen house experiment, relationship between soil native carbon level and soil plasticity parameters was established in a clay loam soil. Plastic limit and liquid limit reduced with depletion in soil C level, though the reduction was drastic from C_1 (33%) to C_2 (33%) depletion level. Upon reclamation particularly with FYM, the plastic limit and liquid limit of degraded soil increased. There was a trend of increase in plasticity index, though not much variation was observed between the treatments.

An incubation study with major soil orders showed that organic carbon content was highly correlated with liquid limit, plastic limit and gravimetric water contents at -33 kPa. Addition of fly ash brought favourable changes to the plasticity parameters such as liquid limit, plastic limit and plasticity index. Toxic dose of copper significantly (17.98-29.30%) reduced the soil microbial biomass C (SMBC) of Vertisols. However application of FYM to soil with increasing doses significantly reduced the copper stress effect on SMBC. Californian Bearing Ratio (CBR) and Resilient modulous values were highest in the treatments with FYM + fly ash (2.79% and 28.88 MPa, respectively) followed by poultry manure + fly ash (2.25% and 23.28 MPa, respectively) depicting their higher strength due to addition of fly ash. Study suggested that fly ash along with organic amendments like FYM or poultry manure can be used for better physical resilience in vertisols of Central India.

*[**Comment of QRT**: As resilience of a soil is very important parameter having implication on amelioration of degraded land, a concerted effort is requiredto develop protocol for resilience study thorough discussion with expert groups and determine soil resilience capacity for major intensively cultivated areas against important degrading forces].*

Development of Phosphorus saturation indices for selected soils of India

Degree of Phosphorus (P) Saturation (DPS) indices were developed for Vertisol, Inceptisol, Alfisol and Ultisol using different extractants namely Olsen (Ol), Bray1 (By1), Bray2 (By2), Mehlich 3 (M3), AB-DTPA (A.D.) and Ammonium Oxalate (A.O.). Column leaching study was carried out with eleven leaching events to determine P movement. In Vertisol, Inceptisol, Alfisol and Ultisol the reactive P concentration in leachate ranged from 0 to 9.8 µg ml^{-1}, 0 to 12.3 µg ml^{-1}, 0 to 10.6 µg ml^{-1} and 0 to 8 µg ml^{-1} in different treatments.The lowest P movement in soil was found in Ultisol followed by Alfisol, Vertisol and Inceptisol. The threshold values for crop yield and sub-surface P leaching were determined using different P saturation indices (DPS). Inceptisols at Delhi are most vulnerable for P leaching followed by Alfisol, Ultisol, and Vertisol which are least susceptible to P leaching.

*[**Comment of QRT**: This study is required to be carried out further to arrive at the conclusion on whether Indian soils under different agroecological regions have reached the P saturation limits due to continuous P fertilizer application.]*

II. Nutrient management for crops and cropping systems

Long–term evaluation of integrated plant nutrient supply modules for sustainable productivity in a Vertisol

Maize yield significantly differed with the application of various integrated nutrient management (INM) modules in long term fertilizer experiment at IISS research farm. Maize productivity was also increased with application of 75% NPK dose of STCR based fertilizer module with integration of different organic sources of nutrients *viz*., poultry manure and urban compost. All INM modules were statistically at par with GRD in terms of maize yield, whereas with application of organic sources of nutrients alone, grain yield was significantly lower. The highest agronomic efficiency and partial factor productivity in FYM based INM module followed by GRD. The application of 5 tonne farmyard manure in every season also enhanced the grain and straw yield of chickpea as compared to residue management (Mulching by maize residues). Increase in grain and straw yield of chickpea might be due to residual fertility effect of organic manures in maize. Among the different INM modules, application of 20 tonne FYM in every season to maize–chickpea cropping system resulted significantly increase in TOC and carbon stock (Mg/ha) followed by other organic based INM modules.

*[**Comment of QRT**: Detailed study on soil quality changes has not been conducted. Differential impact of various organic sources on important soil quality parameters needs to be studied.]*

Integrated Assessment of some IISS Technologies for Enhancing Agro-Ecosystem Productivity and Livelihood Sustainability

Some of the promising technologies developed by IISS were evaluated under farmer field conditions. The technologies evaluated through the project consisted of Integrated Plant Nutrient Supply System (IPNS-I) recommends application of 50% recommended rate of NPKS + 5t/ha farmyard manure (FYM) + biofertilizer to soybean crop and 75% of recommended rate of NPKS + biofertilizer to the wheat crop, Soil Test based Fertilizer Recommendation for Targeted crop Yields (STCR), and use of 2t/ha Phospho-sulpho-nitro compost in IPNS instead of 5 t/ha FYM (IPNS-II). There were wide variations in the performance of each technology under farm field conditions of different operational holdings and all the three technologies performed best in the resource rich large farmer fields. Small farm fields with poor on-farm resources performed better in producing a good yield and a reasonable profit to the farmer compared to the medium farm fields with moderate on-farm resources for all the three nutrient management technologies. Availability of irrigation water was the major constraint in the selected agro-ecosystem and it affected mostly the wheat crop of medium farmlands.

*[**Comment of QRT**: Follow-up action is required for dissemination of the technologies.]*

Yield gap analysis of maize for the state of Madhya Pradesh

Understanding the causes of yield gap in a region allows farmers to prioritize their efforts in improving yield and profit in a sustainable and environmentally sound fashion. The yield gap of **maize crop** assessed from a well calibrated and validated APSIM crop model for the state Madhya Pradesh showed that the yields obtained in farmers' fields are far below the water-limited potential yields in all the districts and the state as a whole. The farmers' yield is just about 30% of the water limited potential yield and experimental yield is about 47% of the potential yield. This indicated that that there is a good potential to improve the grain yield of maize crop by 3 t ha^{-1} provided optimum dates of sowing and good management practices are adopted.

Organic farming and produce quality

In varietal testing for suitability for organic farming in central India, soybean cultivar RVS-2002-4, maize cultivar Kanchan and chickpea cultivars, cv. JG-130 were found superior.100 % organic system of nutrient management was superior compared to organic (75 %) + innovative. Nutritional quality constituents such as amino acid, protein and oil content of different varieties of soybean and maize were compared. Among the copping systems soybean-wheat /chickpea performed better than soybean-mustard/linseed cropping system. The performance of wheat, chickpea and mustard crops under organic was nearly consistent. Various sources of organic manures showed different efficiency in improving crop yields: cattle dung manure (CDM) in soybean; CDM + Poultry manure (PM) + Vermicompost (VC) in durum wheat; CDM + PM in mustard. Soil biochemical activities were found maximum in100 % organic as compared to INM indicating beneficial effect of addition of organics on soil microorganisms.

*[**Comment of QRT**: Study should lead to a logical conclusion in respect of impact of organic farming on produce quality of crops, particularly vegetable crops.]*

Biochar as a acid soil ameliorant

The amendment effect of biochar produced from *Leucaena* biomass was investigated in an incubation study in acidic soil (Alfisol; pH (H_2O) = 4.5) of north-west India. The mean increase in soil pH was 0.65, 1.35 and 2.0 unit at 2, 4 and 6% (w/w) of biochar incorporation, respectively. Application of biochar significantly reduced NH_4-N content of soil; whereas it increased Nitrate-N, exchangeable K and Ca+Mg concentration. Biochar reduced exchangeable Al concentration to non detectable limit. Thus *Leucaena* biochar was found having potential as an amendment for N transformation and availability to plants and may act as alternative to lime for reclamation of acid soils.

*[**Comment of QRT**: Considerable research has been done in various institutions on use of biochar as pH amelioration in acid soil. Hence this study should be conducted in comprehensive way after analyzing the constraints in disseminating the information in the form of technology.]*

Effect of soil application biochar on yield of maize and gram

In a field experiment, biochar addition at 5 or 10 t ha^{-1} resulted in increased maize yield but significant increase could only be noticed alongwith 120 kg N ha^{1}. Biochar additions could enhance the maize yield at 5 or 10 t ha^{-1} and were statistically at par with each other.

A field experiment showed that total dry matter yield of maize crop was higher with soil test crop response equation based (STCR) fertilizer application and in the treatments where basal dose of N was skipped and total N was applied in two equal splits. Soil amendment with biochar (prepared from *Leucaenaleucocephala*) also improved biomass yield. The N use efficiencies were higher with split application of N, followed by in the treatments where biochar application.

*[**Comment of QRT:** Besides studying the agronomic benefit, study should have investigated effect of biochar application on different soil quality parameters leading to yield increase.]*

III. Enhancing input use efficiency

Phosphorus use efficiency in soybean and chickpea genotypes under varying climatic scenario in a black soil of central India

Onset and distribution of monsoon are the major determinant for time of sowing of Soybean and chickpea. Phosphorus use efficient varieties of soybean were selected under optimum and adverse showing conditions. Under optimum sowing conditions the P use efficiency of these varieties fall in the order, JS 9752>JS 335> JS 9305 > JS 9560. But under adverse sowing conditions, the P use efficiency recorded in the order, JS 9752> JS 9560 > JS 335 >JS 9305. In case of chickpea, order of P use efficiency under optimum sowing conditions falls in the order JG 16> JG 11> JG 315 ≥ JG 218. But under adverse condition (late season) the P use efficiency of these varieties followed in the order, JG 218 > JG 11> JG 16 ≥ JG 315. Under late sowing conditions, organic farming recorded higher yields in all varieties than other treatments.

Evaluating potential of zeolite for increasing P use efficiency

Under laboratory incubation study, untreated rock phosphate (Jhamarkotra 1) released more P in Alfisol than in Vertisol. Zeolite treatment led to a gradual but decreasing rate of release of P in the soil system. The study indicated that, in Alfisols, it should be possible to renew the system's ability to release P from rock phosphate in the soil by adding more NH_4-zeolite or by adding acid clay zeolite.

*[**Comment of QRT**: The study should be conducted further on developmentof technology for its dissemination in farmers' field]*

Modified urea materials and agronomic interventions for enhancing nitrogen use efficiency and sustaining crop productivity

Among different modified urea materials, neem coated urea (NCU) recorded higher grain, stover and total dry matter yield of maize crop and NUE, followed by biochar coated urea (BCU) and pine oleoresin coated urea (POR). The increase in total dry matter yield might be due to better synchrony of N release from modified N material with the crop demand. The N use efficiencies i.e. agronomic use efficiency (AEn) and partial factor productivity (PFPn) was also significantly differed with the application of different modified urea materials.

Effect of Urea Pastilles on Crop Productivity and Nitrogen Use Efficiency

Urea pastilles were evaluated against normal prilled urea at three different locations in vertisol, alfisol and inceptisol. Irrespective of crops and location, highest grain yield of wheat was recorded where N was applied at the rate of 120 kg/ha through urea pastilles; though it was statistically at par with the prilled urea. However, urea pastilles at lower dose (90 and 60 kg N/ha) recorded significantly higher maize grain yield in vertisol as compared to prilled urea application. Total soluble sugar and N content in leaf was significantly higher when it was applied through urea pastilles as compared to through prilled urea. The highest ammoniacal and nitrate -N content was recorded with urea pastilles (@120 kg N/ha).

*[**Comment of QRT**: This study pertains to evaluation of product from manufacture (not developed by IISS)]*

Evaluation of urease inhibitor product for nutrient use efficiency in wheat

Slow release N sources were compared for its use efficiency in wheat crop. Application of N in single dose through LIMUS urea (developed by a private farm) resulted in statistically similar yield to that of 120 kg N through prilled urea in 3 splits. Higher N use efficiency was observed with Neem coated urea (NCU) as compared to prilled urea. There was slight improvement in the apparent recovery by the wheat crop with LIMUS urea. At equal level of N application even NCU has shown better results.

Nanotechnology for improving nutrient use efficiency- A potential phosphorus fertilizer

Feasibility of utilizing the vast deposits of low grade rock phosphate available in India in crop production using nano-science and nano-technology was explored. Pot culture experiments on maize growth inVertisol, Alfisol, Aridisol and Inceptisol indicated that nano sized rock phosphate was better than the micron sized rock-phosphates. Crop's P utilization potential from nano-rock phosphate was at par with SSP in Vertisol and Inceptisol. Since dry form of nano phosphate cannot be applied directly to fields, it should be mixed with the FYM/Compost. In a field experiment with sorghum and finger millet, nano-rock phosphate was applied at 50 kg P_2O_5/ha in water suspension stabilized with linear Alkyl Benzene Sulphonate (LAS). Mean yield of sorghum increased from 1350 kg/ha to 2228kg/ha and of finger millet from 640 to 1048 kg/ha. The gas exchange analysis of sand cultured soybean and rice grown with Fe, Cu and Zn nanoparticles revealed that photosynthesis rate was higher with Fe NP treatments followed by Cu NP and Zn NP treated plants.

*[**Comment of QRT**: IISS should also attempt for bringing this into Fertilizer Control Order and collaborate with industries for dissemination of this technology].*

Nanoparticle delivery and internalization in plant systems for improving nutrient use efficiency

The impact of nano-micronutrient fertilization on growth and metabolism of plants viz. wheat and maize were studied under hydroponic as well as sand culture system using ZnO, CuO and Fe_3O_4 nanoparticles (NPs) mostly within the size range of 50 nm. Taller plants with more biomass were observed with CuO-NP treatment but not with Fe_3O_4-NP treatment. Micronutrient NPs treated plants showed lower level of stress as indicated by anti-oxidant enzyme analysis. With sub-optimal concentration of micro-nutrients higher Fe and Cu content in shoot; higher Cu & Zn in root was observed; and highest Cu content was observed in shoot as well as root. The TEM analysis indicated that the nanoparticles entered the root cortical cells and were found near the plastids of mesophyll cells at the junction of root and stem.

Programme 2: Conservation Agriculture and Carbon Sequestration vis-à-vis Climate Change

I. Conservation agriculture

Short-Term Effect of Conservation Agriculture Practices on Soil Quality

Short-term (3 years) effect of three contrasting tillage systems viz., no- tillage, reduced tillage and conventional tillage and four cropping systems viz., soybean + pigeon pea (2:1), soybean - wheat, maize + pigeon pea (1:1) and maize - chick pea on crop yield and soil quality parameters were studied through a field experiment in a Vertisol of central India. Results showed that soil quality as expressed through soil quality index (SQI) was better in maize + pigeon pea (1:1) and soybean + pigeon pea (2:1) under reduced tillage and no tillage systems as compared to the conventional tillage system. Conventional tillage showed negative effect on soil quality which may not be good for sustainable agricultural production in the long run. The value of SQI was positively and significantly correlated with soybean grain equivalent (SGE) yield for all the tillage and cropping system. This indicates that the index parameters may be used for computing the soil quality under different management practices.

Conservation tillage effect on soil organic carbon and soil biochemical activity

A study compared effects of different tillage (conventional, reduced and no-tillage) and cropping systems (Soybean + P. Pea (2:1), Soybean – Wheat, Maize + P. Pea (1:1), Maize–Gram) on soil biological parameter after three years of experimentation. Soil organic carbon was higher in reduced tillage and no-tillage compared to conventional tillage at 0-5 cm and 5-

15 cm soil depth. Similarly, soil enzymatic activities were higher in conservation tillage (no-tillage and reduced tillage system) as compared to conventional tillage.

Macro-aggregate fractions help in sequestrating carbon under conservation tillage system

Relative proportion of macro-aggregates (> 250µm) of the surface 15 cm soil in a long-term tillage experiment increased significantly under conservation tillage practices like no tillage and reduced tillage compared to conventional tillage system. Reduction in tillage operations and addition of crop residues reduced the breakdown of bigger aggregates while it promoted formation of more macro-aggregates from micro-aggregates under the changed hydro-thermal regime. Total organic matter content of the soil also increased under conservation tillage with soybean-wheat cropping system. Macro aggregates contained more organic carbon than the micro-aggregates. Macro-aggregates from no-tillage system contained more carbon than the macro-aggregates from conventional tillage system. Macro-aggregate fractions played a major role in locking and thus sequestering organic carbon under conservation tillage system in Vertisols. The study helped in elucidating physical stabilization mechanism of organic carbon sequestration.

Impact of Conservation Agricultural Practices on Soil health

Effect of long-term conservation agriculture practices on soil health was assessed in the ongoing (started in 2004) experiment on in rice-wheat cropping sequence at IIFSR, Modipuram. Soil carbon concentration in 0-5 cm of soil depth was found maximum less than zero till seed drill and happy turbo seeder plot. Higher soil organic carbon (SOC) was recorded under unpuddled condition as compared to puddled condition. Among the different tilling methods, higher SOC concentration was recorded in zero seed drill and happy turbo seeder (0.72%) in 0-5 cm of soil depth. In 5-15 and 15-30 cm of soil depths, SOC concentration was found maximum in Farmers practice under the treatments of zero till drill and Turbo happy seeder under unpuddled condition. Lowest SOC concentration was recorded under bed planting method. Under unpuddled (rice) condition, zero till and happy turbo seeder maintained highest (0.72%) SOC. This indicates that soil carbon could be build up under no till system in rice-wheat cropping system provided rice crop is direct seeded. Unpuddled condition maintained highest concentration of labile C ($KMnO_4$ oxidisable) content and lowest was recorded under puddled condition. Zero till drill method of sowing under unpuddled condition led to highest concentration and roto till drill under puddle condition maintained lowest of labile carbon in soil. Zero till drill maintained high concentration of labile C even under the farmers practice (manual transplant).

Reduced tillage package for soybean-wheat cropping system for sustaining productivity and improving soil health in Vertisols

A reduced tillage package of practice suitable for this agro-ecoregion has been identified for soybean-wheat system from the experience of the long-term tillage experiment. The reduced tillage system consisted of preparation of seed bed after onset of monsoon by one pass of duck-foot Tyne cultivator and sowing of soybean by no-till seed drill. The weeds in rainy season are controlled chemically by application of pre-sowing herbicide glyphosate and a post-emergence herbicide Pursuit. In winter season wheat is sown directly by no-till seed drill after application of pre-sowing irrigation and after harvest of wheat standing residues are kept on the surface. The reduced tillage system was found as effective as conventional tillage practices in terms of grain yield of crops with the added advantage of saving of energy and time during sowing. Reduced tillage helped in managing residues, sequestration of carbon and improvement of water transmission characteristics and aggregation of soil.

*[**Comment of QRT**: In stead of merely monitoring SOC under different soil management system, Institute should develop innovative way to protect SOC and enhance C sequestration.]*

Impact of crop covers on soil and nutrient losses through run off in vertisol

Study was conducted in Vertisol with three sole crops (soybean, maize and pigeon pea) and three intercrops [soybean + maize (1:1); soybean + pigeon pea (2:1) and maize + pigeon pea (1:1)]. The maximum runoff and soil loss was recorded under cultivated fallow. The total runoff and soil loss followed the order of, cultivated fallow > pigeon pea > maize > maize + pigeon pea > soybean + maize > soybean + pigeon pea > soybean. Among the sole crops treatments, higher nutrients losses were recorded in sole pigeon pea followed by maize and the lowest in sole soybean but in case of intercrops, the maximum nutrient losses were recorded in maize + pigeon pea (1:1) followed by soybean + maize (1:1) and the lowest in soybean + pigeon pea (2:1). Slow growth of pigeonpea during the early rainy season months were responsible for higher incidence of runoff and sediment losses from the field as the field remained partially covered during the rain fall events compared to soybean field where vegetation quickly covered the bare field.

Root architecture in wheat crop as influenced by soil compaction levels.

The root systems of wheat cvs Sujata and Malwa Shakti showed a great response to soil compaction levels. There was significant difference in the root architecture of both the cultivars with increase in bulk density (BD) from 1.2 Mg m^{-3} to 1.6 Mg m^{-3}. Between the two cultivars of wheat, the main axis length was longer in Malwa Shakti than Sujata at 1.2 and 1.4 Mg m^{-3}, whereas, there was not much difference in main axis length at 1.5 and 1.6 Mg m^{-3} BD levels. However, the main axis length of the both the cultivars decreased significantly with increase in soil compaction levels. Increase in BD, decreased the number of primary axis significantly in both the cultivars and higher number of primary roots were observed in Malwa Shakti than Sujata. Hence, the cultivar Malwa Shakti proved superior in performance over Sujata under changing soil compaction.

*[**Comment of QRT**: Under CRP on Conservation Agriculture (CA), only benefits of CA are being measured. Even though considerable researches had been undertaken in the past on conservation agriculture, adoptability of this by farmers is poor. IISS should not investigate on weed control under CA. Instead it should collaborate with Directorate on Weed Research, Jabalpur for this. Focus should be on identifying constraints in respect of farmers'*

acceptability, particularly on machinery developed for seed-cum-fertilizer till drill and delivering fertilizer nutrients in the root zone at required quantity. Repetition of works done in the past or being carried out under other organizations like BISA must be avoided.]

II. Carbon sequestration

Determination of potential mineralizable carbon in soil

Potentially mineralizable organic C (PMC) indicates the total metabolic activity of heterotrophic microbes releasing labile organic carbon as CO_2. After determination of potential carbon mineralization in different soil types under different land uses, factors affecting potential carbon mineralization was determined using the principal component analysis. An empirical model was developed to predict PMC in any soil type by measuring only few parameters namely, total C, total N and clay content of soil.

Determination of attainable carbon content of soil

Information on attainable soil carbon content provides more pragmatic approach for increasing soil carbon content under a given set of climatic and soil conditions. Attainable carbon content of soil was determined by using soil series dataset on sand, silt, clay, organic carbon and rainfall of different states of India applying statistical techniques.

Soil Carbon and Nitrogen Turnover Model

A new soil carbon and nitrogen turnover model has been developed by using the soil and crop dataset of long term fertilizer experiments of India. Soil carbon and nitrogen prediction model is controlled primarily by net primary production (yield), mean annual rainfall and temperature, texture (sand, silt, clay content), bulk density and soil initial carbon content. The model simulates soil carbon dynamics for different annual crops and plant communities. The model computes total organic carbon, Walkley & Black C content, carbon in resistant (passive) and mineralizable (active+slow) pools, carbon stocks, total N, and available N. The model determines (i) the relative allocation of carbon in different pools and (ii) computes the carbon and nitrogen turn over.

Soil Organic C Stability in Relation to Available N

Mechanism of soil carbon stability in different soil types as affected by long term application of chemical fertilizers and organic manure and consequently its effect on N availability has been identified. Application of balanced fertilizer (NPK alone) resulted in a build-up of soil carbon in the resistant pool in Vertisol whereas it contributed more towards the slow pool in Alfisols. Carbon stability affected the N dynamics in soil. Availability of N in soil is well correlated with the amount of carbon in the acid-hydrolyzable pool rather than total soil organic carbon content. Therefore, the carbon content of acid-hydrolyzable pools (mineralizable carbon) could be used as a tool to predict nitrogen availability to crops in a wider range of soils.

Soil organic pools and carbon sequestration under long-term field experiments:

Soil organic carbon in water stable aggregate represents slow pool of C that fraction was increased with decrease in the water stable aggregate size classes. Irrespective of treatments, macro aggregates (2000-250-µm) dominated followed by micro aggregates (250-53µm. The passive pool representing humic acid carbon (HA-C) was comparatively lower than fulvic acid carbon (FA-C) in the treatments receiving NPK and NPK+FYM possibly due to higher root biomass and regular application of newly humified manure in to soil.

Gradual depletion of nutrients, structural degradation and changes of microbial composition may have collectively contributed to the decline in the crop yield in soybean-wheat (Jabalpur) and rice-wheat system (Raipur). Balanced use of N, P, K plus FYM is an important management option for soybean-wheat and rice-wheat system followed by NPK+ green manuring to improve and sustain the soil-plant-microbial interrelationships under the impact of temperature and moisture regimes. Soil aggregate dynamics in relation to microbial activities were studied under different levels of organic matter (0- 10 tonnes of carbon/ ha) with and without tillage operation under soybean-wheat system in Vertisol. For that soil samples were collected at 0-5, 5-10-and 10-15 cm depth after harvest of soybean. It was observed that acid hydrolysable carbohydrates increased with increase organic matter application and decreased with increase the depth of soil. At 0-5 cm soil depth it was varied from 456 to 767 ppm in these treatments. The soil respiration varied from 14.4 to 17.6 mg CO2-C/100g/10d in conventional tillage and 15.6 to 20.3 mg CO2-C/100g/10d in No-tillage.

Modelling soil organic carbon using APSIM model from the long term fertilizer experiment (LTFE) of Jabalpur

Crop simulation models that involve SOC dynamics may provide robust and more precise methods to estimate SOC changes arising from management practices over different landscapes and time periods. Study conducted to explore the possibilities of using APSIM crop simulation model to simulate SOC at the surface layer (0-15 cm) under balanced fertilization of a long-term fertilizer experiment of Jabalpur indicated that the model could explain the observed changes in SOC over 40 years of experimentation with good coefficient of determination (R^2=0.69) and root mean square error (RMSE=0.02%).
*[**Comment of QRT**: Different groups in IISS are working on soil organic carbon in soil without any specific direction. Institute should identify the agenda of research on SOC and C sequestration and set the target.]*

III. Climate change on crop and C sequestration

Effect of temperature on C mineralization

The temperature sensitivity of soil organic pools and alterations in the microbial composition were studied. It was observed that the CO_2 emission was increased with increase in temperature from 25 to 45 ^{o}C and it was relatively greater under 60 % moisture holding capacity (MHC) of soil than submerged condition. Continuous application of inorganic fertilizer N or NP alone could not improve active pools of carbon (viz, soil microbial biomass C and N, water soluble carbon and acid hydrolysable carbon) in

Vertisols and Alfisols under soybean-wheat and rice-wheat system. However, application of fertilizer NPK significantly improved greater quantity of active and slow pool of carbon. It was also further observed that the combination of NPK with FYM application maintained higher quantity of carbon pools at the surface soil (0-15 cm depth).

Soil respiration in most recalcitrant pools (<53-µm) was increased by 13.9% at 45^oC as compared to 25^oC in all these treatments. Simultaneously estimation of labile C (Ao) revealed a 4.9 to 55.4% increase in the substrate pools from N, NP, NPK and NPK plus FYM at 25 to 45^oC in 250-2000-µm size clam. The mineralization rate constant (k) increased by 10.5 to 32.5% with increased the temperature. . The hydrolysable carbohydrates decreased by 23 to 37% of SOC from 25 to 45oC temperature and particulate organic carbon (POM-C) by 12 to 23% of SOC from 25 to 45^oC. It was pronounced under 60 % moisture holding capacity of soil as compared to submerged condition. This study clearly indicated that reduction of slow pools of carbon significantly contributed GHGs emission in terms of CO2 and CH4 as compared to recalcitrant pool of carbon.

Increase levels of CH4 production potential was observed with increase in temperature from 25 to 35^oC and decreased at 45^oC. It was observed that the CH4 production potential was relatively greater by the application of FYM+NPK in soybean-wheat system under submerged condition in Vertisol. In case of rice-wheat system, the CH4 production potential was greater under the treatment receiving NPK+ green manuring. In-situ CO2 efflux was increased with increase in temperature and decreased with moisture level and it was greater during evening than morning under field condition. The CO2- efflux was greater in NPK+ FYM treated plots as compared to NPK treated plots, which clearly indicated that newly added organic matter improved greater soil microbial activity resulted in greater GHGs emission.

Q_{10} was relatively greater in 60 % moisture holding capacity as compared to submerged condition. Phenolic groups are found relatively lower in humic acid (HA), where as Aliphatic C-H stretch is more in HA under soybean –wheat system indicated that this soil carbon is more susceptible to microbial action. Temperature exerts a great influence on the C and N mineralizations depend upon types and amount of substrate utilization. Also, under these circumstances, the microbial composition is altered along with the kinetics of microbial respiration and N mineralization.

Effect of elevated CO_2 and temperature on water productivity and nutrient use in soybean-wheat cropping system

In an experiment under Open Top Chambers (equipped with automated sensors for monitoring of key atmospheric parameters, viz., air temperature, atmospheric CO_2 concentration, soil temperature, atmospheric humidity, photosynthetically active radiation and soil moisture), effect of climate treatments (CO_2 and temperature as the key variables) and nitrogen application levels on nutrient and water use of soybean-wheat system was investigated. Seed N concentration was not significantly affected by the climate change, but elevated CO_2 resulted a significant reduction in N concentration in straw under. Significantly higher N uptake was observed under elevated CO_2 treatment at N_{100} due to higher grain yield, leaf biomass and leaf N concentration. Change in climatic parameter had significant effect on P and K uptake only under limited N levels.

Quantifying effect of climate change on maize productivity using APSIM model

Simulation studies on climate change effects on maize (Zea mays, L.) productivity in Vertisol of Madhya Pradesh using a well validated and parametrized maize module of APSIM crop growth model revealed that there is a potential for improvement in the grain yield of maize crop by 3 t ha^{-1}, provided optimum dates of sowing and good management practices are followed. Simulation showed that with increase in temperature by 5^0C, the grain yield of maize decreased from 4.7 to 2.9 t ha^{-1} in case of soils having higher plant available water capacity (PAWC 72-140 mm) while it decreased from 3.7 t ha^{-1} to 2.4 t ha^{-1} in case of soil having lower PAWC (< 72 mm). On an average, increasing the temperature by1^oC could reduce the grain and biomass yield by 0.3 t ha-1 and 0.4 t ha^{-1}, respectively and decreased the duration of crop by 4.3 days. Increase in temperature during soybean growing period would decrease soybean yield while decrease in temperature from the current climate would favour soybean yield in central India. On the other hand, increase in CO_2 concentration favoured soybean growth only when the temperature is increased up to 1 degree from the current climate, otherwise the positive effect of CO_2 is masked.

Soil N_2O emission as influenced by total N application and soil available N under conservation tillage

In conservation tillage manure interactive study in soybean-wheat cropping system, annual N_2O emissions (y) increased linearly with increased application of fertilizer and organic N to soil as well as with increase in soil available N. Soil available N and fertilizer N application explained about 59 to 61% variation in annual nitrous oxide emissions in soybean-wheat cropping cycle in Vertisols of central India. However, grain yield explained greater variation (69%) in N_2O emission.

*[**Comment of QRT**: Some useful information has been generated on climate change impact study on soil quality and crop productivity. Institute should focus its research towards developing technology for mitigating the adverse impact of climate change on soil quality and nutrient use efficiency.]*

Programme 3: Microbial Diversity and Genomics

I. Microbial diversity

Soil biodiversity under Bt and non-Bt-cotton rhizosphere:

Rhizosphere soil of Bt and non-Bt cotton- based cropping system were compared for soil biological properties as well as diversity. In soil, Bt-cotton did not pose adverse effect on culturable soil microbial populations. Bt-cotton-legume systems improved soil microbiological and biochemical attributes. Bt-cotton growth stages influenced soil microbiological and biochemical properties. It was observed that gemnogenous heterotrophs was ten fold greater in Bt cotton based cropping system as compared to non-Bt cotton based cropping systems. Relative abundance biological activities were found greater under bt-cotton based cropping system than non bt- based cotton system.

*[**Comment of QRT**: Culturable microbial population/diversity constitutes a minute fraction of total biodiversity. Hence study is inconclusive. Detailed investigation should be undertaken using appropriate Genomic/proteomic toolsin such study having severe implications].*

Soil biodiversity under long-term field experiments:

Microbial diversity was explored in long term fertilizer experiment in Mollisols (Pantnagar) and Alfisol (Ranchi). Cultivation of independent molecular techniques Terminal restriction fragment length polymorphism (T-RFLP) was used to assess the diversity of soil microbes. Microbial diversity indices comprising species richness and evenness were found higher in FYM followed by control and 100% NPK. Ribotypes of soil samples with FYM were dominated by Bacillus cellulyticus, Geobacillus, Rhizobium and clostridium. Treatment comprising 100% NPK was dominated by Methylobacter, Ralstonia, Chloroflexi, and Nitrospira sp. While the unamended control soil was predominated by Arthrospira, Paenibacillus, Clostridium, sp, and many uncultured soil bacterium. This study suggest that diversity of soil microorganisms in soil varied under influence of long term fertilizer application, and the prevalent groups are related to fertilizer sources and type.

*[**Comment of QRT**: Further detailed study should be conducted to use this information for developing useful technologies for farmers].*

Organic manure is the source of GHG emission from soil

Production of N_2O from soil reduced considerably when biochar amended organic manure applied. CH4 consumption correlated significantly with methanotrophic microbial population indicating the significant role of biochar in mitigating GHG emission from compost.

*[**Comment of QRT**: Technology should be disseminated widely].*

Soil biodiversity affecting climate change

Rise in atmospheric methane (CH_4) can influence redox metabolism and methanotrophs diversity in vertisol. It has been predicted that soil CH_4 consumption potential will increase due to rise in atmospheric CH_4. However, it is unclear how this altered function of soil will influence soil biogeochemical process. Experiments were carried out to examine the effect of positive CH_4 feedback response on CH_4 consumption potential, population dynamics of methanotrophs and reductive biogeochemical processes in a tropical vertisol. Results revealed that rise in soil CH_4 consumption rate enhanced diversity of methanotrophs.

Apparent CH_4 consumption rate k (µg CH_4 consumed g^{-1} soil) increased from 0.49 to 1.09 over three repeated CH_4 feeding cycle. Potential denitrification rate, potential iron reduction rate, potential sulfate reduction rate increased in response to rate constant k. Abundance of methanotrophs and heterotrophs varied significantly with soil CH_4 uptake.

Iron cycling microbes can mitigate global climate change: The Real time PCR quantification of methanotrophs (*pmoA* gene) in soil during wetting-drying cycle indicated that iron redox cycle stimulated methanotrophs abundance. It was observed that decrease in crystalline Fe minerals might have promoted CH4 oxidation by (1) activating pMOA gene abundance and (2) attaching methanotrophs to less crystalline Fe minerals. This provided information on the prospect of exploring Fe bacteria to mitigate greenhouse gas emission from the agricultural fields.

Novel microbial community associated with Bioenergy crop *Jatropha curcas*. Experiments were carried out to understand (1) nutrient cycling microbial population and (2) stress mitigating microbes in the rhizosphere and phylosphere of bioenergy crop *Jatropha curcas*. Isolated straines were characterized with potential nutrient cycling properties. Analysis for 16S rRNA gene sequence of phylosphere microbes revealed prevalence of mostly N_2 fixing, and methane oxidizing groups, which are hypothesized to aid in plant's stress response. Application of *J. curcas* plant extractants to soil increased abundance and activity of N_2 fixers, P solubilizers, heterotrophs, and methanotrophs. The product also minimized N loss (low N_2O-N loss) and aided in C storage (CH_4 mediated C sequestration).

*[**Comment of QRT**: This product/information should be evaluated through field experiment under Programme 1].*

Soil microbial response to the pesticide contamination

A study was undertaken to understand soil microbial response to the pesticide chloropyrifos contamination under different climate drivers like elevated CO_2, temperature, soil moisture. Production of N_2O was high (18.06 ng g^{-1}) under normal environmental condition, while the rise in CO_2, temperature and chloropyrifos reduced N_2O production to 2.94.

II. Decomposition of organic residues and composting process

Rapid composting of city and agricultural waste:

To accelerate the decomposition process of agricultural waste (cotton stalk, maize stalk, sugarcane trash, and pigeonpea straw) and city waste were studied in closed vessel system under controlled temperature. Fresh cow dung slurry was mixed with individual waste and all ingradients allowed at 50-60 ^{o}C temperature for two month to prevail thermophilic stage. The physico-chemical properties of composts were analysed. A total of 60 morphotypes of Bacteria and 20 morphotypes of actinomycetes and 10 morphotypes fungi werte isolated by using specific media. The compost quality parameters were assessed and it was found that city waste requires about 30 days and agricultural waste requires about 60-70 days for decomposition.

*[**Comment of QRT**: Already technology has been developed for faster decomposition of organic residues/wastes. Institute should review the already developed technologies and make an effort to faster decomposition than existing technologies.]*

Rapo-Compost Technology*:*

A new technology has been developed to speed up the compost time using consortium of Ligno-cellulolytic thermophilic organisms. This technology has been developed by ICAR-IISS in collaboration with ICAR-CIAE and ICAR-NBAIM. This technology is more suitable for recycling of kitchen waste and vegetable wastes. Consortium of Ligno-cellulolytic thermophilic bacteria (*Bacillus sps*.), Fungi (*Aspergillus sps*.) and actinomycetes (*Streptomyces sps*.) has been used for faster and accelerated decomposition.

Rapo-compost would prepare quality compost within 1-1.5 months from domestic and vegetable waste. The manurial value improved and maturity is attained at 30 days of decomposition. Large quantities of waste materials can be recycled back to the field after converting them to quality manure. Rapid composting kills all plant-disease producing organisms. Insects do not survive at high temperature during composting process. Most weeds and weed-seeds are also killed.

*[**Comment of QRT**: Details on the performance of this technology/prototype is required. Follow-up of this technology for dissemination to end users is required. Third party evaluation is required which will be helpful in dissemination.]*

***In-situ* agricultural residue decomposition technology**

Application of ligno-cellulolytic fungi, actinomycetes and bacteria along with cowdung slurry, starter nitrogen, molasses and curd accelerated the *in-situ* decomposition process resulted in rice and wheat residue decomposition in agricultural field within 30 days and for sugarcane about 45 days. The crop yield of rice and wheat were substaintially improved by the application of NPK along with in-situ residue incorporation. Further it was observed that soil organic carbon, actvitity of enzymes, available N, P and K were relatively greater than application of NPK fertilizer.

*[**Comment QRT**: Adequate data should be generated on decomposition state of crop residues in order to arrive at any conclusion on effectiveness of this technology.]*

Greenhouse gas emission from composting systems:

GHG emission from different animal manure management in India is not known. Therefore, experiments carried out to measure GHG from different composting systems like FYM, vermicompost, poultry manure and phospho compost. Emission flux for CH_4 ranged from 0.1 – 1.5 mg m^{-2} d^{-1} while N_2O emission was found to be the highest 10-12 mg m^{-2} d^{-1} in poultry manure. Greenhouse gases (CH4 and N2O) emission from 'Static' composting pit of FYM was high as compared to the composting system where feedstock is occasionally turned. Organic manure is the source of GHG emission from soil. Production of N_2O from soil reduced considerably when biochar amended organic manure applied. CH4 consumption correlated significantly with methanotrophic microbial population indicating the significant role of biochar in mitigating GHG emission from compost.

*[**Comment of QRT**: GHGs emission from different farm-composting systems should be quantified and technology should be developed to minimize the emissions from different composting methods.]*

Isolation and culture of methanotrophs to mitigate GHG emission from composting system:

Methanotrophs from FYM were isolated-enriched under laboratory condition and tested for their efficiency in enhancing CH_4 oxidation potential of the compost. Methanotrophic bacteria at 10^8cells per gram of compost (FYM) showed maximum oxidation (22 µg g^{-1} d^{-1}) while with higher bacterial population did not show any significant increase in CH_4 oxidation rate.
Most often the odor from poultry manure is a result of the uncontrolled anaerobic decomposition of organic compounds and release of gasses molecules such as H_2S. The strain 3M and 4S+M isolated from a poultry manure were found most promising in terms of time and S oxidation potential and thus have potential to control odor emanating from poultry manure pit.

*[**Comment of QRT**: This odor removing technology can make composting of city wastes socially acceptable and environmental friendly in urban areas. Hence, effort should be made to test/validate this technology under on-site condition.]*

Microbial activity in organic farming system:

Liquid organic preparations (beejamrutha, Amritpani etc) contain less number and groups of culturable microbes compared to cow dung manure, Biodynamic compost (BD), BD500 or CPP. Chemical analysis of various organic nutrient supplementing preparations also revealed the low NPK and micronutrient content in liquid organic preparations. Foliar application of organic and biodynamic preparation caused low chlorophyll content of the leaf but after 45 days of sowing in control, panchagavya treatment and biodynamic treatment. Increase in soil microbial activity was observed in the organic and Biodynamic treatment compared to control and chemical treatment. Total count of phyllospheric microbes was highest in panchagavya, biodynamic and organic treatment.

*[**Comment of QRT**: The investigation should answer the questions for which the study was undertaken]*

III. Use of fungi to remove heavy metals from composting system

Biosorption of heavy metals by fungi

Susceptibility of six mesophilic fungi *Trichoderma viride; Aspergillus heteromorphus; Rhizomucor pusillus; Aspergillus flavus; Aspergillus terrus; and Aspergillus awamori* to heavy metals Cd and Zn was investigated and degree of their susceptibility was determined. Functional groups present on these fungal mycelium were identified which might be responsible for sorption of heavy metals. The biosorption capacity of fungal cells for metals has been studied and it was higher for all the fungi for Pb.

*[**Comment of QRT**: Innovation in the study must clearly be indicated.]*

Bio-filter: A technology for heavy metal removal from compost

The biofilters were prepared and evaluated for heavy metal reduction from MSW compost. A perforated stationary filter has been developed (2 feet length and 1.5 feet high and 4.5 inches width). During humication stage of compost (about 45-60 days of decomposition) this filter is embedded in the compost pit. Technique for mass multiplication of the fungi on bajra seed was used in predesigned biofilter. Six fungi *viz.Trichoderma viride, Aspergillus heteromorphus, Rhizomucor pusillus, Aspergillus flavus, Aspergillus terrus* and *Aspergillus awamori* were identified as good heavy metal bioaccumulator. The multiple consortia of microbes then allowed to multiply inside the stationary filter for 15 days. A series of perforated biofilter blocks were inserted in the municipal solid waste compost. After 30 days, it was observed that the removal of Pb was maxium by these fungi followed by Ni and Zn. After every 15 days of humification filter is allowed to remove from the compost pit. *T. viride, A. heteromorphus* and *A. awamori* were the efficient bioaccumulator among these six fungi. Biofilter has been designed and evaluated under matured compost.

*[**Comment of QRT**: Thorough study must be conducted before arriving at any conclusion on efficacy of heavy metal removal.]*

Programme 4: Soil Pollution, Remediation and Environmental Security

I. Soil pollution assessment

Standard reference soil for heavy metal analysis

Standard reference soil is required for quality control check during analysis of soils for heavy metals contents as it indicates efficiency of digestion methods and accuracy of instrument during measurement. Protocol for preparation of standard reference soil has been developed for heavy metal (HM) analysis and about 25 kg of reference soil material (clayey texture) has been prepared in this way. About 250 bottles (100 g each) were prepared and from that 25 bottles were randomly selected over the whole bottling procedure for homogeneity and stability testing. From the homogeneity test it was found that heavy metals like Cu, Pb, Cr, Ni, Zn had less than 10% co-efficient of variation (CV) and Cd had 27.45% CV. This material can be used as control check during HMs analysis for soils. The moisture content of final soil sample was 1.07% (w/w), has clayey texture with 42.37% clay content, 0.46% SOC, pH 7.98 and $CaCO_3$ 5.76%. The average total content (mg/kg) of Cu, Cd, Pb, Cr, Ni and Zn in the soil was 53.46, 0.12, 20.68, 74.91, 60.89 and 61.02, respectively.

Determination of Baseline concentration of HMs in soils of Sehore and Vidisha, Madhya Pradesh

Baseline concentration (BC) is the natural ambient concentration of chemicals in the soils without human influence. It will act as base for delineation of contaminated areas due to anthropogenic activities. Through analysis of large number of soil samples and using statistical tool, upper baseline concentration of different heavy metals in black cotton soils of Sehore and Vidisha districts has been estimated as 178.1 ppm Cu, 0.7 ppm Cd, 24.4 ppm Pb, 116.9 ppm Cr, 81.8 ppm Ni and 85.2 ppm Zn. These BC values can be a useful tool for environmental impact assessment (EIA) around industrial areas.

*[**Comment of QRT**: This information should be used for delineating potentially contaminated area. Institute should develop protocol for Environmental Impact Assessment in potentially threatened agroecosystem]*

Geo-accumulation Index of heavy metals in tannery contaminated area of Kanpur

Chromium (Cr) is commonly found heavy metal in tannery effluent and is also one of the most detrimental elements to plant growth. On the basis of geo-accumulation index (I_{geo}), land can be assessed on whether it is contaminated with heavy metals or not. For this, geo-referenced soil and groundwater samples collected from long-term (>50 years) tannery effluent irrigated areas of Kanpur were analyzed for heavy metal concentration. Significant buildup of heavy metals such as Cr, Ni, Cd, Pb, Zn, and As were observed in soil. Computed geo-accumulation index indicates that soils in the effluent irrigated area of Kanpur were uncontaminated to moderately contaminated with Cu, Ni, Zn, Pb and As; moderately contaminated in case of Cd; and heavily to extremely contaminated by Cr.

*[**Comment of QRT:** Technology should be generated for reclamation and safe cropping in land contaminated with tannery industry wastes through on-site experiments. For this collaborative project may be developed with IIPR, Kanpur].*

Status of heavy metals content in and around Singrauli (M.P.) and Sonebhadra (U.P.) Industrial area

The study was taken as per direction of Hon'ble National Green Tribunal to confirm whether nearby agricultural land area has been contaminated with heavy metals due to the activities of thermal power plants. Average content of heavy metals in the soils from impact zone were 0.42 (range 0.03 to 2.6) mg/kg Cd, 33.1 (range 8.3 to 38.3) mg/kg Cr, 18.0 (range 3.7 to 43.6) mg/kg Cu, 22.8 (range 3.7 to 52.3) mg/kg Ni, 15.3 (range 7.6 to 42.9) mg/kg Pb, and 61.5 (24.0 to 132.6) mg/kg Zn. There is no significant change in the heavy metal contents in the soils nearby industrial and mining area when compared to the soils of agricultural and forest land far away from the impact zone. Further, the contents of total heavy metals Cd, Cr, Cu, Ni and Pb in the soils of agricultural and forest land in the impact zone are within the range normally observed in case of soils of unpolluted area as reported in literature. Only 1 soil sample collected from the forest area of Murdhwa nalla in Sonebhadra (U.P.) contained significantly high Cd (2.57 mg/kg Cd) and this location is about one Km away from a caustic soda plant. Two ash samples collected from ash dyke pond of thermal power plants have also been analyzed for heavy metal contents and results show that their contents are quite low as compared to the contents found in several soils in the study area. Analysis of red mud sample (a waste product from the Hindalco aluminium industry of Renukoot, Sonebhadra) indicated that it contains high level of Cr (647.33 mg/kg) and therefore, may contaminate soil if gets discharged into the agricultural land.

Non point sources of phosphorus loading to Upper Lake, Bhopal

Eutrophication in Upper Lake of Bhopal was reported from different literature. Phosphorus entry into the lake water was ascribed as one of the major causes of eutrophication leading to deterioration of water quality. In order to identify the sources P entry into lake, study was carried out wherein geo-referenced soils (in the catchment area having predominantly agricultural activity), sediments and water samples from different sampling points in lake. Different P fractions in the lake water viz., total dissolved P, total reactive P, dissolved reactive P, dissolved organic P and particulate P were quantified during both pre-monsoon and post monsoon period. Study revealed that P loss from the agriculture field and its entry into lake water-body was mainly associated soil loss /sediment P. The bioavailable fraction was more in domestic waste water at discharge point where algal blooms were noticed.

II. Soil pollution impact assessment

Heavy metals uptake and phytotoxicity

Uptakes of Cr and Pb by spinach crop were investigated in three soil types viz., alluvial, swell-shrink and lateritic soils. Fractions of total metal extracted by dilute CaCl2 were trace to 0.054% in case of Cr and from 0.012 to 0.074% in case of Cr, indicating stronger fixation of Pb by soil as compared to Cr. Transferabilityto plant biomass of lead in alluvial soil was higher as compared to black and red & laterite soils Transferability to plant biomass of chromium was lower in red & laterite soil as compared to black and alluvial soil. Phytotoxicity of lead at similar level in soil was more in alluvial soil as compared to black soil. Dry weights of aboveground biomass of spinach at highest level of Pb application were about 40% and 69% as compared to control in alluvial and black soils respectively. Chromium up to application of 800 mg/kg had no adverse effect on the growth of spinach in both black soil and red & laterite soil; but had significant adverse effect in alluvial soil causing about 47% decrease in aboveground biomass.

*[**Comment of QRT:** Chemical transformation of heavy metals in different types of soils leading to their fixation should be investigated for developing appropriate technology for amelioration.]*

Critical limits for identifying heavy metals contamination and their threats in major soil types of India

Soils from Kanpur (Udic Ustochrept), Indore (Typic Haplustert) and Ranchi (Typic Haplustalf) were used for determination of maximum safe concentration limits of Cr and Pb in alluvial, swell-shrink and lateritic soils. Soil Pb contents causing 20% reduction in aboveground biomass yield of spinach were computed as 393 mg/kg for black soil and 168 mg/kg for alluvial soil. Similarly, soil Cr content causing 20% reduction in aboveground biomass yield of spinach was computed as 265 mg/kg for alluvial soil. Pb is soil is fixed more strongly as compared to Cr. Maximum safe concentration limits (above which soils may contaminate food) of Pb and Cr in different soils were determined as 84 and 87 in alluvial soil; 78 and 332 in laterite soil; and 143 and 52 in black soils respectively. Dilute (0.01M) $CaCl_2$ extractable heavy metals are used as rapid screening method for identifying unsafe soils. For this method, critical limits of Pb and Cr were determined as 0.006 and 0.034 in alluvial soil; 0.002 and 0.071 in laterite soil; and 0.007 and 0.018 in black soils respectively.

*[**Comment of QRT**: ICAR should make an effort to see that this information is used by Govt. in formulation soil protection and reclamation policy.]*

Interactive effect of cations, anions and metals on Cr uptake by plant

Tannery industry effluent contains many other heavy metals, cations and anions besides Cr. While most of metal uptake-response experiments have been carried out ignoring the influence of other factors, information on interactive effect of other constituents in the effluent on the target metal can present realistic scenario on the severity of its toxicity. Batch experiments were conducted to understand interaction of (i) Cd and Zn on Cr uptake, (ii) Na^+ and Ca^{+2} on Cr uptake and (iii) Cl^- and SO_4^{-2} on Cr uptake by spinach.

***Effect of Metals**:* When cadmium at 2 mg/kg along with chromium at 100 mg/kg soil was applied, chromium concentration and uptake were decreased in root and shoot. Meanwhile, zinc application had no significant effect on chromium uptake and concentration in spinach biomass. It was concluded that cadmium at higher dose had an antagonistic effect over chromium. On the other hand, in chromium, cadmium and zinc combinations particularly at their higher levels, a competition among each other was found.

Effect of cations: Increasing the Na and Ca levels reduced the Cr concentration in plant roots and shoot part. The maximum reduction was observed when Na applied @ 80 mM compared to rest of the treatment. The increasing the pH reduced the availability of Cr in soil and reduced the bioavailability fractions of Cr, which is directly reflected in respective treatments.
Effect of anions: Increasing the concentration of Cl^- ions in soil reduced the Cr concentration in both root and shoot. Similarly, increasing the concentration of S from 4 to 8 *m*M kg^{-1} also reduced the concentration and uptake of Cr. Application of sulfate ions augmented the plant growth and counters the negative effect of Cl ions and Cr. Study revealed that the addition of S fertilizers could minimize the Cr toxicity in high Cr contaminated soils.

*[**Comment of QRT**: The basic information generated on interaction should be used for developing amelioration technologies in Cr contaminated land.]*

Chromium Toxicity Effect on Soil Enzymatic Activities

Tannery effluent contains larger amount of chromium (Cr), which is reached agricultural field by the irrigation during crop production. Accumulated Cr concentration in soil significantly affected soil enzyme activities i.e. dehydrogenase activity, alkaline phosphate and fluorescein diacetate, was studied. For this, a laboratory study conducted with graded doses of Cr (0, 5, 10, 15, 20, 40, 80 and 100 mg/kg) were applied through $K_2Cr_2O_7$, and enzyme activities were measured at 7, 15, 30 and 45 days after incubation. Increasing the concentration of Cr (0 to 100 mg/kg) reduced the enzyme activities and the maximum reduction was observed in the early stages of incubation. Among the enzyme activities, dehydrogenase activity was more sensitive to Cr toxicity. Dehydrogenase activity was decreased by 71.3% in 100 mg/kg Cr treated soil over control. Thus, it is concluded that Cr contamination of soil through anthropogenic activities like tannery effluents irrigation in soil, has significant adverse effect on soil microbial and enzymatic activities.

Impact of nanoparticles on agroecosystem

Nano-particles impart toxicity to ecosystem including soil microorganisms and plant. Titanium oxide nanoparticles are increasingly used in several cosmetic, house hold, paints etc., which ultimately enters into soil ecosystem in several ways. Impact of TiO_2 nano particles on soil enzymes was investigated. Results revealed that at lower doses up to 40 ppm of TiO_2 nano particles enhanced the activity of the enzyme like urease, dehydrogenase, alkaline and acidic phosphatase (induction), but the enzyme activities were reduced (inhibition) at higher doses of 100 ppm TiO_2 NP. The copper oxide nano particles showed remarkable antibacterial activity against both Gram-positive (*B. subtilis*) and Gram-negative (*E. coli*) bacteria. Under laboratory conditions, copper oxide nano particles have been shown to eliminate up to 99 % of germs in contaminated water within the short period of time.

*[**Comment of QRT:** IISS should collaborate with reputed institutions having good infrastructural facility related nanotechnological research to develop products/technologies useful for agriculture.]*

III. Urban and industrial wastes in agriculture

Impact of sewage water irrigation on food chain contamination

Heavy metals build-up and crop contamination were investigated in the long-term sewage irrigated area along both sides of 50 km long Patra Nala of Bhopal region. The untreated sewage water sample contained significant concentrations of plant nutrients. Long-term use of untreated sewage water for irrigating crops resulted in significant increase in soil organic carbon along with increase in population of soil microorganisms and soil biochemical activities. Long-term sewage irrigation for crop production led to significant build up of trace metals in soils. The concentration of heavy metals in surface soils of sewage irrigated fields were 2.1, 3.2, 1.4, 1.8, 2.0 & 1.6 times more than tube well irrigated field. Among the crops wheat, palak, coriander, radish, chenopodium, mustard grown in the area, the high metal accumulation of Cu, Cd, Pb, Cr and Zn was reported in mustard. The heavy metal risk assessment (Hazard Quotient, HQ) was calculated for all the crops and found that all the crops having heavy metal value in safe level.

Impact of sewage water irrigation on C sequestration in soil

Long-term use of untreated sewage water to crops resulted in significant increase in soil organic carbon (SOC) than soils irrigated with groundwater. Collected geo-referenced soil sample from different sewage water irrigated farmers fields along with drainage channel at a distance interval of 1-2 km. Long-term untreated sewage water irrigation has been found to sequester carbon in the upper 60 cm of soil profile in the farmers' fields of peri-urban areas around Bhopal city. Large addition of organic matter from sewage water irrigation and anaerobic conditions developed due to heavy loading of organic matter had reduced organic carbon mineralization and has resulted in build-up of SOC. Hence, long term sewage water irrigation can be a good means of carbon sequestration in Vertisol and can thus be referred as a soil quality sustaining practice.

Utilization potential of soft-beverage industry sludge

Sludges generated from effluent treatment plant (ETP) of a soft drink manufacturing company (M/s Hindustan Coca Cola Beverages Pvt. Ltd., Pilukhedi) were evaluated for their potential for use in agriculture. The sludge samples have high manurial value as indicated by high contents of organic matter (19-32% organic C), nitrogen (2.6-2.9%) and phosphorus (2.3-2.7%), and also considerable amount of secondary nutrients like Ca & Mg and micronutrients like Cu, Fe & Mn. However, contents of Cd, Pb and Cr were more than the permissible limit for composts (FCO, 1985) for application in agricultural land. These also contain high amount of salts. Sludge enhanced production of maize, wheat (food grain) and spinach (vegetable). Concentration of heavy metals Cd, Pb and Zn in soil increased significantly at high rate of sludge application. Although high rate of ETP sludgeapplication increased concentrations of several heavy metals in straw portion of maize and wheat crops, grains didn't get contaminated. Spinach leaves got contaminated with Cd due to sludge application. On the contrary, high rate of sludge application reduced as contamination in spinach leaf. Although ETP sludges generated from soft drink manufacturing company has very good fertilizing value, high contents of heavy metals particularly Cd poses considerable risk to agriculture particularly for growing vegetable crops.

Effects of different methods of preparation on the distribution of heavy metals in different size fractions of municipal solid waste composts from various Indian cities

The present study compares the distribution and nature of heavy metals in composts from 12 cities of India, prepared from different types of processed urban solid wastes, namely, mixed wastes (MWC), partially segregated wastes (PSWC) and segregated bio-wastes (BWC). Compost samples were physically fractionated by wet sieving, followed by extraction of heavy metals by dilute HCl and NaOH. Results show that bigger particles (>0.5 mm) constituted the major fraction in all 3 types of composts, and had a relatively lower concentration of organic matter and heavy metals, the effect being more pronounced in MWC and PSWC in which a significant portion of the heavy metals was distributed in finer size fractions. Cd, Ni, Pb and Zn were extracted to a greater extent by acid than by alkali; the difference being greater in MWC, which contained a higher amount of mineral matter. In contrast, Cu and Cr were extracted to a greater extent by dilute alkali, particularly, from BWC containing a higher amount of organic matter. Water-soluble heavy metals were generally related to the water-soluble C or total C content as well as to pH, rather than to their total contents. This study concludes that wet sieving with dilute acid can effectively reduce heavy metal load in MWC and PSWC.

*[**Comment of QRT**: Under 'Swachh Bharat Mission', emphasis is being given to environment friendly recycling of city sewage effluent and solid wastes. As a result, considerable amount of sewage-sludge and city waste compost are being generated which may have considerable environmental threat due to pollutants. The QRT strongly feels that IISS should initiate research on environmental angle towards formulating policy for safe use of sewage sludge, and city/industrial wastes. This programme may be carried out extensively through network mode.]*

IV. Remediation of pollution and Rehabilitation of polluted sites

Phytoremediation of soils contaminated with heavy metals

Phytoremediation, being more cost-effective and fewer side effects than physical and chemical approaches, has gained increasing popularity in both academic and practical circles. Study attempted to screen some floriculture plants (Tuberose, Chrysanthemum, Dahlia, Aster, Rose and Calendula), ornamental xerophytes (*Euphorbia milli, Agave Americana and*

Furcrea gigantia) and cotton for suitability during remediation of soils contaminated with Cr. The study revealed that the ornamental xerophytic plants and rose showed great tolerance and stronger ability to Cr but could not be classified as Cr hyperaccumulators. Nevertheless, these plants have great potential to be used for phytostabilization of contaminated soils by Cr. Cotton plant was found to be an excluder of heavy metals Cd, Pb and Cr; and therefore could not classified as a hyper-accumulator. However, the plant could be a potential crop for phytostabilization of Cd, Cr and Pb.

Removal of heavy metals from municipal solid waste compost

An experiment was conducted to investigate removal of heavy metals from municipal solid waste composts through extraction-cum-wet sieving procedure. Fourteen compost samples from different cities, prepared from mixed wastes (unsegregated/ partially segregated) were selected for the study. Extractants compared were water, EDTA (0.05N), HCl (0.1N) and raw distillery spent-wash (RSW) containing 0.01N EDTA. Compost samples were treated with extractants (unstirred in 1:5 ratio) for 48 hours and thereafter, these were washed on 0.5 mm sieve to remove finer particles and extracted metals. The retained >0.5 mm MSW compost materials were dried in oven at 70ºC for 24 hours. Total heavy metal contents in the dried samples were determined by acid digestion method. Results showed that removal of finer particles with water only reduced, on average, Cu by 22%, Cd by 19%, Pb by 21%, Cr by 26%, Ni by 42%, Zn by 15% and as by 24%. Among the extractants, 0.05N EDTA was usually most efficient in removing Pb and Cr; whereas, RSW+0.01N EDTA was most efficient in removing Cu, Cd, Ni, Zn and As. Extraction-wet sieving using efficient extractants (0.05N EDTA and RSW+0.01N EDTA) reduced different heavy metals on an average by about 34-58%, indicating that this method has considerable potential in diminishing the magnitude of soil contamination potential from the regular use of MSW composts in agriculture.

Reclamation and Rehabilitation of Copper Mining Affected Land in Malanjkhand Area of Madhya Pradesh

A collaborative project with Hindustan Copper Limited, Malanjkhand, entitled “Reclamation and rehabilitation of copper mining affected land in Malanjkhand area of Madhya Pradesh” has been initiated. The area is affected with mine-tailings from ore beneficiation process. The tailing samples were neutral in reaction and contained 11.7 mg/kg Cd, 20.5 mg/kg Co, 18.5 mg/kg Pb, 36.5 mg/kg Ni and 67.5 mg/kg Zn. In order to enhance biological activity in the soils, a portion of the affected area has been planted with Vetiver (*Chrysopogon zizanioides*) grass.

Management of Municipal Solid Waste Contaminated dumping area of Bhanpur, Bhopal

Dumpsite for municipal solid wastes are potential threat to environment including air, water bodies and nearby land as it contains several toxic contaminants which can enter human and animal through various routes. As municipal solid waste dumpsite in Bhopal is proposed to be closed in near future, cost effective & environment friendly method of for its closure/management is required. With the permission from municipal authority, a part of the dumpsite has been selected for rehabilitation study. Dumpsite has been overlaid with soil and trees and grass were planted on it for investigating vegetation establishment and phytoremediation.

Effect of soil and nutrient management practices on Green house gas emission

Soil nutrient management is a key component contributing to the greenhouse gas (GHG) flux and mitigation potential of agricultural production systems. However, the effect of soil nutrient management practices on GHG flux and climate change mitigation potential as estimated in terms of net global warming potential (NGWP) and greenhouse gas intensity (GHGI) is less understood in agricultural soils of India. The present study was conducted to compare three nutrient management systems practiced for nine consecutive years in a soybean-wheat cropping system in the Vertisols of India, in terms of NGWP and GHGI. The treatments comprised of 100% organic (ONM), 100% inorganic (NPK), and integrated nutrient management (INM) with 50% organic + 50% inorganic inputs. The gas samples for GHGs (CO_2, CH_4 and N_2O) were collected by static chamber method at about 15 days interval during 2012-13 growing season and the soil organic carbon (SOC) sequestration was estimated by the changes in SOC stock in the 0-15 cm soil over the 2004-2013 period. The cumulative N_2O and CO_2 emissions were in the order of INM > ONM > NPK with significant difference between treatments ($p < 0.05$). However, significantly higher SOC sequestration under ONM (1250 kg ha^{-1} yr^{-1}) followed by INM (417 kg ha^{-1} yr^{-1}) resulted in lower NGWP and GHGI under the two treatments compared to NPK. The NGWP was estimated to be -3583, -404 and 170 kg $ha^{-1}yr^{-1}$ under ONM, INM and NPK treatments, respectively. The wheat equivalent yield was similar under ONM and INM treatments and was significantly lower under NPK treatment. The results suggest that GHG mitigation along with sustained food production in the soybean-wheat system can be simultaneously achieved with organic manures as the major component of nutrient management, which also offers ancillary adaptation benefits to climate change.

*[**Comment of QRT:** Study on selection of appropriate hyperaccumulator of heavy metals should be given focus in future research and should be carried out with appropriate planning based physiological traits. Institute should also collaborate with appropriate plant science and crop science institutes in the country to improve genetic potential of hyperaccumulation of heavy metals.]*

Publications

The research findings of the Institute have been published through Annual Reports, Newsletters, Workshop proceedings, Bulletins and in Books. The publications of research findings in Journals of repute, both national and foreign, have been encouraged. The research papers of the Institute scientists have appeared in 15 Indian journals and 34 foreign journals that are either purely devoted to soil science research or are devoted to other disciplines related to soil science as shown below. The popular articles have also appeared in different magazines. The publication activities of the institute scientists are also in the form of publication of book chapters, souvenirs, pamphlets. The Institute brought 68 publications in the form of bulletins, annual reports, folders etc. both in Hindi and English during the period under report.

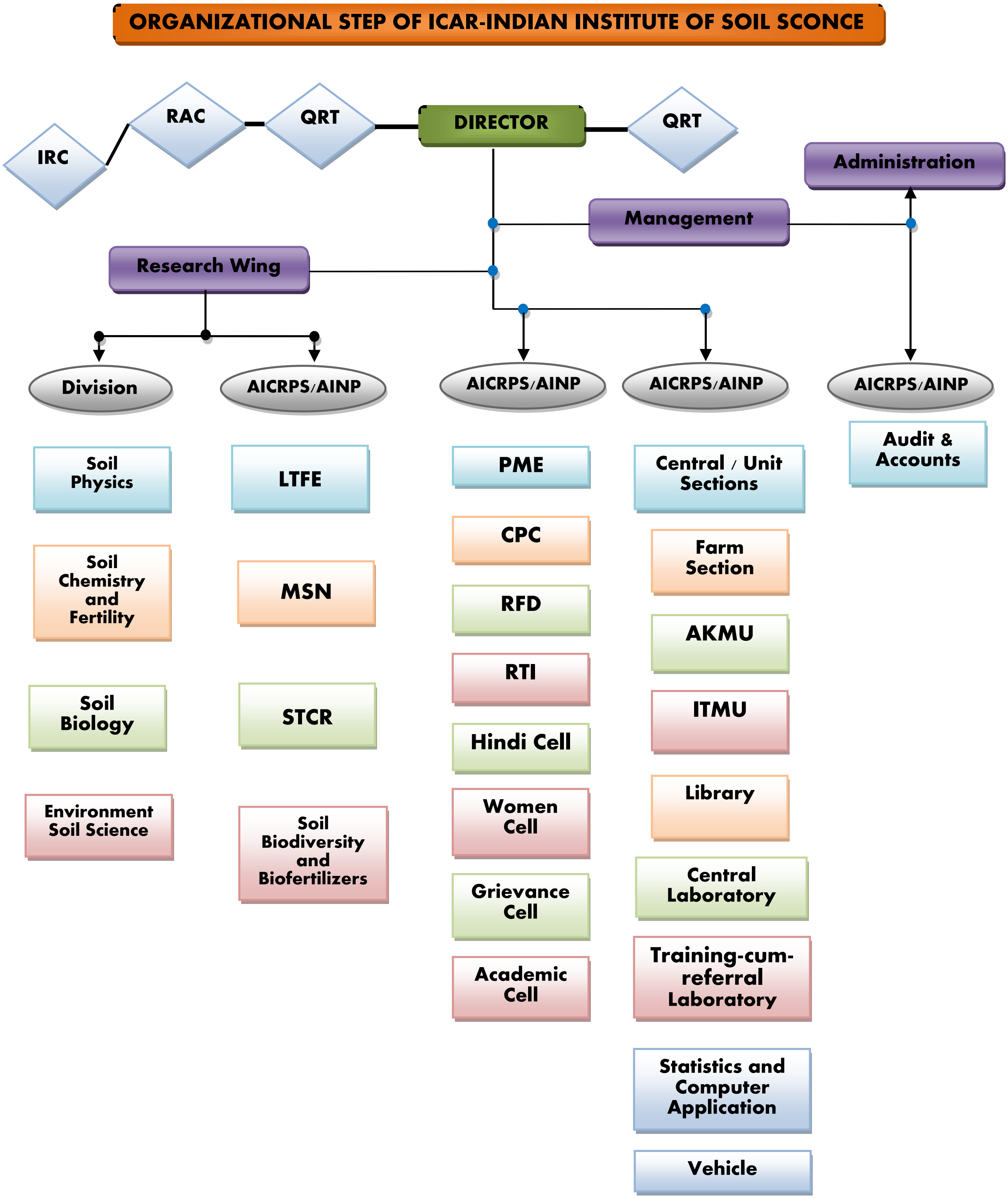
Status of Books/Bulletins and reports at IISS, Bhopal

Sl. No.	Particulars	Year				
		2012-13	2013-14	2014-15	2015-16	2016-17
1	Research articles	22 (14)*	31 (16)*	33 (21)**	23 (16)**	30 (16)**
2.	Chapters in Books	20	67	21	23	48
3.	Bulletins	2	7	3	7	7
4.	Pamphlets/News Letters	0	5	0	3	0
5.	Books/reports	6	9	5	8	8
6.	Reviews/popular articles	13	32	22	21	24

*Figures in parenthesis indicates numbers in International journals"; ** Figures in parenthesis indicates number in journals with NAAS rating >6.

(vi) Structure and Organization

The present organizational set up of the Institute, which comprises of Divisions, Sections and Coordinating Units of AICRPs, is given below.



The Institute is presently having Director and 47 scientists (4 Principal Scientist as HOD's, 6 Principal Scientists, 12 Sr. Scientists and 25 scientists). Out of Scientists, 2 Sr. Scientists and 1 Scientist have been placed in AICRP units. One Sr. Scientist is additionally looking after the duties AINP on SBB. Four AICRP Coordinators are also in position and provide help to the Institute in its various research programmes. Out of the 57 sanctioned posts, 9 positions in scientific cadre are still vacant.

Institute has 19 sanctioned positions in technical cadre and 53 positions in administrative cadre. Of these, 2 and 14 positions are lying vacant in technical and administrative cadre, respectively.

(vii) Management Practices

The Director is the overall in charge of the Institute. PCs of AICRPs, Heads of Divisions, Principal Scientists, Senior Scientists and Scientists assist the Director in technical matters. The four All India Coordinating Research Projects (AICRPs) on soil and nutrient management aspects are functioning with coordinating units at the Institute. The units provide the required linkage with the SAUs and other institutes for effective research collaboration. The Institute, in its research activities, is guided by high-powered Research Advisory Committee (RAC) and Institute Research Council (IRC). Management of the Institute is guided by the Institute Management Committee (IMC). The administrative structure of the institute is decentralized with activity based approach. The Administrative Officer and the Assistant Finance & Accounts Officer assist the Director in administrative and financial matters.

The organizational practices and procedures adopted by IISS for its internal governance and academic administration focus on four critical functions: (a) Research management, (b) Staff involvement in administration (c) Budget finance, and (d) Infrastructure support.

Research Management

The Institute's research activities are broadly grouped into four theme areas, namely, (a) Soil Health and Input Use Efficiency (b) Conservation Agriculture and Carbon Sequestration vis-à-vis Climate Change (c) Microbial Diversity and Genomics(d) Soil Pollution, Remediation and Environmental Security. Leadership role for each theme area has been assigned to the respective Head of the Divisions of Soil Chemistry & Fertility, Divisions of Soil Physics, Division of Soil Biology and Division of Environmental Soil Science. Generally, scientists in a division concentrate on researches related to the theme area led by the concerned HOD. In few cases however, scientists had taken up projects in other theme areas as well.

Research projects are primarily taken up based on the priorities as reflected in the perspective plan document of the Institute. A few projects are also taken up in response to the demand from different stakeholders. New research proposals are discussed in the Institute Research Council (IRC) meeting before approval and implementation. No new study is authorized unless its synopsis (RPP-I) as per format of Project Based Budgeting is presented by the investigator and approved by the Institute Research Council. Progress of research projects is discussed in subsequent IRC meetings.

The Research Advisory Committee (RAC) meeting is held once a year. In the meeting the works accomplished and proposed by the institute are presented by the programme leader and the RAC gives the comments and suggestions on the overall research programme. Research output from ongoing and completed research projects is published in Annual Report of the Institute and also in the form of research papers in journals for wider dissemination.

The Institute took positive steps to encourage and institutionalize inter- and intra-disciplinary collaboration to address various issues. For generating better understanding of the issues concerning soil science research amongst the scientists with diverse specialization, for creating awareness on latest researchesdifferent fields of soil science and also for developing better interdisciplinary understanding, Institute should organize lecture series regularly (may be fortnightly).

The Institute's laboratories have alsocollaborated with each other in systematic examination of the physical, chemical and biological properties of soils. As per RAC recommendations, the flow of samples from the on-going experiments at the co-operating centers of the AICRP's have not been properly institutionalized and streamlined for conducting basic and strategic research at the Institute, but some initiation has been made.

Almost every scientific staff is provided with computing facilities in the division. All Principal Investigators (PIs) of externally funded projects are delegated with powers as per the provisions made by the funding agency. Project Coordinators are empowered to carry out expenditure as per council's guidelines. Financial powers to sanction expenditure upto Rs.2000have also been given to HODs for the purchase of small items or contractual labour urgently needed for the research work. However, the recruitment of Research Associates/ Research Fellows is carried out by the Institute Administration.

Since the technical support staff available in the Institute is limited and is also deployed for laboratory maintenance, library management, general maintenance and computer services,the staff available for technical support needed for research work is limited. To tide over the situation, the technical support emanating from the temporary staff recruited under externally funded projects is also being utilized.As Institute have intensified interactions with farmers' through MGMG program and is also providing analytical services to farmers' and outside agencies, QRT recommends for one Young Professional for each of the Divisions.

Staff Involvement in Administration

The institute administration is decentralized to a large extent. Most of the functions are assigned to, and undertaken by various committees. These committees cover important functions like budget, publications, official language promotion, library, maintenance, stores, seminars, vehicles and transport, farm, land development, building construction, and purchase.Each committee comprises of a few scientific/administrative staff as its members. Individual members of the staff manage some functions. The chairpersons and members of all committees are appointed by the Director. During vacancy of the position of regular Administrative Officer due to some or other reasons, scientists were assigned additional duty of the said officer. Also during leave period of officers in administration section, scientists were assigned the additional duty of managing the Administrative unit.

Staff meetings are held at regular intervals. Divisional meetings and Senior Officers' meetings have been encouraged in which all scientists, administrative, technical, supporting, and project staff participate. Management and administrative issues are discussed and implementation of earlier decisions isreviewed.

Institute Grievance Cell

The Grievance Cell was duly constituted by the Management Committee in the Institute to address the grievances and suggest appropriate follow-up action. The members included are one Principal Scientist as Chairman, and Administrative Officer, Asstt. Finance and Accounts Officer and four members elected from different categories of Scientific, Technical, Administrative and supporting staff as members. Action to constitute a new grievance cell has also been initiated. The Institute also has a 'Women's cell' and a 'Committee for Prevention of Sexual Harassment of Women Employees' constituted as per rule to address women grievance and safety related issues expeditiously.

Institute Joint Staff Council (IJSC)

The Institute Joint Staff Council (IJSC) has been constituted with Director as Chairman and one Scientist, Administrative Officer, Assistant Finance and Accounts Officer, and three members elected from amongst the staff as members. Members and office bearers are elected to represent various categories of the staff. The Council is a link between the Institute management and staff and considers the welfare matters of the staff members. Members of staff are invited to attend IJSC meetings to expose them to the work culture promoted by the ICAR. Important circulars and information received from the Council by the Secretary, IJSC are briefly presented in the staff meetings to promote awareness about the rights and responsibilities of every member of staff.

(viii) Collaboration with SAU's and Other Research Institutions

The Indian Institute of Soil Science has established research linkages and collaborations with other ICAR institutes and State Agriculture Universities (SAUs) through its network of National Agricultural Innovative (NAIP) projects, Consortia Research Platform on Conservation Agriculture (CRP-CA), AICRPs and their cooperating centers. AICRPs on LTFE, STCR, MSNPE and one AINP on Soil Biodiversity &Biofertilizers located at IISS, Bhopal have 82 co-operating centers spread over most of the SAUs spread across 39 locations of the country. NAIP projects have also been carried out and coordinated from IISS, Bhopal with 3-8 cooperating centers under each project located either at SAUs or ICAR Institutes. Linkages have been strengthened by organizing workshops/ meeting of AICRP projects in which scientists of co-operating centers have participated. Efforts have also been made to strengthen research collaborative activities with SAUs through guiding PG/ Ph.D. students by the institute scientists. The IISS has also encouraged interactions by exchanging its Annual Reports with about 194 ICAR Institutes/SAUs). The Annual Reports of other Institutions are also received in the library for reference and exploration of further collaboration in research projects.

Recently Institute has been recognized as a partner in India-UK collaboration (Indo-UK nitrogen fixation centre), wherein IISS, Bhopal is one of the Virtual Joint Centre of collaborative project on Agricultural Nitrogen.

Inter –Institutional linkages were in place with different institutes such as PDCSR, Modipuram (U.P.) in the form of co-operating centre for network project on organic farming;

CIAE, Bhopal on aspects of conservation agriculture, green house gas emission, carbon sequestration, composting; NBAIM, Mau (U.P.) for research on microbial diversity; Govt. of Nagaland on INM for rice; CRRI, Cuttack for NAIP project on climate change; and CAZRI, Jodhpur for NAIP project on Nanotechnology.

In addition to above linkages were also developed with non-government organizations such as M/s Sandvik Asia Pvt. Ltd., Pune for evaluation of urea pestle; M/s Coca Cola India Pvt. Ltd, Gurgaon for assessing utilization potential of sludge in agriculture; M/s Nagarjuna Fertilizers and Chemicals Pvt. Ltd. Hyderabad for evaluation of plant nutrition product (NP-1) and for developing Rapid Soil Test Kit; BASF Pvt. Ltd. (Mumbai) for evaluation of urease inhibitor product (Limus); NUALGI Biotech, Bangalore for evaluation of nano-nutrients product (NUALGI) for improving nutrient use efficiency; PRII, Gurgaon for evaluation of new slow release 14-7-14 NPK fertilizer and polysulphate for its use efficiency; Zuari Agro Chemicals Ltd for evaluation of S and Zn containing complex fertilizers; Indofil Industries Ltd. for evaluation of Zn- and B-metalosate as foliar supplement;Aquasorb Pvt. Ltd, Vishakhapatanam for evaluating 'Aquasorb' for increasing water and nutrient use efficiency; and Hindustan Copper Ltd., Malanjkhand for rehabilitation of mining related degraded site.

(ix) Human Resource Development

Scientists of the institute participated in different human resource development activities like attending conferences/symposia/seminars, various meetings, workshops, undertaking trainings, participating panel discussions, farmers fairs, delivering scientific lectures etc. Following are the summarized activities related to HRD.

Number of HRD events and number of participation by Institute scientists (in parenthesis)

Activities	2012-13	2013-14	2014-15	2015-16	2016-17
Conferences/ symposia/seminars	26 (97)	25 (100)	32 (101)	23 (37)	34 (115)
Workshops	21 (39)	17 (68)	15 (67)	14 (18)	20 (152)
Meetings	37 (138)	30 (79)	29 (43)	26 (34)	32 (93)
Trainings undertaken	1 (45)	2 (2)	4 (7)	9 (11)	10 (16)
Others	1 (1)	3 (8)	-	13 (19)	9 (14)

Under skill development programme, scientists, administrative staff, technical staff and skilled supporting staff of the institute have undertaken training at different ICAR institutes and other organizations.

Institute organized 42 training programmes during 2012-17 for researchers, teachers, KVK officials and officials of soil testing laboratories under different Model Training Course, Short Course, Training programmes etc., wherein advanced knowledge and skills were imparted on various subjects related to soil.

(x) Linkage with Clients/end Users

The institute has developed good linkages with the farmers in the adjoining districts for direct dissemination of the technologies. As per the Govt. of India instruction, Institute has adopted 55 villages under*Mera Gaon Mera Gaurav* (MGMG) programme, wherein scientists have frequent interactions with the farmers either one-to-one basis or through organizing *Kishan Sangosthi*and try to address farming related issues as well as disseminate the available technologies to improve production. Field trials on INM & balanced fertilization technologies are also being disseminated through 'Farmers' First' programme being operated at different villages. The Institute also organized several farmers' day and training programmes for the farmers' of M.P. and other states. In addition, the scientists had demonstrated several field demonstrations of technologies developed by IISS. Extension personnel of the Department of Agriculture as well as from fertilizer companies also participated in the farmers' day organized by the institute. In addition, different groups of the farmers' from different state of the country visited the institute during this period. In addition, farmers were made aware of different soil, fertilizer and water related technologies through celebration of World Soil Day, Agricultural Education Day etc.Under prestigious 'Soil health card mission' of Govt. of India, Institute prepared and distributed large number of soil health cards to farmers.

(xi) Human, Physical and Financial Resources

Human Resources

The Institute has 47 scientists, 18 technical and 45 administrative & supporting staff. There are four Heads of Departments andfour AICRP Co-coordinators. The cadre strength of IISS is given below.

While fixing the cadre strength of scientists at the institute by ICAR, the strength of laboratory and field technicians, supporting and administrative staff was not indicated. At present 47 scientists are working at the institute against the sanctioned strength of 56. There are 4 divisions, 1 Referral Laboratory, 1 Central Laboratory, Library, Technical Cell, ARIS Cell, Farm Section and 4 AICRPs and several NAIP and ad hoc research projects are being managed with the existing staff with great difficulties. The institute is having acute shortage of manpower in technical, supporting and administrative cadre. Decades back, the ratio fixed by the ICAR for one scientist to administrative staff was 1:0.5, technical-1:1.5 and supporting staff is 1:2. Accordingly the, institute should have been provided with 28 administrative posts, 84 technical posts and 112 supporting posts. However, presently these ratios are highly deviated due non-recruitment of administrative, technical and supporting staff.

Category	Sanctioned	In-position	Vacant
Scientific			
Pr. Scientist	13	11	2
Sr. Scientist	16	12	4
Scientist	28	24	4
Total	*57*	*47*	*10*
Technical	*19*	*17*	*2*
Administrative & Supporting	*53*	*39*	*14*
Total	129	103	26

Physical Resources

The Main Institute Building of the Indian Institute of Soil Science at present consists of six laboratories, one each in four divisions, one central laboratory, one soil biodiversity laboratory and one referral laboratory, sitting space for scientists, Director's office, technical cell, ARIS cell, museum, administration, library, committee room, conference hall, etc. The original plan prepared and vetted by Director (Works) ICAR for the IISS Main Building is of 7472 sq. meters but by the end of IXth Five Year Plan only 3472 sq. meters of built-up area has been covered. In the XII plan, construction of an additional laboratory block has been completed and construction of two additional laboratories is under progress. One more laboratory remains to be constructed as per the original plan of Main Institute Building.

The Institute has four divisions viz., Soil Physics, Soil Chemistry and Fertility, Soil Biology and Environmental Soil Science and one section i.e. Remote Sensing & GIS catering to different research activities.

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

The Soil Chemistry and Fertility division has the responsibility to conduct basic and strategic research related to nutrient management and fertility improvement of soils of India, 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.

The Soil Biologydivision has the responsibility to undertake research on management of soil biota, biofertilizers, 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.

The Environmental Soil Sciencedivision has 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 All India Network Project on Soil Biodiversity-Biofertilizers are functioning at the Institute.

Instrumental facilities: The Institute has advanced analytical instruments such as Inductively Coupled Plasma- Optical Emission Spectrometer, Total organic carbon analyzer, Spectro-radiometer, Fourier Transform mid-infrared (FT-MIR) spectroscope, portable X-ray fluorescence (pXRF) spectroscope and Greenhouse gas (GHG) analyzer, Pressure plate apparatus, Guelph permeameter, digital cone penetrometer, image analysis system for leaf and root, Ksat-permeameter, rainfall simulator, Yoder's Apparatus, IR-thermometer, Flame photometer, UV-Visible Spectrophotometer; Flow Injection Analyzer, HPLC, GC, NIR-spectrophotometer, Gel doc, RT-PCR, PCR, Nano drop Spectro photometer, Gel Electrophoresis, Anodic stripping voltametry, CN analyzer, Leaf area meter, lyophilizer, BOD and COD analyzer, BET surface area analyzer. The 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.

During the period under review, Institute procured major following instruments:

During 2012-13: Nano Particle Size Analyser (Horiba Dynamic Laser Scattering Particle Analyser, Gel Doc, Computers, Laptop, Mini Bead Beater, Freeze Dryer, PCN Assembly for Under ground irragation system, Tension Infiltrometer, High Speed Micro Centrifuge, Nanodrop Spectrophotometer, Gas Chromatography (GC), Real time PCR System, CCTV Camera.

During 2013-14: Protein analyzer, image analyzer, digital research microscope, refrigerated centrifuge, surface area and porosity analyzer, BET instrument, digital soil penetrometer with data logger, soil moisture meter (TDR), multimedia projector, 5 KVA UPS, printers, desktop computers, server, laptops, printers & HDDs, fire extinguisher, flame photometer, Quartz double distillation unit, and stainless steel fabricated filters.

During 2014-15: Broad Bed Furrow (BBF) Machine, BOD Incubator.

During 2015-16: Digital multifunctional Copier Machine, Biometric Attendance Device, Autoclave Vertical, Desktop Computer, Angel Rotor for High Speed Centrifuge, Flame photometer, pH-EC Meter, Water purification system.

During 2016-17: Open top chambers (OTCs), Photosynthesis Analysis System, Digital Cone Penetrometer, Microplate Reader, Turbo Happy Seeder, Microwave Oven, Hot Air Oven, CCTV Camera, GPS, pH-Meter, Pocket Penetrometer, Flame Photometer, Bottle Top Acid Dispenser.

Almost 69% of the Equipments approved under EFC document of XII plan could not be purchased.

Library: The institute Library has collection of core books and journals mainly in the field of soil science, and the collection contains 2591 books, 2555 bound journals and 2364 Annual Reports. Procurement of journals (hard copy) has been discontinued since 2007. Scientists and other researchers of the Institute have been provided online accessibility of scientific journal articles through Consortium for e-Resources in Agriculture (CeRA) (www.cera.jccc.in). 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 worldwide with two major databases, i.e., SOIL-CD and AGRIS-CD.

Conference & committee room: TheInstitute 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. 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

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 Vindhya plateau of western Madhya Pradesh. The institute developed four run off water collection ponds for water harvesting and its efficient use on the farm.

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.

Financial Resources

The Institute started with an annual budget of Rs.98 to 130 lakhs during the initial years. The non-plan budgetary provisions were only 10-20 percent of the total budget upto 1996-97. It is only after 1996-97 the share has increased gradually. It surpassed the plan expenditure in 2000-2001. The information on budget (Rs. in lakhs) during XII plan (2012-17) is presented in tables given below:

TABLE: 13. 3. Expenditure Components, 2012-2017 for IISS, Bhopal and AICRPs and AINP (Rs. In lakhs)

Sl. No.	Name of Scheme	EFC Allocation			Total EFC Allocation	Expenditure					Total Expenditure
		GIA Capital	GIA-Salary	GIA-general		2012-13	2013-14	2014-15	2105-16	2016-17	
1	ICAR-IISS, Bhopal	1110	0	986	2096	249.9	159.5	155.8	275.4	264.6	1105.2
2	AICRP on MSN	615	2662.9	1550	4827.9	734.2	654.7	675.0	720.0	554.4	3338.3
3	AICRP on STCR	53.7	2958.5	747.8	3760.0	672.8	719.9	680.0	655.0	511.5	3239.2
4	AICRP on LTFE	90.7	1800	811.1	2701.9	379.9	393.8	344.0	560.0	361	2038.6
5	AINP ON BNF	206.5	962.2	594.9	1763.6	230.0	190.0	185	309.6	228.3	1142.9
6	CRP on CA	2800	0	3500	6300	0	0	4.99	311.6	230	546.6
	TOTAL	4875.9	8383.6	8189.8	21449.4	2266.8	2117.9	2044.8	2831.6	2149.8	11410.9

Resource generation: Though resource generation was not high at IISS during initial years, it increased substantially during later years. The resource generation from different heads at IISS was as follows:

Year	Rupees in lakhs
2012-13	63.27183
2013-14	51.85206
2014-15	108.23322
2015-16	127.89361
2016-17	452.09489

(xii) Planning for the Future

The Indian Institute of Soil Science is mandated to enrich and harness the knowledge of soil science and other related disciplines to enhance agroecosystem productivity, nutrient and water use efficiency, minimize soil and environmental pollution, improve soil and produce quality, recycle organic and other wastes, sustain biodiversity etc. through developing technologies and intervening management systems.

In the consequent of ever increasing population, soil scientists are facing constant challenges of aggrading/sustaining soil productivity; appropriate management of soil related continuously dwindling agricultural inputs and protection of this finite non-renewable soil resource from non-agricultural human activities. In this background, innovations in management and technological solutions are being demanded from soil and plant scientists so that country can continue to fulfill the societal requirement and harmony between food production system and other economic activities becomes sustainable. Major soil and plant nutrient supply related constraints being perceived nowadays are: deteriorating soil physical and chemical properties affecting rhizospheric environment, increasing plant nutrient supply cost due to low nutrient use efficiency and rising cost of fertilizer, deteriorating soil microbial and faunal diversity particularly species related to nutrient cycling, deteriorating quality of irrigation water and other agricultural inputs and entry of toxic pollutants affecting soil organisms, plant growth and food quality etc. 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. In spite of identification of agroecosystem specific major soil related constraints, country is still awaiting to overcome the obstacles of enhancing the crop productivity and profitability in the farming sector at desired level. Worsening the situation, pressure of developmental activities like urbanization and industrialization are putting accelerated pressure on the already dwindling soil quality. Fortunately, rapid scientific advancements and availability of new tools, techniques, and approaches promise technological breakthroughs to accomplish these difficult missions. A major research effort is required to develop improved strategies for halting and reversing soil degradation if long-term productivity is to be secured. Enhancing food production and use efficiency of applied nutrient through improved soil health require integrated strategies through rational utilization of both land and water resources and addressing crucial management issues with more attention to basic and strategic issues..

Enhancing Nutrient and Water Use Efficiency

In order to attain the target of doubling income of farmers' by 2022, need of the hour is to increase the use efficiency of costly fertilizer nutrients and irrigation water so as to cut down cost of food production. Since inception, institute is making multi-directional efforts in this direction: improvement in methods of application, reducing solubilization rate, nano-sized indigenous minerals for increased solubilization etc. Institute should conduct extensive study to assess effectiveness of these technologies under different crop production systems. Due to low efficiency fertilizer nutrients, build-up of plant nutrients like P, Zn etc. have been observed in several regions due to their continuous application. Several plant nutrients like N, K, S are subjected to loss from rhizosphere through solute flow to water bodies deteriorating their aquatic environmental quality. IISS should concentrate its research to tap the immobilized nutrients and to trap the mobilized nutrients left out of the agroecosystem. Soil water plays an important role in transport of plant nutrients through xylem and therefore, in determining their use efficiency. As water is predicted to become increasingly less available for agriculture in the coming years, IISS should undertake comprehensive research to understand the interaction between water and fertilizer nutrients under different agriculture systems like intensively tilled agriculture, conservation agriculture, organic farming, dryland agriculture; which can help in generating integrated nutrient and water management technologies formaximizing the use efficiency of both the costly resources.

Sustaining Better Soil Health

Declining soil health is one of the major reasons responsible for reduced response of crops to applied nutrients and lower profits to farmers. Database generation for key indicators of soil quality, are therefore, essentially required for different soil types, cropping systems and management practices under various agro-ecoregions of the country for quick assessment of soil health with a view to identify aggrading/degrading production systems. The IISS alongwith different centres of AICRPs coordinated from the institute have attempted to find out key indicators for soil quality assessment for different agroecological regions. However, many a times the reported results do not seem to be cheap (for assessment), robust and implementable by the end users. There fore, there is a need to critically analyze the objectives, methodology and area of application for such study. Future research should also focus on developing a workable index for resilience of natural and anthropogenically degraded soils so that preventive/reclamation strategies can be developed.

Soil Organic Carbon (SOC) Management in Different Agro-Eco Regions

Soil organic C (SOC) is a panacea for maintenance of soil health and role of SOC on soil health and nutrient supplying capacity has been estabilished through extensive researches in the country and abroad. However, the country is bestowed with wide range of soil types and climatic conditions, where soil related constraints in crop production also vary tremendously. Such soil related constraints surfaces as poor soil physical conditions, adverse chemical environment, low nutrient supplying capacity, build-up of pollutants affecting soil biodiversity and crop productivity potential. Decomposability of SOCinfluences C sequestration and nutrient supplying capacity in contradictory manner, both of which however have positive influence on crop growth. Hence inter-relationship between soil and organic matter should be studied systematically in depth to arrive at critical SOC level in different agroecological zones required for sustainable crop production along with appropriate strategy to maintain this.Because of its obvious importance for maintaining of soil health of the country, IISS is engaged heavily in research on SOC; however, the efforts under various programmes are disjointed and inadequately structured for meeting national needs.

Safe Recycling of Organic Wastes in Agriculture

Huge quantity of organic residues and wastes are being generated in the country through agricultural, agroindustrial and urban activities. These organic materials are valuable resource for improving health and fertility of soils of the country which are already deficient in SOC. While crop residue burning in agricultural land after crops like rice, wheat, sugarcane etc is immensely causing air pollution, continuously accumulating urban wastes are causing GHG emissions, deteriorating water quality and affecting human healths nearby cities. There is an urgent requirement of managing these wastes through appropriate recycling at the source of generation (i.e. agricultural land). Major researchable issues in this area are developing in-situ rapid decomposition of crop residues, and rapid composting methods for urban wastes through appropriate microbial techniques and composting system management.

Maintaining Soil Biodiversity

Microbial community plays a critical role in organic recycling, nutrient mobilization, removal of environmental contaminants, reclamation of degraded soils, and improvement of soil physical conditions by enhancing aggregation and C sequestration.Each of the functionalities of the soil microbes has to be exploited 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. Genomic tools for quantitative assessment of soil health are already available and need to be measured in various soil types and management systems.

Conservation Agriculture

Efforts to develop refine and disseminate conservation agriculture technologies have been underway for nearly two decade due to several benefits related to cost of production and environment. Although significant progress has been made since then, there are several constraints that affect adoption of CA. There is a need to develop nutrient management technology under various irrigation water availability scenarios, particularly in respect of implements for placement of fertilizers at required quantity based on soil test.

Climate Change and Its Impact on Soil Processes

Carbon dioxide (CO_2) concentration in atmosphere continues to rise at approximately 1.8 ppm per year and might reach a concentration of 600–1000 ppm by the end of this century. Greenhouse gases from human activities are the dominant drivers of these global climactic changes. Increasing CO_2 levels impact agriculture, affecting both growth and development of crops and ultimately impacting yield and food production. Changing climate may influence vegetation and cropping patterns, and consequently nature of rhizospheric biochemical environment. Increased CO_2 concentration, temperature and changing rainfall pattern are bound to affect chemical and biochemical reactions kinetics affecting soil nutrient cycling processes.Some area may face increased salinization, while other area may experience increased processeses of laterization or podzolization. Future research focus in this area should be to understand interactive effects of future climatic parameters (as predicted by appropriate models) on SOC and nutrient availability dynamics as well as to devise strategies to combat the adverse effects of climate change.

Rapid Testing of Soil Properties

Soil testing is important tool towards prescribing right quantity of nutrients applications, procting land from degradation and minimizing cost of production. However, vast requirements for soil testing in country in conjunction with prescribing the right quantity of fertilizers before sowing demands rapid testing of soil samples. Present conventional soil testing methods, though well validatedand accurate, are time consuming. Hence there is a need for fast and accurate soil testing methods through multipronged researches like multinutrient extractants, use of modern non-destructive tools like MIR-spectroscopy etc.A cheap and reliable soil test kit for use by farmers is also required for decision making on fertilizer use at the farm level.

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. Due to increasing threats from different anthropogenic activities like mining, industries, urban expansion, use of toxic & contaminated agricultural inputs etc., protection and reclamation of agricultultural land is emerging as important issues to be addressed. Therefore, the environmental 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.

Taking preventive measures against pollution is critical because cleaning contaminated soils is extremely expensive and difficult. For this accurate diagnosis of contaminated soils and potentially threatening soils are very important. Although Government has formulated adequate quality control standards in respect of air and water, such standards are lacking in case of soil protection. In this direction, there is an urgent need to determine different parameters and formulate various standards with respect to baseline concentration levels of pollutants, maximum allowable level and intervention level to support the decisions in assessing soil quality and to develop guidelines for heavy metal loading limits in soils through the application of different solid and liquid wastes. Although Environmental Impact Assessment is routinely carried out by Govt. agencies for decision making on establishment of industrial areas, there is no definite protocol available on impact assessment of agroecosystems under threat prone areas. Institute should make an attempt to develop such protocol. There is an urgent need for developing soil protection policy for the country, for which IISS may take the lead to organize consultation meetings with various related organizations.

Persistent Organic Pollutants: Newer Challenge to Agroecosystems

Several persistent organic pollutants (POPs) like PCBs, DDT, BTEX, PCDDs/DFs are entering the agricultural land through wastewater irrigation and use of contaminated manures.

Most of these are toxic/carcinogenic to human and animals, highly resistant to microbial degradation and have potential affect soil biodiversity and contaminate plant parts. However, impact of these pollutants has not been investigated under tropical and sub-tropical countries in India. Hence, the institute should take initiative on conducting research on this aspect.

Safe Utilization of Industrial and City Wastes for Enhancing Soil Productivity

Industriesand urban centers are generating considerable wastes in the country and their environmental friendly disposal is a tremendous challenge. Several of these wastes are being used by farmers in agricultural land due having some beneficial component. Some of these wastes also have potential for agrading productivity of degraded land. However, most of these wastes may also contain harmful contaminants and have potential to contaminate soil resource and food chain. Hence, appropriate technological solutions are urgently required for their beneficial but safe utilization in the agricultural land. Intensive study is required for determining sink capacity of various soils for the toxic heavy metals and also for determining loading limits of various industrial and city wastes.

Reclamation of Polluted Agricultural Land

Instances of soil pollution are being reported from several parts of the country particularly nearby industrial and urban areas posing threat to organisms including human beings. Geogenic pollution like arsenic contamination in food crops particularly in eastern region of indo-gangetic plain is posing severe threat to human health. There is a need for developing reclamation technologies for growing safer food and fodder crops, which are adoptable by farmers', economically viable and effective for longer duration. Involvement of stakeholder in the technology development processes through on-site experiments will be more effective in their successful dissemination.

Exploiting 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. In the field of soil and water management, nanoparticles of several minerals / compounds have shown potential to enhance nutrient use efficiency through nanoformulations and removal of contaminants from soil and water.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 nano-particles requires special safety precautions because of health hazards and risks to the environment.

If IISS is to continue to play the role as a leader in soil science, complete modern research facilities for studying soil environmental processes should be developed. Facilities for clay mineralogy, radiotracer, metal speciation, trace organics, organic pollutant study need to be created under different programmes. Creation of specialized laboratories as per international norms is required for fundamental research as per the vision of the institute, and their maintenance requires special attention to enable the institute in enriching the knowledge pool that can be valuable resources for sustainable crop production and environmental protection. Such laboratories can also help in developing international linkages, serve other governmental organizations in the country and generate resources for the institute.

Impact Assessment of Soil Management Technologies

Agricultural research is a public-funded activity. Therefore, it is imperative to undertake impact assessment of agricultural research so as to ensure accountability in the use of the public resources and maintain credibility of the research system. Impact assessment also aids in improving the decision-making processes through past experiences and learnings in prioritizing the research agenda in concordance with the emerging societal needs so as to improve the efficiency, equity and sustainability of the research. Impact assessment is also an important tool for the technology and service delivery systems to better understand the processes of technology dissemination and its pre-conditions, which differ considerably across socio-cultural environments, to make technologies work for the benefit of the farming communities and to demonstrate the benefits of the technologies to other stakeholders including agro-based industries and policy makers.

Pay-offs from investment on research on natural resource management, that is soil, water and biodiversity are as attractive as those from the crop breeding research. Unfortunately, very little attention has been paid towards assessing the social, economic and environmental impacts of the natural resource management research in India despite the fact that the agricultural research system has generated a huge amount research output on various aspects of natural resource management, such as soil fertility enhancement through nutrient balancing, micronutrient supplementation, bio-fertilizers, green manuring, etc.; and resource and environment conservation technologies, like zero tillage, laser leveling, micro-irrigation, carbon sequestration, water quality and waste water use, etc. Research on the soil and water complements the crop breeding research. However, because of the limited evidence on its economic and environmental impacts, the natural resource management research suffers from lack of attribution. Impact assessment of the natural resource management research has become more important now than ever before because of qualitative deterioration of the land and water resources, and dwindling funds allocated for research on this area.

Impact assessment is a dynamic process and has evolved over time in response to the changing paradigms of agricultural research, socio-economic conditions and clientele preferences for technology traits. Accordingly, the canvass of impact assessment has also broadened from simple comparison of yields and returns to encompass a wide range of impacts including social, economic and environmental costs and benefits and their distribution among various stakeholders that is producers, consumers and innovators. There is an increasing demand to target research to maximize its impact on the food and nutrition security, food quality, poverty and environment protection.

In context of the above, Quinquennial Review Team has observed that only a little work has been done to assess the impact of soil and water management research generated at the Indian Institute of Soil Science and impact assessment has not moved beyond yield comparisons under different technological scenarios; and to some extent their benefit-cost analysis lacks rigour due to lack of qualified and trained manpower. Many of the research outcomes have been claimed by the institute as technologies without validation and dissemination to the end users. QRT suggests that potential techniques claimed by the scientists should be termed as technology only after its evaluation and dissemination.

(xiii) Overall Assessment of IISS

Indian Institute of Soil Science has made sincere efforts through several institutional and multi-institutional research projects to achieve the objective of carrying out basic and strategic research on soils especially physical, chemical and biological processes related to management of nutrients, water and energy; and of developing technology for sustainable systems of input management that is most efficient and least environment polluting. In this direction, the Institute has made very good contribution both in terms of basic understanding of various soil processes and developing technologies for efficient and safe crop production. With ever increasing demands and challenges, the IISS has to go on expanding the horizons of activity to suit the changing scenario, and also go on raising the bar to keep in tune with the global competition by fine tuning of objectives.

(xiv) Recommendations

Research

a. Database on soil and its utilization

All georeference databases on soil fertility and soil quality may be placed in IISS database portal for use by all stakeholders. Necessary linkage may be established with other national institutes such as NBSS&LUP, NRSA, CSSRI etc for this purpose.

b. Improving fertilizer use efficiency

Attempts may be made to develop new fertilizer formulations or modified products for enhancing use efficiency of plant nutrients through public-private partnership mode. Based on the findings of AICRP-LTFE and AICRP-MSNPE efforts may be made to mobilize soil-fixed plant nutrients like P and Zn.

c. Climate change and soil processes

Although IISS has addressed the issue of climate change impact on agriculture during past several years, focus was mainly on estimation of potential yields of crops or crop cultivars for a given level of input with varying weather conditions; yield gap and sustainability analysis; and assessment of the impact of climate change on productivity of different crops and cropping systems. The institute should undertake basic research on impact of climate change (as predicted through different models) on various chemical and biological processes (including C sequestration) operating in soil.

d. Carbonsequestration in soil

A road map for C-sequestration in terrestrial ecosystem with special focus on agroecosystem needs to be developed particularly in determining critical C inputs for a zero change in soil organic C, its increased stabilization in soils and also finding out crops and cropping systems that contribute sufficient amount of C inputs for a net aggadation of soil organic C.

e. Nanotechnology

Nanotechnological tools have potential to enhance nutrient use efficiency. Research in this area in IISS is quite meagermainly due to lack of appropriate instrumental facilities. Institute may undertake collaborative research with expert organizations/institutions and/or with industries under PPP mode to improve use efficiency of plant nutrients and to utilize indigenous minerals (rock phosphate, gluconite/waste mica, pyrite, calcite / dolomite and sphalerite / smithsonite) effectively as source of plant nutrients.

f. Accelerated decomposition of agricultural and urban wastes

IISS should develop and demonstrate accelerated decomposition technology for urban wastes in view of scarcity of land for waste-dumping.The research must be carried out with the involvement of expert private organizations associated with MSW handling & processing for effective dissemination of the technology.

In situ, fast decomposition of crop residues (rice, wheat, sugarcane etc.) will avoid burning as it leads to air pollution and C loss from agroecosystem. IISS should take up comprehensive studies following standard scientific protocols on developing appropriate technology for *in-situ* decomposition of ligno-cellulolytic residues of rice, wheat and sugarcane keeping in view of availability of time for decomposition between crops.

g. Safe utilization of contaminated wastes in agriculture

Recognizing the importance of 'Swachh Bharat Mission', the QRT feels strongly that IISS should initiate research for safe use of sewage sludge, and city/industrial wastes after critical analysis of heavy metals flow in Soil-Plant-Animal-Human pathway in urban/industrial areas.The safe concentration limits of heavy metals for soils in different agro ecological regions of the country should be established**.**

h. Phytoremediation/bioremediation of heavy metal contaminated soils

Heavy metal contamination in soils is coming up as a bigger environmental issue with increased urban and industrial activities. IISS should develop phytoremediation / bioremediation technology for land degraded due to mining/industrial/urban activities after studying root morphology, nutrient and heavy metals uptake through on-site experiments.

i. Complementarities in research

The QRT observed lack of complementarities/integration in research programmes among the divisions of the institute as well as between the divisions and the AICRPs'. To reduce over-lapping and enhance synergistic output, it is imperative that there should be strong linkages amongst the units.

The country needs a centre of excellence for advanced research and training on "Soil pollution and remediation". IISS has the requisite expertise in various disciplines, and with the advanced laboratories this institute will be a suitable place for such centre of excellence

j. Creation of awareness to save soil

Soil resource of the country is degrading at a rapid rate. It is now estimated that about 81% of soil of the country is under one or other forms of degradation. Under the International decade of soils (2015-2024), the IISS should play a key role for creating awareness amongst different stakeholders of soils – its uses and abuses for human survival and welfare.

Economic Impact

To enhance visibility of the research work done at the Institute, QRT recommends that the IISS should identify the NRM technologies and practices generated by the scientists of the Institute that have potential to improve crop yields cost-effectively; and subject these to a rigorous analysis for their economic and environmental impacts, *ex ante* as well as *ex post* wherever applicable and prioritize these for their transfer to the farming communities and other stakeholders. Outcome may be clearly defined in all the programs.

Administrative and Personnel

a. In tune with the Govt. of India emphasis on skill development, IISS should also take initiatives in training youths in specialized areas having self-employment opportunities. Therefore, QRT recommends that Institute should initiate Certificate courses on Soil testing, Compost making and Biofertilizer preparation for the youths having appropriate level of education.

b. The cadre strength of the administration section is inadequate to deal with the work of the sanctioned scientific strength. So QRT recommends that long pending vacant positions may be filled up at the earliest.

c. Presently, all the divisions are having grossly inadequate technical staffin spite of increased quantum of research and extension related works. Therefore QRT recommends that all the divisions may be provided with additional technical staff and contractual manpower.

Laboratories and Equipment

a. Although the Institute building complex is nearing its completion with the creation of four advanced laboratories as per the architectural plan, major part of the building as well as the residential complex has become more than 22 years old. Moreover, the laboratories are mostly carrying out chemical analysis involving acids and other corrosive chemicals. As a result, laboratories and instrument rooms have become shabby and needs overhauling to make these as per international standards. Several major and minor instruments which have been purchased long back, have outlived or have become out-of-order and therefore need urgent replacement. Therefore, QRT recommends that IISS, Bhopal may be granted one time renewal grant of Rs. 25 crore for replacing old outlived and condemned instruments with new ones, and repairing/overhauling of residential and Institute buildings & laboratories.

b. The QRT also recommends purchase of new high end equipment facilities/equipment such as MIR Spectroscope, Thermal imaging camera, ICP-Mass spectrophotometer, AAS with graphite furnace/hydride generator, Microwave digestion, SEM with EDX attachment, High energy ball mill, X-ray diffractometer, mercury analyzer, HPLC, Ion-chromatograph to carry out advanced research.

Linkages and Collaborations

IISS has been working in close collaboration with other ICAR institutes. For effective dissemination of technologies, the institute should have effective linkages with state departments of agriculture,SAUs, KVKs and NGOs working at the grass-root level.

D. REVIEW REPORT OF AICRP ON LONG-TERM FERTILIZER EXPERIMENTS

(i) Brief History

To study the long-term effects of inorganic fertilizer on soil health, sustainability and soil environment, the ICAR initiated the All India Coordinated Research Project on Long-Term Fertilizer Experiments (LTFE) in September 1970 at 11 centers. The sites were identified in irrigated and intensively cropped areas representing different agro climatic regions. These experiments were established on Alfisols at Palampur (Himachal Pradesh), Ranchi (Jharkhand) Bhubaneswar (OUAT) and Bangalore (Karnataka), one on a Vertic Ustropept at Coimbatore (Tamil Nadu) and Mollisol at Pantnagar (Uttaranchal), two each in Vertisols at Jabalpur (Madhya Pradesh) and Hyderabad, three in Inceptisols at Ludhana (Punjab) and IARI (Delhi) and Barrackpore. Six more centres one each at Akola (Maharashtra), Junagadh (Gujarat), Parbhani (Maharashtra), Pattambi (Kerala), Raipur (Chhattisgarh) and Udaipur (Rajasthan) were included during 1995-96 to represent additional AEZs. Ten /Twelve treatments with some modifications as per regional requirements were implemented after taking exhaustive crops are in progress since 1996.

The QRT in 1997 recommended expansion of the project's mandate and the title was modified as "**AICRP on Long Term Fertilizer Experiments to study the soil quality, crop productivity and sustainability".** During next review by QRT (2002-2006) it was suggested that the project should also focus on physical and biological properties and also work to identify soil quality indicators for evaluating soil quality.

(ii) Mandate and Objectives

Mandate

- To conduct long-term fertilizer experiments in different soil types under diversified cropping systems
- To collate information on long-term soil fertility trials

Mission

Soil Fertility Management through Integrated Plant Nutrient Supply for Enhancing and Sustaining Crop Production and Maintaining Soil Quality

Objectives

- To study the effect of continuous application of plant nutrients, singly and in combination, in organic and inorganic forms including secondary and micronutrient elements (as per the need) on crop yield, nutrient composition and uptake in multiple cropping systems

- To work out the amount of nutrient removal by the crops/ cropping system.
- To monitor the changes in soil properties as a result of continuous manuring and cropping with respect to the physical, chemical and microbiological characteristics of the soil in relation to its productivity
- To investigate the effect of intensive use of biocidal chemicals (weedicides and pesticides) on the build up of residues and soil productivity
- To make an assessment of the incidence of soil borne diseases and changes in pests and pathogens under the proposed manuring and cropping programme

(iii) Priorities, Programmes and Projects

Priorities

The mandate and objectives of the AICRP on LTFE were initially to study the long-term effects of inorganic fertilizer alone and in combination with organic manure on yield, yield response and soil fertility, but later emphasized effects on soil quality and sustainability. There was substantial build up of P and Zn in alluvial soils of Ludhiana, Pantnagar, Bhubaneswar and therefore, superimposition of treatments was suggested. There is limited understanding on nutrient transformations and dynamics in different soils. So specific projects have been planned in collaboration with the centers to study the changes in organic and inorganic fractions specially nitrogen, phosphorus, potassium and sulphur in different soils at various locations. The results indicated that soils cannot retain carbon indefinitely even if a large amount of organic manure is dumped regularly. Each soil has got its carbon retaining capacity depending on soil texture, climate. So carbon budgeting in different soils under various cropping system is needed to find out the minimum amount carbon to be added annually to maintain stable SOC levels. Results indicated that at different location different soil properties are responsible for sustainability, so at each location soil parameters that are responsible for soil productivity should be identified.

Programmes

There are 10 treatments in each experiment. These are: $\mathbf{T_1}$-50% optimal NPK dose; $\mathbf{T_2}$-100% optimal NPK dose; $\mathbf{T_3}$-150% optimal NPK dose; $\mathbf{T_4}$-100% optimal NPK dose + hand weeding; $\mathbf{T_5}$-100% optimal NPK dose + zinc or lime; $\mathbf{T_6}$- 100% optimal NP; $\mathbf{T_7}$-100% optimal N; $\mathbf{T_8}$-100% optimal NPK + FYM; $\mathbf{T_9}$- 100% optimal NPK (Sulphur free/sulphur source); $\mathbf{T_{10}}$- Unmanured (Control). However, on the basis of results obtained in the past at several locations, treatment are sub-divided to study the impact of micro and secondary nutrients at Pantnagar, to reutilize P accumulated over the years, effect of lime in Alfisols, one treatment was converted into organic and FYM dose was reduced to 5 tons.

A provision for one or two additional treatments was kept that may be of local or regional interest. The treatments are replicated 4 times in a randomized block design. The plot size varied from 100 to 300 m^2 except at Palampur centre where it was only 15 m^2 because of non-availability of large- sized plots in the hilly areas. Six more centres one each at Akola, Junagadh, Parbhani, Pattambi, Raipur and Udaipur were initiated during 1995-96 to represent additional agro-climatic regions. The treatments at new centres are broad based to accommodate more nutrient management options and also have one treatment on exclusively organic treatment. The existing treatments were sub-divided into two to superimpose additional treatments at some of the LTFE centres namely Pantnagar, Ludhiana, Bangalore, Ranchi, New Delhi, and Jabalpur to study the build-up or deficiency of nutrients including treatments of local importance.

(iv) Structure and Organization

The project is under the Natural Resource Management Division of ICAR and has 15 centres in different SAUs plus 2 centres in ICAR Institutes with Coordinating cell at Indian Institute of Soil Science, Bhopal. The project has positions of one Project Coordinator, 17 Associate Professors/ Sr. Scientists, 18 Assistant Professors/ Scientists, 12 Technical, 3 Administrative and 18 supporting staff. The Project Coordinator plays a key role in planning, coordinating and monitoring the research programme of the centres and financial aspects. He also acts as liason between ICAR and SAUs.

(v) Management

The project is executed in collaboration with SAUs and ICAR institutes. At each location researchers are appointed for implementing the programme. Council bears the 75% cost of the programme and the remaining 25% is added by SAUs.Project Coordinator holds discussions with the scientists of the centre and other authorities of SAUs to facilitate the work of the centre. Project Coordinator is responsible for monitoring and implementation of the programme as per approved plan. The head quarter provides administrative and financial support from time to time.

(vi) Collaboration with SAUs and other research institutions

Details of centres AICRP on Long term Fertilizer Experiments

Sl. No.	Location	Year of start	Taxonomic Class	Cropping system	AE zone	Sub-zone
1.	Barrackpore (W.B.)	1971	Eutrochrept	Rice-wheat-jute fibre	15	15.1
2	Ludhiana (Punjab)	1971	Ustochrept	Maize-wheat-cowpea fodder	4	4.1
3	New Delhi	1971	Ustochrept	Pearlmillet-wheat-cowpea fodder (till(1981-82) Maize-wheat-cowpea fodder (since 1982-83)	4	4.1

4	Coimbatore (TN)	1971	Vertic Ustopept	Fingermillet-maize-cowpea fodder	8	8.1
5	Jabalpur (M.P.)	1972	Chromustert	Soybean-wheat-maize fodder	10	10.1
6	Bangalore (Karnataka)	1972	Kandiustalf	Fingermillet-maize-cowpea-fodder (Cowpea discontinued w.e.f 1994)	8	8.1
7	Hyderabad (A.P.)	1971	Tropaquept	Rice-rice	7	7.2
8	Ranchi (Jharkhand)	1972	Haplustalf	Soybean-potato-wheat (till 1984) Soybean-wheat (since 1985)	12	12.3
9	Bhubaneswar (Orissa)	1972	Aeric Haplaquept	Rice-rice	12	12.2
10	Palampur (H.P)	1972	Hapludalf	Maize-potato-wheat (till 1977-78) Maize-wheat (since1978-79)	14	14.3
11	Pantnagar (Uttaranchal)	1971	Hapludoll	Rice-wheat-cowpea fodder	14	14.1
12	Junagadh (Gujarat)	1996	Vertic Ustochrept	Groundnut-wheat	2	2.4
13	Akola (Maharashtra)	1996	Haplustert	Soybean-wheat	6	6.2
14	Pattambi (Kerala)	1996	Typic Haplustalf	Rice-rice	19	19.2
15	Raipur (M.P.)	1996	Haplustalf	Rice-wheat	11	11.0
16	Udaipur (Rajasthan)	1996	Ustochrept	Maize-wheat	4	4.2
17	Parbhani (Maharashtra)	1996	Chromustert	Sorghum-sunflower	6	6.2

(vii) Significant Achievements of AICRP on LTFE

(a) Technology generated

1. Saving phosphatic fertilizers

Continuous use of phosphoric fertilizer led to accumulation of P in soils particularly in alluvial, black cotton and acid soils. Hence to utilize the accumulated P, application of only half of the recommended dose of P to both finger millet and maize in red & lateritic acid soils, and in soybean – wheat in Vertisol. Technology has been developed to save P fertilizer by applying half dose P in both rabi and kharif crops or only in rabi crop and no P in Kharif crop in Indo-gangatic alluvial belt, alfisols of Karnataka and in Vertisols of Jabalpur and Sewni district of Madhya Pradesh. On the basis of this technology every year 1 milliom tons of P is saved which is worth 5000 crors in Haryana, Punjab and Western UP).

2. Use of FYM to sustain productivity of acid soils

FYM @ 5 t/ha/year has been found a better option than lime @ 2-3 t/ha/year as an ameliorant for acidic alfisols (Ranchi, Palampur and Bangalore) to improve and sustain crop productivity. Thus by implementing the technology an additional 40 m ton food grain can be produced from 25 m ha area suffering from acidity.

3. Sustaining soil quality through balanced use of chemical fertilizers

Continuous use of balanced chemical fertilizers improved soil organic C and did not cause any adverse effect of soil microbes. Further, there was no significant accumulation of heavy metals even after 40 years.

4. Maintaining threshold soil organic C

Threshold values for maintaining soil organic C was established and in general, balanced fertilization (100% NPK) could maintain it. Master parameters for soil quality assessment were identified for alfisols, Vertisols and Inceptisols.

Other significant achievements

- Non-observance of deficiencies of different micronutrients under balanced fertilization with organic manure was due to mobilization from their reserve pools in soils except in Mollisols at Pantnagar.
- If the crop productivity is maintained at a higher level over the year, it would likely to have good impact on soil physical condition due to incorporation of good amount of residual biomass through stable and root.

- In-spite of high amount of carbon in Vertisols, available N content is always low compared to other soil having the similar amount of carbon. Study indicated that availability of N is dependent more on hydrolysable carbon.
- In Vertisols in-spite of high status of non-exchangeable K and lattice K, crop needs external supply of K through fertilizer. Available pool of K is depleted at faster rate compared to other resistant pools if K is applied in less quantity than removed by the crop.
- The sustainable yield index (SYI) of rice and wheat crops at Barrackpore, Pantnagar and Raipur indicated that imbalanced nutrient application recorded significantly lower values compared to the balanced nutrient application. Even the application of 50% NPK along with biofertilizer could not sustain the yield of rice and wheat at these centres. The treatments showed the trend of SYI in the order of NPK+FYM> 150% NPK> 100% NPK> 100% NP> 100% N> control.
- In Alfisols group of soils, lowest SYI was observed in 100% N alone treatment. The reason for low SYI probably is due to deterioration of soil health in terms of pH and availability of P and K which affects the nutrient supplying capacity of the soil. The SYI values calculated were either near to zero or negative in 100% N treatment in maize, wheat, soybean, finger millet at almost each respective centres i.e Palampur, Ranchi and Bangalore. Interestingly control (no fertilizer /manure) recorded little bit higher SYI values than the 100% N. Thus results indicate that use of N alone should not be advised to farmers under any situation.
- The N-balance calculations made in soybean-wheat system at Jabalpur clearly demonstrated that soybean fixed 98 to 238 kg N and out of this adds of 24-66 kg ha^{-1} biologically fixed N to soil which is taking care of subsequent wheat to some extent at Jabalpur.
- In-spite of increase in organic carbon and N status of soil at Jabalpur, decline in productivity of soybean was noted over the years. Such decline has been attributed to increase in maximum temperature and erratic distribution of rainfall.
- Soybean-wheat in Vertisols was found as carbon sequestering system and C accumulated in resistant pool is difficult to be accessed by microbes. This is the reason in spite of high organic C, available N status is less in these soils.
- Balanced use of nutrient reduced the half life of herbicide and pesticides used in the experiment by 10- 12 days and incorporation of FYM further reduced the half life 5 days more because of higher activities of microorganisms.
- Balanced nutrient application recorded higher SQI values than imbalanced treatments.
- The modeling of soil data with climate revealed that amount of carbon to be retained by soil is dictated by clay (Texture) content of soil, rainfall and climatic temperature.
- Under TSP programme efficient nutrient management and the training resulted in increased crop productivity (20 - 60 percent) and also their income and profit.

(c) Technology Transfer

The basic objective LTFE was to understand the dynamics in soil process as a result of adoption of different management practices. Over the years, several lessons were learnt that could be directly translated into field practice. Several economically viable technologies emerged which are detailed below:

- In acid soils with low available P and K, FYM was found better soil amendment than lime for sustaining productivity of the cropping systems. Increase in productivity is resulted due to increase in efficiency of nutrients. Implementation of technology may produce 40 mt an additional food gram 25 m ha acid soils.

- *In situ* green manuring in rice-rice system in Western Ghat resulted in increase in productivity, saving of 50% NPK fertilizer alongwith a number of intangible benefit like increase soil carbon, soil health, environment issues , mitigation of environment etc.

- In intensively cultivated areas of country continuous use of P fertilizer resulted in high accumulation of P in soil. P dose could be reduced to half without loss in productivity. This strategy has been introduced in package of practice in Punjab and Haryana. Farmers are advised to apply P during winter and grow crop during rainy sason withouth P. This has rsulted in saving of 1 m tonns of P each year worth 5000 crores of foreign currency.

(viii) Linkages with client/end users

The LTFE being a long-term commitment, much better linkages and interaction among various institutions is needed. A strong need was felt to create systematic database at each centre and at Coordinating Cell at IISS, besides IASRI, New Delhi. The Project made attempt for better interaction amongst Institute's Scientists, PDCSR, CRIDA and other ICAR Institutes and AICRPs under NRM Division and the scientists working on Long Term Fertilizer Experiments independently.

1. **Linkages with State Agricultural Universities (SAUs)**: Linkages are desirable between LTFE project centres and other projects operational at the SAUs where the centres are located. There is need for greater multidisciplinary work drawing upon the expertise of weed scientists, plant protection experts and economists for periodic assessment of the situation. One suggestion of QRT is that stronger linkages be forged with KVK and State Agricultural Department to take technology to farmers' fields.

2. **Linkages with ICAR Institutes**: Linkages of LTFE project with ICAR institutes located in different agro climatic regions should be established to an adequate level to monitor the changes in soil quality, productivity and sustainability under the impact of continuous use of fertilizer in intensive cropping systems.

3. **Linkages with other AICRP Centres:** Facilities for micronutrient analysis exists in Cooperating centres of AICRP on Micro and Secondary nutrients and Pollutant elements where they coexist with AICRP - LTFE. The linkage AICRP Ago-metereology and AICRP, INM, PDCSR Modipuram was developed.

4. **Linkages with extension Agencies/Media:** Technology developed through syntheses of data generated over the year at each location is demonstrated at farmers' field and disseminated through Radio, Doordarshan and Print Media.

5. **Interaction Workshop:** In order to create better interaction and to develop programme systematically, workshop of AICRP LTFE should be planned by inviting more experts so as to identify emerging trends in nutrient imbalances and deficiencies and to formulate future strategies for maintaining soil health. A National workshop of AICRP on LTFE was held inJune, 2015 at HPKV, Palampur,

(ix) Human, Physical and Financial Resources

Human Resources:

The Project Coordinator operates under the technical advice and administrative control of Deputy Director General (NRM) and Assistant Director General (Soils), Indian Council of Agricultural Research (ICAR), New Delhi in association with administrative support of the Director, Indian Institute of Soil Science. Functionally, he is independent to carry out the technical programme, release of funds and in dealing financial matters with SAUs, ICAR Institute Centres and voluntary centres. The scientists working in AICRP, at different centres are encouraged to attend training courses organized by ICAR and SAUs to update and refresh their skill. The finance provided by ICAR in monitored regularly.

The project had sanctioned manpower of 70 for XIIth plan which includes 36 scientists, 1 technical, 3 administrative, 18 supporting staff and 12 research associates.

Physical Resources: For conducting the experiment at research farm and farmers' fields, resources are provided. For analytical work, finance is provided to purchase the instruments and modernize the laboratory at each centre. Each centre is maintaining good infrastructure in laboratory.

Financial Aspects: The project had a financial outlay of Rs. 2701.87 lakhs in the XIIth Five-Year Plan to meet the arrears and purchase of Instruments. Funds are released to centre as per the requirement and regularly monitored physically and also through AUC submitted by them. The ICAR provides 75% financial support to the State Agricultural University centres to meet the requirements of pay, TA, recurring and non-recurring contingencies.

The ICAR share of budget during the XIIth five-year plan period (2012-2017) is given below.

Head-wise plan budget for XIth Plan actually spent

Budget Head	**ICAR Share**
Recurring	Rs. in lakhs
Pay and Allowances	1246.64
T.A.	17.35
RC	160.44
Total(A)	**1424.43**
Non Recurring	
Equipments	34.72
Works (Lab renovation)	0.00
Total (B)	**34.72**
Total (A+B)	**1459.15**
Others	
NEH	25
TSP	75
Total (C)	100
Total (A+B+C)	**1559.15**

The QRT observed that AICRP on Long term fertilizer experiment field's sites are very large in size. As a result, it requires more labor and time and thus a contingency provided to the centre is not adequate. LTFE is permanent setup and during summer season this particular experiment is left out which is vulnerable to theft/grazing by animal and bird. So, continuous watch and ward is needed to protect the experiment. Soil samples of LTFE are of high value, so to keep them in safe custody each centre needs storage infrastructure. Therefore, additional funds are required for maintaining the experiment.

(x) QRT Observation on outcome from different centres

PAU, Ludhiana

The pH of Punjab soils has declined, while organic carbon and phosphorus content of the soils has increased over the years. It has been recommended that farmers may avoid the application of phosphorus every year. Outcome of LTFE in all the centres should be incorporated into fertilizer recommendation of the region.

GBPUAT, Pantnagar

Presentation of the centre was very poor as data generated was not properly analyzed and interpreted. There was no new information generated during last 5 years. Recommendation on zinc application by was different from the recommendation from AICRP (micronutrient).

CSKHPKV, Palampur

Scientific reasoning for no crop growth in the 100%N alone treatment should be investigated. Although pH has dropped from 5.8 to 4.8 in this case, crops have been found to grow even below pH 4.5. Results on C pool study should be properly interpreted and used in soil nutrient management recommendation. Cropping system and treatment structure are same in both Ludhiana and Palampur centre and therefore, basic soil processes leading to a difference in observations in these two soil types should be understood and investigated. Inferences drawn from the results on climate change impact on crop yields is not proper in the existing treatment structure, as impact of varietal change and soil health change can not be isolated. Through scientific discussion, a protocol should be developed for studying climate change impact.

IARI, New Delhi

It has been indicated that due to continuous mining of potassium there has been a change in the mineralogical structure of the soil clay. Recommended dose of NPK was decided decades back and it may not be relevant today. STCR recommended dose should have been looked into. It should have been investigated on whether fertilizer management can affect the carbon distribution in the soil fractions. Due to scarcity of lime, cheaper and alternative sources of amendment materials should be tried in LTFE experiments.

TNAU, Coimbatore

Most of the achievements presented are not new and these have also been presented during previous QRT 5 years before. The centre reported carbon sequestration even in the control treatment. Centre should work on basic research particularly on identifying master indicators for soil quality assessment and on impact assessment of Climate Change on soil health. Reasons for increased ammonium fixation with farmyard manure application should be looked into. Justification of continuing the treatments of applying 25 kg/ha zinc sulphate and 10 t/ha FYM every year needs reviewing.

PJTSAU, Hyderabad

Amount of NPK being added through FYM should be analysed and recorded every year. Justification for continuing the treatment of FYM at the rate of 30 t/ha is required. Effect of FYM on yield should be explained on the basis of nutrient dynamics. It has been observed that hundred percent NPK + FYM has increased dehydrogenase activity more than farmyard manure treatment, in spite of more FYM has been added in the later treatment. Farmers practice gives lower yield as compared to 100% RDF, although farmers practice had higher doses of NP fertilizers as compared to RDF. These observations should be explained with scientific basis. Continuation of same RDF dose decided 40 to 50 years back should be reviewed by all the LTFE centers. Proportion of C incorporated through FYM sequestered in the soil under long term nutrient management should be quantified under different soil and climatic conditions. Manpower in this centre has been changed frequently which is desired at the interest of the project.

UAS, Bangalore

The center presented that pH has decreased in all the treatments from initial pH. Changes in soil physical properties due to imbalance fertilization should be explained with scientific reasoning. The results on nitrogen fractionation study should explain nitrogen dynamics in order to interpret observation on crop yields in different treatments. Study may be undertaken to find out if there is any effect of different nutrient management treatments on population of fungi producing glomalin so that carbon sequestration potential of soil due to nutrient management can be understood. Farmers practice needs to be specified by all the centres. Explanation is required on how reducing P dose (in RDF as compared to farmers practice) can increase the grain yield of finger millet.

RARS, Pattambi (Kerala)

The center should work on to quantify on how much C from farmyard manure is ultimately going to slow and passive pools. It is suggested that all centres under LTFE should consider for permanent demarcation of bunds using concrete like structure.

MPUAT, Udaipur centre

Organic farming did not produce yield of Maize up to the level of hundred percent NPK even after 20 years. Variety of maize has been changed 3 times since the initiation of the project. Data on changes in soil organic carbon in different treatments may be analyzed critically to arrive at definite conclusion. Soil must be analysed for total contents of the heavy metals with advanced instruments like AAS coupled with graphite furnace or ICP-OES. On farm experimental trials should be conducted based on the conclusions from LTFE and treatments should be decided accordingly. Nutrient use efficiency in different treatments should also be computed by all the centres. Meaningful conclusions on the changes in soil health due to continuous application of different fertilizer treatments should be derived after critically analysing the huge amount of data generated on N, P and carbon fractions in soil.

PDKV, Akola

The centre should relook into the data and find out the reasons for high percent recovery of NPK in plant update. AICRP should develop a protocol for studying the effect of Climate Change on nutrient dynamics study for all the centres. Data generated on C, N, P, and K fractions in soil should be used to explain changes in soil quality or soil health. Centre should determine critical values of SOC, hydraulic conductivity, dehydrogenase activity etc. for the area through the results obtained in long term fertilizer experiments.

VNMKV Parbhani

The treatment receiving 10 t FYM /ha recorded less SOC as compared to the treatment receiving 5 t FYM. QRT commented that soils should be re-analysed for soil organic carbon content. Data on SOC fractions in soil should be used to explain changes in soil quality.

OUAT, Bhubaneswar

It has been noted that SOC, N, P are increasing in all the fertilizer treatments; however, water stable aggregates did not improve. Reason for this may be explored. Soil quality indicators for low land rice-rice system varied even with seasons and in such scenarion recommendation would be complicated and confusing. The centre should study changes in microbial diversity with different nutrient management in with the help of AINP-SBB centre; and the information/resource can be utilized to formulate bio fertilizers.Centre should collaborate with NRRI, Cuttack for the study on GHG emissions under low land rice-rice system. Carbon balance, carbon sequestration and changes in micro and macro aggregates under such cropping system under different nutrient management scenario should be investigated.

JNKVV, Jabalapur

The centre should study on carbon sequestration and should develop FYM application strategy (rate and frequency) to maintain soil organic carbon.

IGKV, Raipur

In place of monitoring insect infestation, the centre should monitor occurrence of diseases in different LTFE experimental plots. Focus only on two to three issues for future research plans.

BAU, Ranchi

No definite outcome by the centre and no future action plan presented. Major issue for the state being addressed by this LTFE centre should be indicated. Basic difference on the impact of long term of nutrient management treatments between the soils of Ranchi and Jabalpur should be investigated in-depth

CRIJAF, Barrakpore

Phosphorus build up has been observed in treatments receiving P fertilizers. Reducing the phosphorus dose by 1/3 did not affect crop yield. For future research plan, centre proposed only monitoring and assessment study.

JAU, Junagarh

Very poor yield of groundnut was recorded in the LTFE experiment in spite of high average yield in that region indicating poor management of the experiment. Analysis of FYM every year must be accomplished by all the LTFE centres.

(xi) Overall performance of AICRP on LTFE centres

Outstanding: OUAT Bhubaneswar, JNKVV Jabalpur, PJTSAU Hyderabad, IGKV Raipur, BAU Ranchi, CSKHPKV Palampur

Good: PDKV Akola, TNAU Coimbatore, CRIJAF Barrackpore, UAS Bengaluru, PAU Ludhiana, VNMKV Parbhani, IARI New Delhi

Fair: MPUAT Udaipur, RARS Patambi

Poor: GAU Junagadh, GBPUAT Pantnagar

(xii) Overall Assessment of AICRP on LTFE

The LTFE centres have done very good work during the period under report. A vast amount of primary and secondary data has been created generated over the last four and half decades in different agro-ecological regions of the country. These have given invaluable clues for future research directions for different research institutions in the field of soil fertility and related areas influencing growth and yield of crops in major soil groups and cropping systems. Of late, there are sufficient indications from the data on the need to give emphasis on appropriate soil biological and physical indicators for evaluating soil quality and on natural interactions among various biotic and abiotic factors affecting soil processes. Long term fertilizer experiments are a good platform to launch a series of studies sequentially from basic to applied mode including simulation modeling on crop growth to yield, if necessary, in collaboration with other organizations.

(xiii) Planning for the future for AICRP on LTFE

The goal of Indian agriculture is to produce more grain per unit area/unit time/unit input without causing any detrimental effect on soil health and environment. Fertilizer is a key input which is becoming more and more expensive with time. Also, continuous application of fertilizers in agricultural land is apprehended to alter soil health in the negative direction. Thus, the answer to apprehensions can be obtained through LTFEs at different agro-ecological situations. Outcome from the LTFEs can provide valuable clues which can help country in formulating long-term agricultural policy for sustainable crop production.

One of the major purposes of the LTFE experiments should be to understand the basic soil processes and their dynamics under different management scenario. The goal should be to increase nutrient use efficiency after studying the soil processes responsible for nutrient cycling in each soil type which can subsequently be used for developing appropriate technology. LTFE's offer a good experimental basis to quantify carbon sequestration, quality of soil organic matter and nutrient cycling and to estimate the effects of input management on the soil over a period of several decades. These management practices can be tested for their ecological impacts with computer models that simulate SOM changes in soils. Soil indicators sensitive to changes in soil management practices can be identified with confidence. Thus during twelfth plan following researchable issues are important.

1. For sustaining the productivity over a long period, there is need to improve soil health. But unfortunately so far we could not confidently find out soil parameters which can be used to assess soil quality. Soil indicators are not common and differ with soil type. So it is important to identify soil quality indicators sensitive to management practices and responsible for sustainability to development of soil quality index (SQI) under different management practices and cropping systems.

2. Due to industrialization and burning of fossil fuel perceptible change in our climate has been noted which has direct impact on crop productivity and indirectly may influence soil health. LTFE has experimental data over a long period of time and one may find out impact of climate change by doing some modeling exercise taking into consideration of climatic data available in the country. Therefore another issue is: Assess the impact of climate change on productivity and soil health through suitable modeling exercises.

3. Soil carbon is dynamic in nature and key parameter to evaluate soil health but a common value may not work for all kinds of soils. In spite of heavy application of organic manure, soil carbon content does not go beyond the equilibrium value and same is true with minimum level of carbon in soil. So for good soil health, carbon level should be as near as saturation level. So it is crucial to determine minimum threshold and saturation carbon level in different soils.

4. For inventorying the emission of green house gases (CH_4 and N_2O) there is a need to quantify GHG's under different management practices and climatic situations. This will help develop strategy to mitigate these gasses. LTFE experiments with wide range of nutrient management under different agro-climatic zones provide a good opportunity to address this issue of Quantification of green house gasses and their mitigation options.

5. Another important issue is the addition of heavy metals through fertilizers and other soil amendments and their entry into food chain and impact on produce quality. Fertilizer and soil amendments contains heavy metal in very small quantity and it takes several years to add these metal in quantities that can build up their concentration beyond the limit prescribed by the country. Experiments in AICRP are in progress for the last 40 years at fixed sites and fertilizersare added every year in defined amounts. Thus these experiments provide a good platform to address the issue of heavy metal contamination through fertilizers and soil amendments and their impact on soil biodiversity.

(xiv) Consolidated Recommendations for AICRP on LTFE

Scientific

- Impact of climate change on soil processes and on soil quality can only be investigated through long-term experiments. Eleven centers under AICRP-LTFE are more than 45 years old. AICRP on LTFE made a modest attempt to investigate the impact of climate change without developing a robust protocol on crop yields. The QRT recommends that standard protocols should be developed to capture changes primarily in soil processes.

- AICRP centers should **analyze soil samples for different labile/mobile, less labile/mobile and non-labile/immobile fractions of C, N, P, K and micronutrient fractions as well as mineralogy** from different years of experimentation comprehensively to understand the reasons for deterioration in soil quality and crop productivity observed in different regions of the country.

- Detailed analysis for assessing soil quality index should be done at every five years interval in each of the centers.

- Soil samples must be archived year-wise and treatment-wise for future use in each of the centers.

- A standard manual for conducting the trials and analysis of soil, manure and plant samples all the parameters including soil biological parameters must be developed for use of all the cooperating centers.

- Separation of plots with permanent concrete *bunding* may be done to avoid lateral movement of nutrients and water.

- Soil resilience study may be initiated at a few sites where significant deterioration in soil functions is observed.

- The experimental areas under different treatments in LTFEs are treasures carrying signature of past and dreams for the future. Hence, the change in the treatments or super imposing on the treatments should be debated thoroughly before execution in order to avoid the risk of losing valuable resource material.

- One of the objectives of AICRP on LTFE is "To investigate the effect of intensive use of biocidal chemicals (weedicides and pesticides) on the buildup of pesticide residues and soil productivity". Adequate observations have not been undertaken towards this objective. This needs to be accomplished with the help of competent residue laboratories.

- The QRT recommends that the general recommendations (RDF - 100 % NPK) for different crops/cropping systems needs be revisited, to maximize and sustain productivity by all the LTFE centres.

- A simple method for determination of available N content in vertisol needs be established as the present method is not working.

Technology Transfer

The technologies on 'Use of FYM as a substitute of lime to sustain productivity of acid soils' and 'Saving phosphatic fertilizers' as indicated above may be validated with the assistance of KVKs for onward transmission to state government.

Administrative

1. One temporary contractual Senior Research Fellow may be sanctioned to those centers not already having the position for carrying out work more effectively.
2. The universities should adhere to the MoU and not shift experienced scientists out of the scheme without consent of PC.

Financial

1. Amount under contingency to meet out operational expenditure is insufficient and it should be increased 2-3 times depending on nature of research work, number of station trials, satellite trials, no. of working scientists, amount required for vehicle hiring, etc. Also it should be increased by 15% each year.There should be some flexibility in allocation of fund allotted by the council and Project Coordinator should be empowered to allocate fund as per the work load and performance of the centers.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E. REVIEW REPORT OF AICRP ON AICRP ON SOIL TEST CROP RESPONSE

(i) Brief History

Continuous mining of nutrients by crops at different degrees necessitates their replenishment for sustainable production systems from agricultural lands. Build-up and maintenance of soil fertility and consequent provision of balanced fertilization to crops are keys to sustain long-term crop productivity. Nutrient supplying power of soils and crop responses to applied nutrients are required to be assessed accurately during nutrient management programme towards enhancing profitability of farming. Monitoring of soil fertility against depletion and accumulation of certain elements in toxic proportions over time is possible only through appropriate soil tests. Huge cost of fertilizers has become a big deterrent for the farmers to apply adequate fertilizers to crops. Soil test calibration that is intended to establish a relationship between the levels of soil nutrients determined in the laboratory and crop response to fertilizers in the field permits balanced fertilization through right kind and amount of fertilizers.

The soil testing programme was started in India about 60 years ago under the Indo-US Operational Agreement for "Determination of Soil Fertility and Fertilizer Use". Subsequently, entire development in soil testing centred around appropriate chemical extractants selection, identification of critical values to characterize deficient soils, recommendations on fertilizer use which were thought applicable to the medium category of soil testing estimates with an arbitrary adjustment (decrease or increase by 25-50 per cent) for high and low categories of soil test estimates.

The ICAR project on soil test crop response correlation has used the multiple regression approach to develop relationship between cropyields on the one hand, and soil test estimates and fertilizer inputs, on the other. In order to tide over the management problem of conducting field experiments at different sites, which differ from each other in the extent of uncontrolled variables, the project seeks to create artificial fertility gradients in 3 adjoining plots by applying different amounts of fertilizers to a preceding non-experimental crop. Then each of the three large plots is subdivided into subplots of which 3 are control plots, and 21 or 18 receive different quantities and combinations of fertilizer nitrogen, phosphorus and potassium, in a fractional factorial design provided by Ramamoorthy and Velayutham in 1971. In 2005, the conclusions of a collaborative project with IASRI, New Delhi and recommendations of QRT suggested the adoption a new design. This design was constructed by keeping in mind the need to get various combinations of optimum doses for a given response. In this design the number of plots was same as those in previous design, but some different treatment combinations were taken for experiment. Moreover as recommended by QRT, one strip (L1/2 strip) was also dropped from experimentation. The finally proposed design is response surface design.

(ii) Mandate& Objectives

Mandate: To Provide Scientific Basis for Enhancing and Sustaining Productivity of Soil and Crops through Targeted Yield Approach of Plant Nutrient Management with Minimal Environmental degradation.

Objectives

- To develop relationships between soil test values and crop response to fertilizers, in order to provide a calibration for fertilizer recommendation based on soil testing.
- To obtain a basis for making fertilizer recommendations for targetted yields.
- To evaluate various soil test methods for their suitability under field conditions.
- To evaluate the joint use of chemical fertilizers and organic manures for enhanced nutrient use efficiency.
- To derive a basis for making fertilizer recommendations for a whole cropping sequence based on initial soil test values.

(iii) Structure and Organization

The project was started in 1967-68 with eight centers. During 1970-71, five more centers were added. One center (Raipur) was added during 1981-82. Presently, STCR project is working with seventeen cooperating centers (Table 1). The scientific staff working in different cooperating centers is presented in table 2 and 3. In addition to the regular centres, there are eight ad-hoc or volunteers centres, namely, (i) AAU, Jorhat, Assam, (ii) ICAR Research Complex for North East, Manipur, (iii) Ranchi, Jharkhand, (iv) Sher-e-Kashmir Agriculture University, Srinagar, J&K, (v) BHU, Varanasi, (vi) Junagarh, Gujarat, (vii) PJNCARI, Pondicherry. The coordinating cell of the project was initially located at the Indian Agricultural Research Institute, but in April 1975, it was shifted to the Project Directorate, Central Research Institute for Dryland Agriculture, Hyderabad. Only in April 1996, it moved to its present location at Indian Institute of Soil Science, Bhopal.

The project coordinator operating from P.C. unit located at IISS gets advice from the Deputy Director General (NRM) / Assistant Director General (Soils) and works in close association with and under the administrative control of the Director, Indian Institute of Soil Science. Functionally, PC is independent to carry out the technical programme in cooperation with the Director, IISS and the Directors of Research, SAU's and Directors, ICAR institutes.

Staff of Project Coordinating Cell, STCR - Scientist (Statistics), P.A. and technical assistants (vacant) provide technical support to the coordinator, whereas IISS administrative and financial staff provide support in administrativeand financial matters.

The project coordinator plays key role in planning the work through the mechanism of workshops and in coordinating and monitoring the work of centers. Coordinator prepares the budget/EFC memo, gets proper allocation and monitors the expenditure and obtains the audit utilization certificates from the centers. As presented in the following section, project coordinator prioritizes the work, helps in programme planning and execution through workshops and group discussions and monitors the work by visiting the centers and discussing with center scientists and higher authorities in the University/Institute.

The project mainly conducts applied and some basic research work on the development of soil test based nutrient recommendations for crops and cropping systems in different states. The recommendations generated are re-tested in the follow up trials at research farms or in a nearby village and also in the frontline demonstrations in villages.The state soil testing laboratories are involved in the conduct of frontline demonstrations on farmers' fields.

(iv) Major Research Achievements

- During the XII Plan, developed fertiliser prescription equations for 163 crop sunder STCR-IPNS including cereals (48), pulses (7), flower (3), oilseeds (15), millet (2), vegetable (57), medicinal plant (1) and other crops life fibre, fodder etc. (30) for various agro-ecological regions of India which have been verified for field applicability through FLDs/on-farm verification trials. Besides, 75 fertiliser prescription equations under non-IPNS system were also developed.
- Developed fertiliser prescription equation for hitherto untouched secondary nutrient (sulphur).
- Integration of drip fertigation with STCR equation was done for the first time in the history of STCR to address dryland conditions.
- Prediction of post-harvest soil available NPK to do away the need for soil testing after every crop, thereby saving of time and money:
- Developed post-harvest soil test prediction equation for following cropping-systems:
  - Maize (hybrid-NK 6240) - Tomato (hybrid - Lakshmi 5005) for Tamil Nadu.
  - Rice (PRH-10)-Wheat (HD-2581) for Delhi and adjoining areas.
  - Rice (BPT-5204)- Maize (BH 1576) and Rice (BPT-5204) – Rice (Tellahamsa) for Telangan.
  - Post harvest prediction equations for Chickpea based cropping system developed for Uttarakhand.
  - Autumn Rice (Luit) - Winter Rice (Ranjit) by AAU, Jorhat, Assam.

- Mobile based bilingual (Marathi and English) STCR App for fertilisers recommendations of Maharashtra was launched which was prepared in collaboration with National Informatics centre (Govt. of India), Pune
- Online fertiliser recommendation system developed in collaboration with NIC, Pune ((http://www.stcr.gov.in)
- Development of nutrient plan from GPS and GIS based Soil Fertility Maps of 173 districts of India (http://www.iiss.nic.in/districtmap.html).
- Developed user friendly software for the preparation of Soil Health Card as per Ministry of Agriculture & Farmers Welfare, Govt. of India guidelines for M.P. Odisha and U.P.

- Provided and is continuing to provide technical backstopping for GoI Soil Health Card Scheme; developed a manual for sample collection procedure and analysis of soil samples and handed over to Department of Agriculture, Cooperation and Farmers Welfare (DAC&FW), Govt. of India. District wise applicability of fertiliser prescription equations under different agro-ecological regions have been documented and transferred to DAC&FW, Ministry of Agriculture and Farmers Welfare which was included in the online DSS developed under soil health scheme of Govt. of India (http://soilhealth.dac.gov.in/Report/STRCReport/STCRReport).

- **Evolving strategies for economizing nutrient application through STCR approach:**
  - Economizing phosphorus fertilizers in groundnut through STCR approach in Karnataka
  - Refinement of fertilizer doses for groundnut in Kandhamal, Keonjhar and Deogarh districts of Odisha leading to saving of K fertilisers.
  - Developed integrated plant nutrition package involving bioremediation strategies for iron toxicity in lowland rice ecosystem of Assam.

- **Evaluation of soil test method:**
  - AB-DTPA-P for available phosphorus, AB-DTPA-K for available potassium were found suitable under Mollisols of Tarai region of Uttarakhand for chickpea.
  - Evaluated the suitability of soil extractants for predicting plant available potassium to improve the K recommendations for alluvial Soils of West Bengal.
  - Developed soil testing protocol for organic farming system including characterization and quantification of microbiologically exploited organic phosphorus pool.

- A total of 1148 FLDs were conducted during XII Plan period. Organised 153 capacity building programme cum field day benefiting 8029 tribal farmers under Tribal Sub Plan. Also organized 26 training programmes for State Soil Testing Officials; one programme on *Pradhan Mantri Fasal Bima Yojana*; one training exclusively for women in Jammu & Kashmir.

- Patent on “Portable Soil Testing Kit for Agricultural and Horticultural Crops”, developed by IGKV, Raipur centre of AICRP (STCR), has been filed vide Patent Application No. 2522/DEL/2015 dated 25-4-2016 and has been published. (http://ipindiaservices.gov.in/PublicSearch/PublicationSearch/ApplicationStatus).

(v) Infrastructural and Physical Facilities

The project is one of the three All India Coordinated Research Projects located at the Indian Institute of Soil Science. The project has coordinating cell at Indian Institute of Soil Science, Bhopal and 17 cooperating centers in 16 state agricultural universities and two ICAR Institute. There are 7 voluntary centres started during 2011-12 and one voluntary centre opened in 2014-15 without any salaried manpower. Every university/ institute centre has adequately developed laboratory to cater to the needs of the analytical work. In many centres, several sanctioned positions of the staff are vacant. The centers were also allotted sufficient land by the university/ institute to conduct field experiments. The experiments are conducted not only at the main university campus but also at the regional research stations.

(vi) Budget and Finance

The ICAR provides 75% support to the University centers to meet the requirements of pay, T.A. recurring and non-recurring contingencies. The ICAR institute based centers are provided only the contingency and T.A. During the XI plan period 2012-17, total budget allocation was Rs.3760 lakhs, of which about 86% was spent.

Head-wise budget for XIIth Plan actually spent

Budget Head	ICAR share (Rs. in lakhs)
A. Recurring	
Pay and Allowances	2429.03
TA and TSP	734.48 (Out of this, 270 lakhs for TSP)
Total(A)	3163.51
B. Non Recurring	
Equipments	72.18
Works (Lab renovation)	3.75
Total (B)	75.93
Total (A+B)	3239.44

(vii) Linkages

The project has strengthened linkages with ICAR institutes, SAUs located throughout the country, and the extension and development agencies. Linkages have been strengthened by organizing regional and national workshops/ meeting of AICRP project in which scientists of cooperating centers located at SAUs or ICAR institutes have participated. The project has also encouraged interactions by exchanging its Annual Reports (SAUs). The Annual Reports of other Institutions are also being received for the reference of scientists and for exploration of further collaboration in research projects.

AICRP (STCR) had undertaken lead role in the preparation of soil health cards, training of State Soil Testing Officials, propagating Swachh Bharat Abhiyan, implementing Mera Gaon Mera Gaurav programme and celebrating World Soil Health Day. AICRP (STCR) has conducted training of Soil Testing Officials for different State Government as well as other organisations from time to time to build capacities for Soil Health Card Scheme. Apart from signing the MoU with 21 Universities for collaboration, the AICRP (STCR) has provided technologies to several AICRPs/ICAR Institutes.

(viii) QRT Observation on outcome from different centres

PAU, Ludhiana

Use of phosphorus in Punjab is about 3 times the requirement and therefore Low-Medium-High basis of fertilizer recommendation is not valid. It is suggested that an alternative prescription method to STCR equations may be developed. Benefit of Biochar application has been highlighted. Dose of Biochar in the experiment (25 to 50 ton per hectare) was very high in view of its scarce availability/production. P release through biochar may be investigated. Efficiency of different extractants for availability P was compared. The centre should develop multinutrient extractants for all the nutrients including micronutrient.

GBPUAT, Pantnagar

Benefit cost ratio calculation should be on total farming cost basis. Fertilizer prescription equations for a crop should be developed for different soil types.Developing prescription equations for different crops in all the soil types of Uttarakhand should be completed within specified time period.Constraints in adopting STCR equations by soil testing laboratories maybe identified and necessary actions should be taken to address those constraints within 3 years period. Targeted yield is function of many other management functions and therefore appropriate rationalization in equations should be made by all the centres for different crop management scenario. Secondary and micronutrients like sulphur, Boron and Zinc should be integrated in the STCR equations after considering/reviewing the research results generated by AICRP on MSNPE.

CSKHPKV, Palampur

AICRP centres should randomly check the accuracy of soil test results being generated from different Laboratories. Sufficient STCR prescription equations have not been generated for adequate number of crops under different situations. This may be one of the reasons for not popularization of STCR equations in the soil testing Laboratories.

IARI New Delhi

In view of scarce resources available and apprehension on usefulness of expected outcome, long-term experiments based on STCR is not recommended. The centre proposed to continue research on plant-led strategy based on LCC and SPAD value.Centre should work on developing multinutrient extractants.

CCSHAU, Hisar

Research in this centre was focused mainly on refinement of existing STCR equations. Continuing the centre further only for refinement of STCR equations is not recommended.

TNAU Coimbatore

The centre has developed software **DSSIFER 2010** for the purpose of recommendation of fertilizers on the basis of soil test data in the TN state. This has been adopted by the state government. Recommendations and ready reckoners should be developed for cotton and horticultural crops under drip fertigation condition. AICRP on STCR should find out ways to integrate biofertilizer into their recommendation after validation of recommendations from AINP on Soil Biology and Biodiversity.

UAS Bangalore

In spite of havingadequate staff, centre has not developed prescription equations for all the crops as per the suggestions of previous QRT. The centre informed that only 43% of soil health cards issued have recommended on the basis of STCR approach. The centre should work on to cover whole state with their approach of recommendations. In the experiments on Universal soil extractant development, only P and K have been covered. Centre should work comprehensively and develop/explore a Universal soil extractant for all the major and micronutrients. It is suggested to make an effort to integrate STCR approach in the soil health card mission of the country.

PJTSU Hyderabad

The center made detailed presentation on contribution of non exchangeable potassium to crop uptake in 36 soils under 4 soil types and foundno relation between non exchangeable potassium and it's content in rice plants. Generating basic research data on contribution of non-exchangeable potassium in this project may not be justified as such information can not be incorporated in making recommendation. The reason may be explored for higher yield in STCR and RDF as compared to farmers practice even though fertilizers application rate in farmers practice was considerably higher.

KAU, Vellanikkara

Qrt pointed out that works done in this centre is insufficient and has not published any research paper. Prescription equation for rice based cropping system should be developed.

PJNCARI, Pondicherry

STCR equation under IPNS may be limited to crop where manure is available like in vegetables and dose of manure should be rational based on its availability.

As large number of varieties is being released, it is very difficult for a centre to develop equations for each variety of different crops in time bound manner (farmers' need). Therefore equation developed by one centre may be used by other centres after verification under similar situation. AICRP on STCR should also work on modulating coefficients in the STCR equations developed for a region so that the same may be extrapolated to other soil types and crops. Few AICRP centres in collaboration with IISS, Bhopal should work on basic research related to nutrient dynamics and nutrient release pattern so that this information can be extrapolated to predict/forecast changes in recommendation. It has been reported that Olsen extractant is not working for organic farming system. Therefore STCR centres should develop an appropriate soil test method for determining available Phosphorus status for organic farming system.

JAU, Junagadh

This is a voluntary centre and only centre in Gujrat. QRT suggested that the centre should take equations from other centres with similar soil and Agro climatic types and validate for their region.

RAU, Bikaner

Sufficient STCR equations have been developed for different crops in the Bikaner region. The centreproposed that there is a need to develop STCR equations based on fertigation for the crops of other region. Research works on soil carbon pool analysis and multinutrient extractant development were not attempted by the centre as suggested by previous QRT.

MPKV, Rahuri

There are no innovations in the works being carried out at the centre. As suggested by previous QRT, the centre did not attempt on the work related to soil carbon pool analysis. The centre should work on developing STCR equations based on fertigation. A protocol should be developed by some STCR centres on developing equations for organic farming systems. Few AICRP-STCR centres should work on specifically on developing soil test methods based on multi nutrient extractants.

RPCAU, Pusa centre

Study on soil carbon pool may not be relevant in STCR and such study may not be undertaken in AICRP on STCR. The centre is conducting long-term experiment with general recommended dose instead of using its own fertilizer prescription equation. As this long-term experiment is not expected to fulfil any of the objectives of AICRP on STCR, manpower and financial resources should not be used for this experiment. Centre should focus developing fertilizer prescription equations for remaining major crops and also on increasing adoption level of STCR equations by the soil testing laboratories.

OUAT, Bhubaneswar centre

STCR equations were found very useful for small and marginal farmers as compared to big farmers.The center monitored soil health changes of Orissa. Overall soil organic carbon status increased; while available Phosphorus and pH decreased.

JNKVV, Jabalpur

A protocol should be developed on how to incorporate micronutrients soil tests into the STCR equations. Third party evaluation of STCR equations based fertilizer recommendation should be carried out in order to instill the confidence among the farmers and enhance its adoption level.STCR centres should investigate and recommend the frequency of soil testing for nutrient recommendation to farmers as soil-testing for each field evey year may not be practically feasible. AICRP should try to understand the science behind the nutrient aquistion by plant so that there is no need to develop equation every time a variety is released.

Indira Gandhi Krishi Vishwavidyalaya, Raipur

The center presented soil health portal data which has been prepared after analyzing the soil samples using *Mridaparikshak* and several of the data for available nutrients parameters indicated to be either exceptionally low or exceptionally high.

BCKV, Mohanpur

The center developed equations for several vegetable crops. Instead of working of fertigation as recommended by previous QRT, the centre developed STCR under limited moisture condition.Centre should develop nutrient management system for conservation agriculture system. Reason for improved produce quality under Integrated Nutrient Management (INM) treatment but not organic farming treatment should be explored.There is a need for scientific on whether fertilizers cab be allowed under organic farmingif fertilizer is essential for sustaining yields and is not deteriorating crop quality. Not enough fertility gradient was created before conducting experiments to develop STCR equation.

CRIJAF, Barrakpore

Not enough fertility gradient was created before conducting experiments to develop STCR equation. In the program on developing/identifying multi nutrient extractants, the centre recommended Morgan extractant. On the contrary BCKV, Kalyani centre recommended Mehlich-3 for same soil type. QRT commented that for such type of experiments different soil types should have been used instead of using STCR experimental plot only.No need to do carbon fractionation study under STCR.

(ix) Overall performance of AICRP on STCR centres

Outstanding: IGKVV Raipur, OUAT Bhubaneswar, MPKV Rahuri, BCKV Kalyani, TNAU Coimbatore

Good: GAU Junagarh, JNKVV Jabalpur, UAS Bengaluru, PJTSAU Hyderabad, PAU Ludhiana, GBPUAT Pantnagar, RPCAU Pusa, HPKV Palampur

Fair: IARI New Delhi, CRIJAF Barrackpore, PJNCA Puducherry,BAU Ranchi, RAU Bikaner

Poor: KAU Vellanikkara, CCSHAU Hissar

(x) Overall Assessment

The QRT is of the opinion that overall, the AICRP on STCR has delivered very good output in tune with several of its objectives and has achieved the targets set for the centers even under certain limitations. The scientists have covered large number of crops grown in their states and also have demonstrated that considerable amount of fertilizers could be saved if the farmers followed the recommendations and that too without any harm to the soil.

(xi) Visioning for the Future

Soil Test Based Site Specific Nutrient Management

Most of the researches under STCR so far have been focused on conventional agriculture under no or limited stress condition. However, face of agriculture has changed considerably after globalization of Indian economy, reforms in market and infrastructure facility, rising environmental concern. As a result, other forms of agriculture like organic farming, green house agriculture, conservation agriculture, floriculture etc. are becoming popular. Emphasis is also being given on highly intensified agriculture after setting-up of agri-export zones of the country. This necessitates development of specific nutrient management protocol for each type of agriculture systems. Under Integrated Plant Nutrition System (IPNS) approach, target yield based fertilizer prescription equations have been developed in case of commonly used farmyard manure, green manures, biofertilizers, etc. so far. There is a need to develop fertilizer prescription equations with IPNS concept for other locally available manures such as poultry manure, vermi-compost, phospho-compost, humic substances etc. besides development of soil testing protocols for organic farming and developing site specific nutrient management practices for organically produced crops. Research on soil test based fertilizer recommendation should focus more for dryland and for limited irrigation condition.

New methodology for improvement in Soil Testing Services

In view of emphasis of Govt. of India on providing soil health card to every farmer, it has become necessary to speed-up soil testing procedure. Thus there is a need to develop universal extractant and its inclusion in routine soil test services.Also calibration of such soil tests with universal extractant for target yields of different crops grown on different soils is required to develop fertilizer prescription equations.

Increasing adoption of STCR fertilizer prescription equations by stake holders

Considerable researches have taken place under AICRP on STCR during 50 years since its establishment. However, adoption level of the STCR fertilizer prescription equations by Soil Testing Laboratories is quite poor. Even though STCR based fertilizer recommendation was shown to benefit farmers in terms of increase in cropping yield and saving in cost of fertilizer, most STL still prefer for High-Medium-Low soil test based recommendation. Lack of fertilizer prescription equations for all the crops and their varieties in a region has been found one of the reasons for the poor adoption. There is urgent need for developing developing fertilizer prescription equations for all the crops/varieties through basic research on understanding relationship between crop physiology and nutrient uptake for predicting fertilizer requirement to specific crops & varieties.

Plant-led strategy for Nutrient management

Government of India has launched soil health mission in a big way. Testing soil for each of the 144 m farm-holdings and issuing soil health cards is not only difficult but also prohibitively costly. In complimenting these efforts of soil-led strategies for scheduling fertilization, an attempt may also be made for plant-led strategies like deficiency symptom-based recommendation, color chart based, etc. should be popularised among the stakeholders including farmers for easy adoption and increasing fertilizer use efficiency and upkeeping ecosystem health.

STCR fertilizer prescription equations for different modes of fertilizer application

Farmers adopt different methods of fertilizer application like broadcasting, band placement, fertigation etc. based on their convenience and implements available. All these methods lead to variation in fertilizer use efficiency. Therefore, the project should develop fertilizer prescription equations for different application methods, indicating saving in cost of nutrient management under advocated application methods.

STCR recommendation system under contingency plan to combat climate under abnormal monsoon condition

Availability of soil moisture has tremendous influence on nutrient uptake by plant and hence, nutrient use efficiency. Through research and prognosis, this AICRP should develop a system of fertilizer recommendation system based on prediction of monsoon at different regions. For this it should establish a strong linkage with meteorological departments and other governmental departments involved in extension and fertilizer distribution. Appropriate web based information dissemination system should also be generated for use by farmers and other stakeholders.

Increasing Resource generation

ICAR is committed to provide farming solutions including nutrient management technologies to resource poor farmers at free of cost. However, in view of the entry of large entrepreneurs in farming activity under changed economic scenario, considerable scope has been developed for increasing resource generation through providing site-specific nutrient management solutions to the stakeholders engaged commercial activity.

Transfer of Technology

Developing Decision Support Systems for On-line Fertilizer Recommendations to different crops for remaining states needs to be taken up. Mobile Apps may also be developed by the AICRP on STCR for by farmers and STLs on recommendation of fertilizers based on soil test values. Through transfer of technology programme, emphasis should be given for developing the Best Management Practices by integrating STCR based site specific fertilizer recommendations with the best agronomic practices and popularizing them among the farmers. Also for percolating benefits of STCR based fertilizer prescriptions to the farmers' fields, regional training programmes in local languages be organized for the progressive farmers.

(xii) Consolidated Recommendations for AICRP on STCR

Research

- Develop multi-nutrient extractant for assessing the major nutrients applied as fertilizer and fertilizer prescription method for providing faster on-time recommendation.
- The project should develop protocol for testing soils for manure recommendation for organically raised farms. This work may be done collaborating with IISS.
- Till date RDF is the basis of fertilizer prescription in STLs as well as for developing targeted yield equation in spite of changing crop cultivars and soil fertility status. Using the data generated under the project, the RDF may be revisited for use by the STLs.
- Since the initiation of the project, all the centers have generated huge amount of data on crop response to fertilizer application against soil test values during experimentation for the purpose of developing STCR equations. The centers should analyze these data to understand the basic pattern on nutrient uptake by crop types and use this information to develop fertilizer recommendation protocol for newer crops and varieties.
- Farmers adopt different methods of fertilizer application like broadcasting, band placement, fertigation etc. based on their convenience and implements available. Therefore, the project should develop fertilizer prescription equations for different application methods, indicating saving in cost of nutrient management under advocated application methods.

Technology transfer

- Each centre should develop strong linkages with KVKs of the respective state for demonstrating the technologies developed by them. Centers should also develop linkage-mechanism with State Department of Agriculture for faster dissemination of technologies and evaluate their impacts on socio-economic benefits. Only after demonstrating for 3 years and obtaining positive feedback from State Department of Agriculture, the technologies should be recommended clearly defining the geographical areas and soil conditions for which they will be valid. To achieve synergy, SAUs should combine all the best outputs from each scheme into a single package.
- For effective implementation of STCR recommendations in each state, periodical training to Soil Testing Lab personnel and KVK scientists/farmers is highly essential. Separate funds may be provided under recurring contingencies.
- AICRP coordinating unit should prepare manual for standard protocols on methods of conducting STCR experiments (including sample collections, sample storage, analysis of each parameter, record keeping of data etc.) for uniform execution of technical programmes by all the centers.

Administrative

- One contractual Senior Research Fellow may be sanctioned to centers not already having the position for carrying out work more effectively.
- The universities should adhere to the MoU and not shift experienced scientists out of the scheme.

Financial

- Due to rise in prices quality of work is affected if there is compromise in procedures or by not analyzing sufficient samples. Amount under contingency should be significantly increased depending on nature of research work, number of station trials, satellite trials, no. of working scientists, amount required for vehicle hiring, etc.
- Sufficient funds may be allocated for conducting FLDs.
- There should be some flexibility in allocation of fund allotted by the Council and Project Coordinator should be empowered to allocate fund as per the performance and work load of different centers.

F. REVIEW REPORT OF AICRP ON MICRO- AND SECONDARY NUTRIENTS AND POLLUTANT ELEMENTS IN SOIL AND PLANTS

(i) Brief History

During the initial years of the introduction of the modem crop varieties, micronutrient deficiency disorders were discovered as an obstacle to obtain higher yields. In order to delineate the micronutrient deficient areas and to alleviate the nutrition stresses, the Indian Council of Agricultural Research initiated the All India Coordinated Scheme of Micronutrient in Soils and Plants in 1967 with its National Headquarter at the Punjab Agricultural University, Hisar (subsequently shifted to Punjab Agricultural University, Ludhiana in 1970) and 6 Coordinating centre located at Lucknow, Hisar, Jabalpur, Ranchi, Anand and Coimbatore. Later Ludhiana and Hyderabad centres were also created. Realizing the need for micronutrient researches three centres viz. Akola for Maharashtra, Bhubaneswar for Orissa and Pantnagar for Uttar Pradesh was established in the year 1996 bringing the total to 11. The deficiencies of secondary nutrients and toxicities of heavy metal elements were subsequent noticed in many parts of the country which led to the expansion of the objectives. The project was re-named as All India Coordinated Scheme of Micro- and Secondary-Nutrients and Pollutant Elements in Soils and Plants. Currently the Coordinating unit of the scheme is functioning w.e.f. 28.4.1988 at Indian Institute of Soil Science, Bhopal. In the 11th plan five voluntary centres werestarted at Palampur, Jorhat, Kanpur, Ranchi and Mohanpur.

(ii) Mandate and Objectives

Mandate of the Project: To provide scientific basis for enhancing and sustaining productivity of soil resources with minimal environmental degradation with special reference to micro- and secondary nutrients and pollutant elements with following objectives.

1. To delineate and/or reassess and mapping of micro- and secondary - nutrients (MSN) deficient and toxic areas using GPS/GIS, and developing amelioration techniques for their correction.
2. Micronutrients indexing for forecasting emerging micro - and secondary - nutrients deficiencies and toxicities in crops and soils in different soil, crops and management systems.
3. Revisiting the critical limits of micro and secondary nutrients and establishing phytotoxic limits of heavy metals in different soils and crops including vegetables.
3. To develop suitable techniques for increasing fertilizer-use-efficiency along with inclusion of nano-fertilizers, organic manures, sewage sludge for ameliorating the MSN deficiencies in crops and soils.
4. To monitor health hazards from heavy metal or trace element pollutant in soils, plants and animals.

5. To develop agronomic biofortification approaches for micronutrients enrichment and to identify mechanism and processes of micronutrients enrichment and their role in reproductive physiology.
6. To study micronutrients in soil-plant-animal and /or human continuum
7. To disseminate micronutrients technologies through frontline demonstration and suitable publication for enhancing the micronutrients use and its impact on soil, animal and human health and crop productivity.

(iii) Structure and organization

Project coordinator works under the technical advice and instructions from the Deputy Director General (NRM) and Assistant Director General (Soils), Indian Council of Agricultural Research (ICAR), New Delhi, in association with Director, Indian Institute of Soil Science, Bhopal. Functionally, Project Coordinator is independent to carry out the technical programme, release of funds and deal various financial and other matters independently to SAUs centers, ICAR and out sourcing centers. Coordinator plays a key role in planning, coordinating and monitoring the research programme of the centers. Coordinator prepares the budget/EFC memo, gets proper allocation approval and monitors the expenditure, obtains the audit utilization certificates from the centers and releases grants to the centers. Project coordinator prioritizes the research work in workshops and, helps in programme planning based on local needs and assists in execution. The technical programme of each centre is planned in the workshop through collaborative efforts of project coordinator, scientists of the project, ICAR (NRM) representatives and subject matter specialists, state extension agencies and other state university representatives. The workshop is organized biennially and group meetings are conducted annually. The Project Coordinator monitors the research programme implementation by visiting the centers and holding discussions with the scientists and other authorities of the centers.

At present different centres (including P.C. Unit at IISS, Bhopal) of the project has a total sanction strength of 111 in XII plan which includes 1 Project Coordinator, 40 Scientific, 20 Research Associates/Fr. Res. Fellows, 53 Technical, 5 administrative and 12 supporting staff (Table) The project coordinating unit has sanctioned strength of 12 positions, which include one project coordinator, three scientists, two technicians, one field assistant, one steno, one clerk, one assistant, one laboratory attendant and one messenger. The positions of two scientists and one TA (Computer programmer/GIS-GPS) remained vacant so far and needs to be filled on priority. Administrative and financial staff provided to the project is working under the control of Administrative Officer at the Institute. The Project Coordinator is provided support in administrative and financial matters by the IISS.

A. Details on locations of AICRP centers

Location	Date of start	State	Agro-ecological region	Soil type
Project Coordinating Unit				
IISS, Bhopal	24.4.1988	Madhya Pradesh	Central high land (Malwa and Bundelkhand) hot sub-humid, Grid Northern Plain and Alluvial central hot semi-arid region	Medium and deep black alluvial soil
Cooperative Centres				
CCSHAU, Hisar	01.01.1967	Haryana	Western plain and Kutch peninsula hot arid	Desert & saline soils, silty-alluvial soils
RAU, Pusa	01.12.1967	Bihar	Eastern plain, hot sub-humid	Alluvial, clayey, red and lateritic
TNAU, Coimbatore	14.08.1967	Tamil Nadu	Eastern Ghats T.N. upland) & Deccan Plateau, hot semi-arid and hill soils	Red loamy soil black clay and red & lateritic soils
AAU, Anand	01.01.1967	Gujarat	Central (Malwa) high lands and Kathiawar	Medium and deep black, alluvial soils
Lucknow University	01.04.1967	Uttar Pradesh	Northern plain, hot sub-humid (Plant physiological research)	Alluvium derived and Tarai soils
JNKVV, Jabalpur	01.01.1967	Madhya Pradesh	Central high lands (Malwa & Bundelkhand hot sub-humid)	Medium and deep black soil, red and black, alluvial
PAU, Ludhiana	10.10.1970	Punjab	Northern plain and Central highland hot semi-arid	Alluvium derived (Alluvial, sand to sand loam soils)
ANGRAU, Hyderabad	01.08.1975	Andhra Pradesh	Deccan plateau & Eastern Ghats, hot semi-arid	Red and black soils
GBPUAT, Pantnagar	01.04.1996	Uttaranchal	Hill and tarai region, hot sub-humid	Alluvium derived and Tarai soils
PDKV, Akola	01.04.1996	Maharashtra	Deccan Plateau, Hot semi-arid	Medium & Shallow black soil
OUAT, Bhubaneshwar	01.04.1996	Orissa	Eastern Ghat hot sub-humid	Red loam, red and lateritic soils

Table 4 b. Location of the new adhoc centers

Location	Date	State	Agro-eco. region	Soil type
CSKHPKV Palampur, H.P.	1-4-2009	Himachal Pradesh	Hill, sub humid	Hill &mountainous soils , alfisol
CSUAT, Kanpur.U.P.	1-4-2009	Uttar Pradesh	Northern plain , hot semi-arid	Alluvium derived Indo Gangatic alluvial soil
Assam Agril. Univ. Jorhat, Assam	1-4-2009	Assam	Hot sub-humid	Alluvium, hill, red, lateritic soils
BAU, Ranchi, Jharkhand	1-4-2009	Jharkhand	Eastern Santhal pargana hot semi-arid,	Red loam, red and laterite soils
BCKV,Mohan-pur, West Bengal	1-4-2009	West Bengal	Hot sub-humid	Alluvium, hill, red and lateritic soils

(iv) Major Research Achievements

<u>Research</u>

(a) Diagnosis and characterization of micro* and secondary *nutrient disorders in plants

- The visible symptoms of Fe, Mn, Cu, Zn, Mo and B deficiencies in maize, cabbage, cauliflower, mustard, sesame, pea, tomato, radish, potato, bottle gourd, spong gourd, lime bean and spinach and S deficiency symptoms in oilseed, pulses and in cereals crops were critically studied and catalogued through colour photographs. Physiological and biochemical reactions against micronutrients deficiencies in different crops were also documented for public use.

(b) Delineation and reassessment of secondary and micronutrient deficient areas

- Mapping of micronutrients deficiency in different agro-ecological sub regions (AESR) was performed using 1.94 lakh georeferenced soil samples, collected across the country and also taken from other studies. These digitized maps of micronutrients status will be highly useful in formulating strategies to alleviate their deficiency and help policy makers and industries to produce and distribute the right kind of micronutrient fertilizers in different agro ecological regions of India. Average deficiency of different micro and secondary nutrients are: 36.7% for DTPA-extractable Zn; 12.8% for Iron; 23.2% for B, 7.1% for Mn, 4.2% for Cu and 28.5% for S.
- Multiple micro/secondary nutrient deficiencies for, S+Zn (11.5%), Zn+Fe (5.8%), S+B (6.5%), S+ Fe (4%), Fe+B (3%), Zn+B (9.8%), S+Zn+B (2.7%), and S+Zn+Fe (2.2%) has been noticed in different states.

(c) Refinement of critical limits for micro- and secondary nutrients in soil and plant

- Based on large number of field experiments and crop response to micronutrients and sulphur a generalized transition zones were worked out for different nutrients across the soil types. The first 3 categories indicate level of deficiency (acute deficient, deficient, marginal deficient) and next 3 levels specify adequacy (marginally sufficient, adequate and high).

(d) *Evaluated extractants for assessing soil available nutrients*

- Salicylic acid method was found more suitable for the extraction of soil available B in acidic soils. For Zn, Cu, Fe and Mn, both AB-DTPA and DTPA extractants were found to be equally good.

(e) *Dose and frequency of Zn and B application*

- Optimization of fertilizer Zn and B dose and its frequency of application in various cropping system grown on different soil types of India were for rice-rice, rice-wheat, maize-wheat, soybean-wheat and rice-maize cropping system at Coimbatore, Ludhiana, Anand, Pusa, Kanpur, Jabalpur, Hisar, Akola and Bhubaneswar. The results revealed that in most of the soil application of 2.5 kg Zn ha^{-1} every year or 5 kg of Zn ha^{-1} every alternate year is sufficient to meet Zn demand of the crops at moderate yield level. In case of B, application of B @ 1.5 kg ha^{-1} applied in alternate year or 1.0 kg B ha^{-1} applied every year could fulfil its demand in different crops.

(f) *Amelioration of micro- and secondary nutrients deficiencies and enhancing nutrient use efficiency*

- Amelioration techniques were developed for S deficiency in rapeseed –black gram sequence in Assam, in onion in Vidarbha region of Maharashtra; for Zn deficiency in maize-maize cropping system in Hyderabad, for Zn and Fe deficiency in apple at Garsa valley of Kullu; for B and Zn deficiency in rice-wheat cropping system under red and lateritic soils of Jharkhand; for Zn and B deficiency in rice-rapeseed sequence at Jorhat; for sulphur and boron deficiency in rapeseed at Jorhat.
- In view of developing slow-release Zn fertilizer, Zn loaded nano clay polymer composites (NCPCs) were synthesized and experiment was carried out to assess the fixation of Zn in different soils applied through NCPC and $ZnSO_4$. Results indicated that use efficiency of applied Zn through NCPC was 11.77% against 1.39% in case of $ZnSO_4$. There was no adverse effect of NCPC on root length at different growth stages of wheat.

(g) *Heavy metals pollution and their remediation*

- Heavy metals pollution was assessed in the *peri*-urban areas of Latur and Nanded districts of Maharashtra, in sewage and industrial effluents irrigated areas of Jajmau (Kanpur), in sewage and industrial effluents irrigated areas of Ludhiana, and in untreated municipal sewage effluents irrigated areas around Musi river at Hyderabad.
- Background levels of heavy metals were determined in the soil of selected benchmark sites of the Haryana. Results revealed that the content of major heavy metals *viz.* Pb, Cd, Ni, Co and Cr varied from 0.02-6.00, 0.01^{-1} .92, 0.01^{-1} .66, 0.02-2.00, 0.07-0.28 mg kg^{-1} in soils of different states of Haryana. The district level maps showing the

spatial distribution of these heavy metals in soils of Haryana have been prepared.

- Phytoextraction efficiencies of three plants (raya, Lemon grass, and Vetiver) were evaluated for Cd removal from contaminated soil. Different synthetic chelates like EDTA and DTPA significantly enhanced the concentration of heavy metals in plant shoots.

Technology transfer

The farmers across the country were educated about the new technologies generated in the project for enhanced crop production in micronutrient deficient sites through frontline demonstrations. About 1365 FLDs were conducted to show responses of zinc, iron, boron, manganese on oilseeds, pulses and major cereal crops in different agro-ecological zones.

(v) Linkages with clientele/end user

Good linkages with departments of horticulture and plantation crops at various SAUs were developed. In order to study micronutrients in soil-plant-animal/human continuum, collaboration with AIIMS, Bhopal and veterinary colleges under different SAUs have been established.International linkages have been established with International Zinc Association, International Plant Nutrition Institute, Albion, USA and OCP, Morocco for exchange of knowledge and financial support for micronutrient research.

The centers of the project are having good linkages with the KVKs and extension agencies of the states/SAUs for dissemination of micronutrient technologies generated through AICRP-MSPE.

(vi) Human, Physical and financial Resources

Financial Resources

Head-wise break up of budget (Rs in lacs) of AICRP on MSNPE is given below:

Head-wise budget for XIIth Plan actually spent

Allocated Budget in EFC	Rs. in lakhs
Grant-in-Aid Capital	615
Grant-in-Aid Salary	2662.9
Grant-in-Aid General	1550
Total budget allocated in EFC	4827.9
Actual expenditure	3338.26

(vii) QRT Observation on outcome from different centres

CSKHPKV, Palampur

Insufficient number of samples have been analysed to generate the deficiency map of a region or state. If sampling and analytical errors are included, then accuracy and usefulness of such deficiency map becomes doubtful. It is suggested that micronutrient deficiency may be predicted on the basis of available information on soil properties whose effectiveness may be validated in some selected locations. Delineation work may be discontinued.

GBPUAT, Pantnagar

PI indicated that more than 3000 samples have been used for preparing micronutrient and sulphur S status map for whole Uttarakhand State. Soil application of Nanoparticles of Zn and P minerals are efficient in supplying nutrients to plant. For future research plan, PI proposed to work on biofortification, refinement of critical limits and study on soil-plant-animal - human Continuum.

Nanoparticles can interact strongly with the soil particles through several forces limiting their movement within soil matrix. Basic process of interaction and translocation of nanoparticles within soil matrix should be investigated for proper explanation of observed higher efficiency of Nanoparticles of Zn and P minerals. Focus of research should be on developmentof specific Technology or Product. QRT expressed apprehension that it may not be quite easy to conclude anything from the study on soil-plant-animal-human continuum unless subjects of the study are confined and controlled in respect of their movement.

Lucknow University, Lucknow

Though deficiency symptoms are useful for plant-led strategy to manage micronutrients stress, usefulness of such strategy is however doubtful as deficiency symptoms appear at the later stage of plant growth when there is a little scope for micro nutrient management.

CSAUAT, Kanpur

The centre did not analyze results properly to draw any meaningful conclusion.The center concentrated mainly on the delineation study with only 17000 samples analyzed during 5 years period for whole Uttar Pradesh. However the maps are not prepared based on GPS GIS data.Exceptionally high heavy metals have been reported in sewage effluents and smaples have beenanalysed for heavy metals with flame AAS, even though this instrument is not normally recommended because of itspoor sensitivity and detection limits for most of the heavy metals.

PAU, Ludhiana

No relation was observed between plant concentrations of Zn, Ni and Fe with their contents in animal blood serum in the study on micronutrients in soil-plant-animal continuum. In future, such research on soil-plant-animal continuum should be undertaken by any centre only when existence of problem on nutrient deficiency in animal and human is reported. Technical program under this AICRPhas not been changed significantly for several decades and therefore, reorientation of the technical program is required based on the achievements obtained so far and in view of national priorities. The centre reported that there is no multi micronutrient deficiency in Punjab. However the Project Coordinator's report indicates existence of multi micronutrient deficiency. Such contradiction in the results may be looked into.

Hisar centre

As 85% of the area is sufficient in Zn, the centre should go for screening of zinc responsive crop varieties instead of screening for low-zinc tolerant varieties. Protocol for soil-plant-animal continuum study should be developed so that meaningful and appropriate conclusions can be obtained and such study should be undertaken only if existence of problem on nutrient deficiency in animal and human is reported. Interaction between soil moisture and micronutrients under different tillage practice conditions should be studied after identifying the knowledge gap in the previously generated information. Maps under AICRP are being prepared with approximately 150 samples per district. However, number of samples should depend on spatial variability asit may be erroneous to draw any conclusion from such map prepared with insufficient samples and may be ineffective to devise any strategy based on this.

IARI, New Delhi

The center has been initiated in the year of 2015 and is working on enhancing Zn use efficiency through nano-clay-polymer composite. This work may be continued to develop appropriate technology for the benefit of farmersafter suffieient field verification.

TNAU, Coimbatore

The critical limit of 1.2 ppm DTPA Zn in soil followed by the centre should be verified with field observations. Research on zinc biofortification by agronomic means should be discontitued asits application in soils or crops only for increasing the concentration of zinc may not be farmers friendly due to additional investment on fertilizer and labour. Instead the centre should work on screening the existing varieties of cereals of the area which are efficient in zinc accumulation in grain. AICRP on micronutrient should work on predicting zinc deficiency based on the generated information on soil, cropping systems and climatic characteristics.

PJTSAU, Hyderabad

The centre proposed to conduct experiments on revisiting critical limits in soil in view of high phosphorus accumulation in the soil observed in the area. The proposed work to develop sensors for soil testing of micronutrientsmay be undertaken in collaboration with some Technological Institute.

GKVK, Bengaluru

The centre should collaborate with IIHR, Bengaluru for determining critical limits for horticultural crops.

KAU, Vellanikara

In view of scares availability of Ca and Mg, the centre should work on to devise feasible alternate strategy to counter their in the region. The centre should work on redefining critical limits for micronutrients, suitable magnesium source and developing multi micronutrient mixture for horticultural crops.

NIANP, Bengaluru

The centre worked on zinc fortification in fodder crops and their assimilation by animals.The work on biofortification through agronomic means may not be feasible when zinc use efficiency in soil is very low and farmers cannot afford extra investment without any appreciable yield benefits to them.

AAU, ANAND

The work on developing multinutrient extractant should include all the major and micronutrient in order to be more relevant in its purpose. In respect of research on micronutrient in soil-plant- human-continuum, it is suggested that the centre should identify the problem and then address the issue with appropriate methodology. More research focus should be on increasing use efficiency of micronutrient fertilizers. The centre should use available micronutrient minerals for preparing nano-micronutrient fertilizers. In respect of biofortification research, the centre should focus on identifying efficient variety of crops which can be adopted easily by the farmers. Standard protocol for sampling of soils and plants to determine critical limits should be adopted.

PDKV AKOLA

High extent of B deficient soils (26 to 66%) in the stateshould be ascertained through field response study. There should be a mechanism for quality control of data generated by different centres of AICRP on MSNPE. Delineation study should be discontinued. Critical limits for micronutrient should be developed through field study. Increasing use efficiency of micronutrient fertilizers should be given more focus. The centre should attempt research on mobilizing the already applied but immobilized micronutrients in soil particularly zinc so that their efficiency can be increased. The centre should prioritise research based on the already generated information and keeping in view of farmers' requirement, constraints in manpower and fund available.

RPCAU, Pusa Centre

Data on soil chemical properties and available micronutrient contents should be critically analysed to generate some basic knowledge which can be useful in predicting micronutrient availability status in soil.

Nutrient index data did not conclude sufficiently on the changes in micronutrient status. Results on critical limits of micronutrients are highly confusing as limits varied with varieties of same crop. Study toexploreuniversal extractant was not scientifically conducted. Yield levels of rice and wheat in the long-term experiment are quite low indicating poor management of the experiment. At this low yield levels, how anything can be concluded from the results.

OUAT, Bhubaneswar

Reasons for changes in the status of available micronutrients in soilof the state over time should have been explored; otherwise no strategy can be formulated based on these observations. Results on zinc fractionation study in soil should be critically analyzed in order to utilize the information for modifying recommendation to farmers. The centre should have a plan in the research program to mobilize Zn built up in the residual fraction due to continuous application of zinc fertilizer. Revisiting of critical limit should be undertaken only if there is any problem with the existing critical limits.

JNKVV Jabalpur

The center should clearly state the deliverables from the delineation study and crop uptake data. No more delineation study should be carried out by the centre in view of soil health card mission program in the country.Fate of micro and secondary nutrient fertilizer applications in conservation agriculture should be studied.All the centers should conduct comprehensive analysis of samples in the experiments and analyze the data critically and subsequently develop prediction model for recommendation.Results showing wide variation in the zinc content in the grain (6 to 30 ppm zinc) and in blood samples should be relooked.

Assam Agricultural University, Jorhat

Number of data points for field based critical limits determination is less. The experiment on determining suitable extractants is conducted in collaboration with North Bengal Agriculture University at Coochbehar. Observation on acid soils of Assam showing crop yield response to zinc application may be re-confirmed at farmers' field level and reason may be explored. None of the AICRP micronutrient centers are analyzing detailed soil properties for the experimental sites which are hindering basic information generation and interpretation of data.

Birsa Agricultural University, Ranchi

The centre should not continue study in respect of heavy metal toxicity as no such toxicity has been reported in this area.The center analyzed more than 25000 samples in 2 years for preparation of soil health card. The centre should use these data to prepare soil fertility map as the samples were collected using GPSby the scientists of the project. It should develop fertilization protocol in respect of micronutrients for vegetable growing area.

BCKV, Kalyani

The center used quite less number of samples for determining critical limits of micronutrient. The centre should re-determine and validate the critical limit as rice crop responded to zinc fertilizer application even when available Zn status in the experimental soil is higher than experimentally determined critical limit. In view of the considerable information generated and identified problems, the center should concentrate more on heavy metal research in soil-plant-human Continuum involving experts from the medical field.

Central Agricultural University, Imphal

The centre concentrated research on developing technology on micronutrient fertilizer application for fruit crops.

(viii) Overall performance of AICRP on MSNPE centres

Outstanding: GAU Anand, OUAT Bhubaneswar, JNKVV Jabalpur, BCKV Kalyani, TNAU Coimbatore

Good:PDKV Akola, AAU Jorhat, CSKHPKV Palampur, CAU Imphal, IARI New Delhi, ANGRAU Hyderabad, KAU Thrissur, UAS Bengaluru, GBPUAT Pantnagar

Fair: PAU Ludhiana, BAU Ranchi, RAU Pusa, NIANP Bengaluru.

Poor: CCSHAU Hisar,CSAUAT Kanpur, Lucknow University Lucknow

(ix) Overall Assessment of AICRP on MSNPE centres

As per the technical programme, the project has continued its work on micronutrients delineation, deficiencies and their management in field crops and delivered very good output on some of its objectives. However, the project should work on developing decision support system for forecasting emerging nutrient deficiencies in different soil-crop production systems. In addition to increasing use efficiency of Zn and B, the important issue of enhancing grain yield vis-à-vis grain Zn/Fe concentration needs to be addressed through comprehensive research.

(x) Visioning for the Future

Deficiency of micronutrients is widely prevalent among plants and human beings affecting productivity of both. Through considerable researches during past several decades, vulnerable areas requiring intervention have been identified. As human population is largely dependent of food produced from agricultural land, understanding micronutrients flow through soil-plant-animal/human pathway is extremely important. Mechanism of role-partitioning of micronutrients with plants (i.e. physiological role for stimulating yield vis-à-vis their enrichment in edible component) is quite complex, though both are important for nutritional security and better health of human population. Hence, the micronutrient deficiency issue in both crops and human population needs to be addressed through several ways; research to better understanding on the role-partitioning and management of micronutrients in soil and crop, delivery of fertilizers to the needy crop land, creating social awareness on micronutrient rich foods etc. Accurate identification of micronutrients deficient crop land is extremely important, otherwise investment on its fertilization (unlike macro nutrients) may produce no or negative outcome. Even after decades of research use efficiency of micronutrient fertilizers remains significantly low. There is a need for enhancing use efficiency from the existing value of 2-3%. Enriching germplasm with micronutrients through conventional breeding methods, molecular breeding and genetic engineering is a promising method for increasing dietary access to micronutrients. Thus bio-fortification is a sustainable intervention being a seed- based technology. Although developing new crop varieties is domain of geneticists and biotechnologists, existing crops & varieties in a region should be screened for higher accumulator of micronutrients in edible portions. Plant diseases and insects continue to play a major limiting role in agricultural production. The control of plant diseases using classical pesticides raises serious concerns about food safety, environmental quality and pesticide resistance. Potential of micronutrients and trace elements in imparting resistance to diseases and insects in plants has been documented. However, such study has not been conducted adequately, particularly in India as required for using these elements in plant protection.

(xi) Consolidated Recommendations on AICRP on MSNPE

Research

- The methodology used for studying Zn biofortification in cereals needs to be comprehensive and robust including at least the magnitude of response in yield, contents of phytic acid and other antinutrients and promoters, and bioavailable Zn and Fe contents in the ultimate processed foods on Zn fertilization, if the net bioavailability could not be assessed through animal-experiments.
- Micronutrient fertilizers are costly and their use efficiency by crops is very low hardly exceeding 1-2%. Concerted efforts may be made to enhance the use efficiency (in quantitative terms) of such fertilizers either through development of new products/fertilizer materials or through modifications in application/ soil management methods or identifying elite crop cultivars using robust protocols.
- Industrialization has profound influence in polluting the agricultural lands in urban and peri-urban areas. In view of increased industrial and urban activities in the country, there is a need to identify the critically polluted agricultural area and to assess the impact of pollutants on human and animal health so that necessary remedial and management related actions can be undertaken for safe food production. This programme may be restricted to centers with good instrumental facilities required for analysis of heavy metals like ICP-OES, ICP-MS or AAS coupled with graphite furnace.
- A monograph for standard protocols may be prepared and followed for analyzing soil and plant samples and conducting experiments on micronutrient and pollutant elements for ensuring uniformity and comparing results across the centers.
- Thousands of soil and plant samples are analyzed in the project for mapping and delineating deficiencies across the country with huge cost. As micronutrients availability in soils is a function of soil properties, attempts may now be made to predict their availability in soils and to plants developing predictive models using analyzed soil properties in uncovered/unexplored areas. Huge database generated under Soil Health Mission, may also be utilized for this purpose.

- The technical programme of this project had been devised and continuing since several years. Many of the objectives either have been achieved or become irrelevant in the present context. Hence, there is a need for prioritizing the research programmes for each centre based on existing problems as well as expertise and resources available at the Institutes and Universities. There should be time-bound target for achieving the objectives of each of the technical programme.

Transfer of Technology and Training

- Each centre should develop strong linkages with KVKs and State Department of Agriculture of the respective state for demonstrating the technologies developed by them. Technologies should be recommended clearly defining the geographical areas and soil conditions for which they will be valid. To achieve synergy, SAUs should combine all the best outputs from each scheme into a single package.

Administrative

- The universities should adhere to the MoU and should not shift experienced scientists out of the scheme.

Financial

- Since micronutrient research involves costly chemical and repair maintenance and moreover, the labour wages and cost of other inputs has risen exorbitantly, hence quality of work is affected if there is compromise in procedures or by not analyzing sufficient samples. Amount under contingency should be increased significantly depending on work load and past performance of the centers.
- For providing contractual PDF/RA/SRF, Vehicle hiring, replacement of old equipment, purchase of generator, establishment of advanced laboratories etc., funding may be enhanced.
- Where the Atomic Absorption spectrophotometers are obsolete and run down with long usage, they should be replaced with new AAS or ICP-OES on priority so that quality of analysis is maintained.

G. REVIEW REPORT OF AINP ON SOIL BIODIVERSITY-BIOFERTILIZERS

(i) Brief History

The All India Network Project on Biofertilizers was initiated in 2004 during the X plan as a successor of the All India Coordinated Research Project on Biological Nitrogen Fixation (1978-2004) with 11 cooperating centres in various geographical regions. The scope of the project was expanded in XI plan to include work on soil biodiversity. The functions of the AINP on Soil Biodiversity-Biofertilizers are to conduct basic, strategic and applied research on various aspects of soil biodiversity and biofertilizers for cropping systems all over India relevant to the agro-ecological regions, test the superior cultures of biofertilizers in experimental stations, transfer the technology to farmers through demonstrations, supply mother cultures to manufacturing units in the universities and in private sector and popularize the biofertilizer technology. Presently there are 18 centres operating mostly at State Agricultural Universities in different locations of India

(ii) Mandate and Objectives

Mandate: To enhance the productivity, soil and crop quality and supplement a part of the chemical fertilizer needs of crops through exploiting the soil biodiversity extant, for Biofertilizers in diverse cropping systems and agro-ecological zones in India, improve Biofertilizer technology and extend the Biofertilizer applications to disadvantaged areas.

Objectives:

- To exploit the soil biodiversity in various agro-ecologies for biofertilizer applications in diverse cropping systems.
- To study the impact of soil management practices on microbial functions and soil health
- To improve biofertilizer technology to ensure high quality and improved delivery.
- To diversify biofertilizer research and application in drylands, mountainous regions, tribal areas

(iii) Priorities, Programmes and Projects

Thrust Area for XII plan

- Genetic Diversity of Rhizobia
- Soil Genomics for Soil HealthAssessment
- Microbial Diversity and Biofertilizers in Eastern India
- Diversification of Biofertilizer Usage

(iv) Structure and Organization

The Coordinating Centre of the AINP on Soil Biodiversity-Biofertilizers is located at the Indian Institute of Soil Science, Bhopal. The research work of the 18 centres as formulated and approved in the EFC document is coordinated by the Project coordinator with guidance from DDG (NRM), ADG (Soils), ICAR and Director, IISS, Bhopal.

Centres of the AINP SBB project

During the period of 2012-17, the project was being implemented at 18 centres of the project located at:

1. *Assam Agricultural University, Jorhat.*
2. *Acharya N.G.Ranga Agricultural University, Amaravathi, A.P.*
3. *CCS Haryana Agricultural University, Hisar.*
4. *Jawahar Lal Nehru Krishi Vishwa Vidyalaya, Jabalpur, M.P.*
5. *Marathwada Agricultural University, Parbhani, MS.*
6. *Orissa University of Agriculture and Technology, Bhubaneswar.*
7. *Rajendra Agricultural University, Pusa, Bihar.*
8. *Tamilnadu Agricultural University, Coimbatore.*
9. *Y.S.Parmar University of Horticulture & Tech., Solan, H.P.*
10. *Birsa Agricultural University, Ranchi, Jharkhand.*
11. *M.P.University of Agriculture and Technology, Udaipur, Rajasthan.*
12. *Indian Agricultural Research Institute, New Delhi.*
13. *Directorate of Groundnut Research, Junagarh, Gujarat.*
14. *Delhi University, Delhi.*
15. *University of Agricultural Sciences, Dharwad, Karnataka.*
16. *Central Rice Research Institute, Cuttack, Orissa and Reg. Stn., Hazaribagh, Jharkhand.*
17. *Kerala Agricultural University, Thrissur and Vellayani*
18. *G.B.Pant University of Agriculture & Technology, Pantnagar*

(v) Management Practices

The project is executed in collaboration with SAUs and other universities and ICAR institutes. At each location researchers are appointed for implementing the programme. Council bears the 75% cost of the programme and the remaining 25% is added by SAUs. Project Coordinator holds discussions with the scientists of the centre and other authorities of SAUs to facilitate the work of centre. Project Coordinator is responsible for monitoring and implementation of the programme as per approved plan. The head quarter provides administrative and financial support from time to time.

(vi) Major Research Achievements

The project work focuses on continuous exploration of soil biodiversity with respect to plant growth promoting rhizobacteria and rhizobia in all the major agricultural production zones of the country. Soil genomic are carried out to identify the microbial groups adversely affected by unsustainable agricultural practices like extremely high rates of chemical fertilizers or pesticides. The major theme-wise achievements are:

Soil Biodiversity

I. In soils from 100 year permanent manurial trial at Coimbatore, biological properties and enzyme activity in soil was unaffected due to long-term use of inorganic fertilizers. Organic manures favoured the proliferation of two eubacterial phyla - Acidobacteria and Actinobacteria. Balanced inorganic chemical fertilization had no deleterious effect on microbial diversity and functionality as well as the soil processes including respiration and soil enzyme activity.

II. In farmers' fields in tropical Vertisols in Guntur, there were adverse consequences of `very high‟ fertilizer and pesticide usage on soil microbial diversity and function in tropical Vertisols but not at recommended doses.

III. Using metagenomic tool, differences in soil eubacterial community structure and function in organic and chemical farming in soybean and maize at Dharwad were found subtle rather than dramatic.

IV. Through a major Programme on "Genetic Diversity of Rhizobia of Indian Soils", 2000 rhizobial strains of 20 major legumes were isolated and characterized from the major growing zones and soil types in Andhra Pradesh, Madhya Pradesh, Gujarat, Rajasthan, Haryana, Uttar Pradesh and Jharkhand. Work on 16s rDNA, *nif* and *nod* gene diversity was carried out in groundnut, soybean and other major legumes.

V. *Bradyrhizobium japonicum* USDA 110, the strain originally introduced on a large scale in Indian soils more than four decades ago, shared 34-81 % phenotypic and 63-83 % genotypic similarity with rest of the Indian rhizobial isolates. There was conservation of 16S rRNA gene sequences among rhizobia in various soybean growing areas and the evolution of native rhizobial strains among slow and fast growers.

VI. Proteomic analysis of *Rhizobium* isolates of grain legumes carried out in acidic soils of Jharkhand. **S**everal important and "*unique*" protein differences were detected in isolates from normal and acidic pH reflecting the adaptive changes for survival and also post-translational modification of proteins and the presence of iso-forms. Genes were identified in imparting tolerance to acidity.

VII. In *`Haveli'* system of rain water management system in central India, benefits of rain-water conservation in Vertisols were unequivocally demonstrated for carbon sequestration and nitrogen accretion and improvement of soil biological quality.

VIII. Microbial diversity in rice soils of NEH region was explored and effective strains of biofertilizer organisms cultured and deployed. More than 100 efficient cultures from diverse zones of NE region were preserved for use as biofertilizer agents.

IX. P, Zn, and K-solubilizing plant growth promoting strains, CRIDA strains PSB-1 (*Burkholderia cepacia*) and PSB-3 (*Burkholderia cenocepacia*) with abiotic stress tolerance were isolated and screened in Vertisols and found effective. *Bacillus methylotrophicus* SMa5A isolated from apple rhizosphere has been reported as PGPR for the first time.

X. Actinomycetes from arid and semi arid regions of Rajasthan and Karnataka were characterized. They exhibited plant growth promoting attributes in culture and in field studies significantly improved maize and chickpea yields.

XI. The arbuscular mycorrhizal fungal diversity under rainfed rice based cropping systems showed that *Glomus* was the predominant genus in uplands with mostly aerobic soil conditions; while medium lands under transplanted rice with mostly anaerobic soil conditions was dominated by *Gigaspora*.

XII. Bioinoculants developed for tropical vegetables in acid alfisols of Orissa in the tribal areas enhanced yields and brought considerable fertilizer savings of plant nutrient cost incurred for N and P. Biofertilization improved produce quality (Vitamin C, curcumin, lycopene).

Biofertilizer Technologies developed

I. **Suppressing soil borne fungal pathogens**:
Stem rot (*Sclerotium rolfsii*) and collar rot (*Aspergillus niger*) are major diseases of groundnut in Gujarat. Seed inoculation of groundnut @ 5-6 ml/kg seed with *Pseudomonas putida* producing DAPG4 were found quite effective in controlling these fungal pathogens and enhancing yield upto 20%. Repeated application of DAPG-producing fluorescent pseudomonas makes the soil naturally suppressive to soil-borne fungal pathogens.

II. Microbial consortia for enhancing yield:
Mixed microbial consortia have been developed for groundnut at Junagarh (Gujarat), wheat in Vertisols of Jabalpur (M.P.), and black gram in rice-fallow at Amravati (A.P.), rice in Eastern India.

III. A new microbial formulation “Biomix” (Azotobacter, Azospirillum and PSB) as seed inoculants @ 50ml/kg seed of Bajra crop was released at CCS HAU, Hisar and included in Package of Practices of the state government.

IV. Microbial Consortium for Rice in Eastern India: A sustainable and economic bionutrient package for rice was developed based on Pseudomonas-enriched mycostraw, Azospirillum, and cyanobacteria. Validation under participatory mode for consecutive five years showed an increase of yield of 10 % in resource rich and 20 % in resource poor farmers over the farmers‟ conventional practices.

V. Microbially enriched compost in NEH region: Normal farm compost was converted to superior bio-enriched compost by amending with 1% P as Rock Phosphate plus inoculating Azospirillum/Azotobacter and PSB broth culture @ 1% (v/w) each and curing for a month. C: N ratio of final product stabilized at 10-12 : 1, with increase of Azospirillum/Azotobacter and PSB by 300- 400 times and 6 times, respectively. Use of bio-enriched compost @ 1 t/ha minimized the N and P fertilizer requirement by 50% in rice- toria and rice- wheat sequence.

VI. Demonstrations in different regions of North East on dual culture of *Azolla caroliniana* enhanced rice yield upto 4.8 t/ha and reduced nitrogenous fertilizer use. The technology benefits have been well dessiminated in North East region through 10 KVK‟s.

VII. PGPR for biocontrol of white root rot of apple: PGPR - *Bacillus licheniformis* was isolated which completely controls white-root-rot caused by *Dematophora necatrix*. It increases root shoot length and biomass by about 20 % over uninoculated control. Apple seed is treated with liquid bacterial formulation @2.5 mL/Kgafter stratification before sowing. The left over culture is drenched in the bed.

VIII. Biofertilizers for Temperate Vegetables: Biofertilizers for green peas (*Rhizobium leguminosarum*) saved 10 kg N/ha, gave B:C ratio of 1:7. PGPR inoculation of cauliflower (1000 ml liquid inoculum per 1000 g seed before sowing and seedling dip in 2000 ml inoculum at the time of transplanting) gave 24% additional yield, B:C ratio of 1:5 besides saving 25% NP.

IX. Liquid Biofertilizer technology: Liquid inoculants were formulated for *Rhizobium, Azospirillum* and *Bacillus* strains by using cell protectants like arabinose, trehalose, glycerol, polyvinyl pyrrolidone (PVP) in different combinations. It enhanced the shelf life upto12 months in liquid inoculum with high cell counts. There was 15% grain yield increase by liquid inoculants over solid carrier based inoculants in combination with 75% RDF in Maize on Vertisol in A.P.

X. About 924 frontline demonstrations were conducted under this project to evaluate and demonstrate efficacy of biofertilizers in improving crop yields.

(vii) Collaboration with SAU's and other research institutions

The collaborative links with state departments of agriculture in all states are very strong. FLD's are conducted in farmer fields to verify technology generated. This is done through KVK's also. Biofertilizer strains were also tested in collaboration with AICRPs on Groundnut, Vegetables, Pulses, Dryland project and some NAIP projects in Orissa. At AAU, Jorhat, Cultures are supplied to AICRP's on Maize, Agrostology, Floriculture and to IFFCO. Collaboration with Soil Science Departments to study microbial diversity in permanent trails at Coimbatore, acid tolerant rhizobial strains at Ranchi. Collaboration with NBAIM, Mau was strengthened through AMAAS project.
The mother cultures of Azospirillum, Azotobacter, Phosphate Solubilizing Bacteria and Rhizobium (Pea, Lentil, Greengram and Blackgram) evaluated under the projects was supplied to 12 different biofertilizer production units located across India.

International:
Newton-Bhabha Fund of the Department of Biotechnology (DBT) in India and the Biotechnology and Biological Sciences Research Council (BBSRC) in the UK funded a project "India UK nitrogen fixation centre". Project duration is three years starting from 2016. There are 3 VJC's on Nitrogen Fixation in UK (University of Oxford, UK; John Innes Centre, Norwich; James Hutton Institute, Dundee) and 7 in India (IISS, Bhopal; M.S. University of Baroda; NBAIM, Mau; University of Calcutta, University of Hyderabad; I.A.R.I, New Delhi and TERI, New Delhi.

(viii) Linkage with clients/end users

More than 5000 packets (200g each) of *Azotobacter*, *Rhizobium*, *Azospirillum* and PSB were prepared and supplied to farmers. In addition 1000 packets of BGA inoculant and 500 packets (1 and 5 kg) of AM inoculant were prepared and supplied (IARI, New Delhi 2012-

14). Large scale commercial production of biofertilizer was undertaken at biofertilizer unit VN Marathwada Agricultural University, Parbhani and sold directly to the farmers. *Azotobacter, Azospirillum, Rhizobium* and phosphate solubilizing bacteria costing Rs.7,95,000 were supplied to farmers during 2013-14 (MAU, Parbhani). The TSP Programme besides direct income generating programme also helped generating year round employment for neighbours. The programme could check migration of labourers out of the state. Creation of vermicompost pits out of the TSP fund helped preparation of good quality compost throughout the year and kept the rural environment clean and hygienic. Use of biofertilizers helped saving at least 25 per cent of the cost incurred for the purchase of costly inorganic fertilizers.

(ix) Resource Generation

Biofertilizer production from effective microbial cultures of the project during 2007-12 at 5 centres generated revenue of Rs. 334 lakhs, representing 43% return on investment of Rs. 776.7 lakhs (actual expenditure, RE) in the project during 2007-11. During 12th plan (2012-17), Total investment was Rs. 1142.95 lakhs and biofertilizer production was Rs 911 lakhs.

(x) Budget

Head wise break up of the budget spent in AINP on Soil Biodiversity-Biofertilizers is given below:

Head-wise budget for XIIth Plan outlay

Budget Head	**Total**
Recurring	Rs. in lakhs
Pay and Allowances	1378.58
T.A.	29.4
RC	478.3
Total(A)	1886.28
Non Recurring	
Equipments	181.85
Works (Lab renovation)	0.00
Total (B)	181.85
Grand Total (A+B)	2068.13
ICAR share	1608.18

(xi) Achievements by centres along with comments and recommendation by QRT

Delhi University, Delhi

The centre worked mainly on the characterization of soil biodiversity in HCH dump site at Lucknow. Based on the information gathered on biodiversity characterization, the centre should also focus its work on developing technology for bioremediation of site contaminated with the organic pollutants not only in Lucknow but also for the sites contaminated with petroleum products/wastes near refineries.

IARI, New Delhi

IARI was evaluating multi functional potential of Rhizobium like P solubilization & antagonism to pathogens as well as presented on Rhizobium based biofilm using Trichoderma and Microbiome associated with chickpea as molecular marker. The centre should compare selected *Rhizobium* strains with existing standard *Rhizobium* for their potential on nitrogen fixation and antagonism property against pathogens before claiming it as a technology. Collaboration with soil science group is missing in this project. The centre should review the works carried out or being carried out at other places and thereafter, to plan for future work. The AINP should devise a plan on how the *Rhizobium* biodiversity characterization being carried out at different places will be integrated so that appropriate biofertilizer formulations can be prepared for the whole country for the benefit of farmer within a short span of time.

GBPUAT, Pantnagar

The centre worked on Rhizobia isolates for Rasmahs and vegetable pea for the purpose of developing consortia of microbes / biofertilizers required for the specific crops. It was pointed out that considerable efforts have already been put in this aspect without having significant success as *Rasmus* is a shy nodulating crop. Therefore there should be strong justification for putting fresh effort again on this. The AINP should complete the task of biofertilizer development within a short span of time; otherwise it will lose competitiveness in the market.

YSPUHT, Solan

This centre has worked on development of biofertilizers mainly for horticultural crops. A yield increases in apple ranging from 13.5 to 88% has been reported due to soil drenching of biofertilizers. Considerable savings of Nitrogen and phosphorus fertilizer is reported due to biofertilizer application. As a result of these achievements they have been awarded World Bank funded project. The centre should work more on developing by fertilizers for different other horticultural crops.

ANGRAU, Amravati

The centre has extended shelf-life of liquid inoculants to 18 months under room temperature and has claimed saving of fertilizers to the extent of 50% with the application of developed liquid biofertilizer. It is suggested that claim on savings of fertilizer doses needs to be verified before extending the technology to farmers' field. The centre should focus on developing microbial formulations for *in-situ* decomposition of rice and Maize residue instead of working on new biofertilizer formulations. The AINP can also attempt on culturing and multiplication of VA mycorrhiza after reviewing recent developments in the field.

UAS Dharwar

The centre worked on modification of rhizosphere environment by external applications to enhance desired microorganism populations. The centre should work on increasing population of efficient nitrogen fixing bacteria in rhizosphere and on quantification of genes involved in carbon sequestration in different ecosystem.

KAU Vellanikara, Thrissur

The centre claimed to increase crop yield considerably through biofertilizer application, though it has fixed about 20 kg N /ha in soil. The centre has been suggested to confirm the claim again. The centre should focus on delivering complete technology without diluting its effort in so many activities. The centre should also attempt to develop microbial consortia (PGPR) from rich native biodiversity in tribal areas of Silent Valley.

KAU, Vellayani

The centre was mainly involved in mass production, demonstration and distribution of biofertilizers in tribal area. The center claimed that huge quantity of Nitrogen can be saved (about 50% NPK) through application of biofertilizers. Centre should re-confirm the claim as if there is no reduction in the consumption of NPK fertilizers due to application of biofertilizers in the state. Justification of two centres in Kerala under AINP on SBB is required. Centre should integrate biofertilizer dissemination program with ongoing TSP program.

TNAU, Coimbatore

Outcome from this centre appears to be less as compared to manpower available. The centre observed no adverse effect of long-term fertilizers application on cultural biodiversity in 100 years old permanent manual trial. It was suggested to re-analyse the inference "there is no deterioration of soil biodiversity due to high doses of chemical fertilizer application" through further research using genomic tools.Seed coating with inoculants using polymer was found better as compared to conventional method of biofertilizer application. The centre should also work on finding out suitable biological parameters as soil health indicator using soils from permanent manual experiments and LTFE.

DGR, Junagadh

The centre has done commendable job in preserving microbial cultures from different centres. However requirement of at least one SRF was highlighted for maintaining and preserving microbial cultures.

MPUAT, UDAIPUR

Frequent transfer of persons has been observed in this project and present principal investigator has been temporarily placed since 2014. Lack of support by the University for this Project has been highlighted. Centre should follow appropriate methodology for working on zinc mobilizing bacteria so that right conclusions can be made from the study. Priority setting is urgently required in the research under AINP centres.

MAU, Parbhani

The centre about 23% to 29% increase in crop yield only due to application of bio fertilizers containing zinc solubilizing bacteria. AINP coordinating unit should verify this claim through other independent organizations for rapid dissemination. Further the claim on increasing DTPA extractable Zn in soil from 0.52 to 0.73 only through the application of zinc solubilizing bacteria should be reinvestigated at other AINP centres. Centre should also check viability of *Trichoderma viride* (to be able to express zinc solubilization activity) applied in soil be laboratory experiments and find out the conditions under which zinc solubilization is expressed.

HAU, Hisar

The centre claimed 10 times increase in rhizobial population in soil and more than 30% increase in crop biomass yield due to application of biofertilizers. This finding is remarkable, however should be validated through other KVKs before dissemination. Centre should investigate the cropping system dynamics impact on efficacy of bio fertilizers. AINP should investigate whether biofertilizer technologies developed for a region can be extrapolated to other regions or other soil types. While studying economic impact of the technologies, it is essential to separate out the impact of other factors.

RPCAU, Pusa

The centre should have explored the reason on why resource rich farmers getting less benefit from biofertilizer application as compared to resource poor farmers. Fields trials should be conducted with the help of agronomist/Soil scientist for better execution and management of the experiments.

<u>OUAT, Bhubaneswar</u>

AINP centres should investigate whether adoption of biofertilizer technology by farmers is sustained. Scientific bases should be explored for higher micro organism population in solid biofertilizers as compared to liquid biofertilizers. Centre should isolate PSB for biofertilizer which are efficient in acid soils even without use of lime. The centre should compare isolated strains for biofertilizers with standards check (available strains in the market) so that claim on yield improvement can be justified.

<u>JNKVV, Jabalpur</u>

Centre should develop simple and quick laboratory test method or kit for testing spurious for genuine bio fertilizers. The centre should document the reason on how zinc solubilising bacteria is so effective in acid soil which contain little quantity of ZnO, $ZnCO_3$. Efficiency of potassium solubilizers should be defined for soil types.

<u>BAU, Ranchi</u>

The centre should conduct basic research for developing marker technologies. The centre stressed upon the need for one Research Associate.

<u>CRURRS, Hazaribagh</u>

The centre should focus its research on mass production of AM Fungi.

(xii) Overall performance of AINP on SBB centres

Outstanding: DGR Junagarh, HAU Hisar, University of Delhi, YSPUHF Solan

Good: MPUAT Udaipur, OUAT Bhubanesar, JNKVV Jabalpur, AAU Jorhat, BAU Ranchi, TNAU Coimbatore, CRRI Hazaribag, ANGRAU Amrabati, UAS Dharwar, KAU Thrissur, MAU Parbhani,

Fair: RAU Pusa, KAU Vellani, GBPUAT Pantnagar,

Poor: IARI New Delhi

(xiii) Overall Assessment of AINP on SBB

During the period under review, this network project has delivered very good output in field of characterization of microbial diversity in soil as well as on development of biofertilizers for enhancing crop productivity and fertilizer savings. Several biofertilizer technologies have been commercialized leading to considerable resource generation by some centers. However, the project needs to put more effort for disseminating its technologies to resource poor farmers. The project should also develop appropriate microbial technologies for immobilizing soil fixed plant nutrients like P, Zn etc. particularly in heavily fertilized zone.

(xiv) Visioning for the Future

Intensive cropping with use of high analysis fertilizers coupled with an enormous reduction in recycling of organics or other wastes has led to a decline in the organic carbon levels in Indian soils, impaired soil physical properties, reduced soil biodiversity, all of which are contributing to yield plateau and reduced factor productivity. Not surprisingly therefore, continuous emphasis is being put for several decades on developing newer and improved biological technologies in the areas like composting, Biological Nitrogen Fixation by legumes, Biofertilizers, Integrated nutrient management, and Biopesticides etc. Goal is to reduce dependency on fertilizers, recycle organic residues & wastes effectively and save the environment from adverse impacts of industrial and urban activities. Soil biological health needs improvement for all cultivated soils. It is estimated that crop productivity can be improved by more than 10% through improvement in soil biological health of Indian soils.
There is a need to improve productivity of crops particularly pulses using N_2 fixing and nutrient mobilizing capabilities of soil bacteria. Al though considerable efforts have been under taken in the past and is still being under taken in this project on development of biofertilizers, the benefit of research has not reached to farmers as per expectation. To in still the confidence on the biofertilizer technology, considerable research is research is required on improvement of biofertilizers quality with appropriate strains of microorganisms, on increasing shelf-life of the product, viability of the isolated strains at different soil types, agronomic management and stressed environment. During the period under review, the project identified various genetic traits (*nod* and *nif* genes) in native rhizobia for pulses in selected soil types and screened for efficient performers to develop more efficient biofertilizers for pulses. There is urgent need for extension and popularization of this technology in order to enhance the income of pulse growing farmers. Also, this work should be completed for left-out pulse growing areas. As such there is a great potential in terms of biodiversity and to develop the efficient *Rhizobium* for the legumes grown in Hill, *Bhabhar* and *Tarai* area particularly Rajma and Peas.

Build up of soil P is being reported in some intensively fertilized agroecoregion of the country. Development of P solubilizer containing biofertilizers can help in reducing doses of P fertilizer application in these areas.

Studies in the project indicated that biofertilizers have considerable potential to increase agricultural productivity in resource poor tribal areas. Organic products fetch a high income for the farmer and hence the use of biofertilizers will improve the standard of living of tribals. Hence, biofertilizers developed for tribal areas particularly in Madhya Pradesh and Kerala need to be popularized through demonstrations in collaboration with KVKs and may be refined, if required.Facilitating the access to technology as well as capacity building among tribals will help to generate more employment opportunities and thus get higher income and diversify the livelihoods in rural areas.

Refinement of liquid biofertilizer technology for growing consortia of microbes, use of nanotechnology in such areas as development of nano- encapsulated biofertilizers and development of nano-biosensors for monitoring biofertilizers quality are required for efficient use of soil biology and biodiversity research. In view of the difficulties of culturing and multiplying VAM strains in synthetic media, more sincere efforts are required to refine the available on-farm multiplication protocols of native VAM mass inoculum already developed.

Soil biodiversity is important for sustaining multifunctional quality of soils. Hence focus should be to understand relationship for microbial diversity harbored within it with soil types and management methods; and to exploit the generated information for developing biological technology to restore degraded land and improve fertility of intensively cultivated soils. Heavy use of chemical fertilizers alters the soil physical and chemical environment which may affect microbial profile in the soil. Similarly pesticides have been reported to change soil microbial diversity depending on their toxicity & degradability. Due to expansion of urban area, more and more peri-urban agricultural land area in the country is using sewage effluent for irrigation contaminating the land with various pollutants like heavy metals, detergents, pesticides, antibiotics, and various persistent organic pollutants; all of which have the potential to change soil biodiversity considerably. Considerable work has been done on culturable microorganisms under these changed rhizospheric environments. Therefore, focus should be on to investigate impacts high chemical fertilization, high pesticide application, and intensive municipal sewage-effluent irrigation on the unculturable fraction of microorganisms through metagenomic study. This work is likely lead towards the development of a soil health indicator based on biological parameters (particularly microbial).

(xv) Consolidated Recommendations for AINP on SBB

<u>Scientific</u>

- Changes in soil biodiversity under different stress regimes as well as in different management treatments in the experiments under AICRP on LTFE & AICRP on Dry land Agriculture (wherever possible) may be investigated to develop site specific microbial formulations.

- The AINP should collaborate with crop AICRPs and other institutes involved in *Rhizobium* and PGPR research for developing efficient biofertilizer formulations and avoiding duplication.

- Due to continuous phosphatic fertilizers application, considerable build-up P in soils has been observed particularly in intensively cultivated areas. Biofertilizer formulations involving phosphate solubilizing bacteria (PSB) should be developed to exploit the accumulated fixed P from soil. This work may be done in a consortia mode with AICRPs on LTFE, STCR and MSNPE. Potassium and zinc mobilizers may also be included.

- Concerns are expressed on viability of microorganisms in biofertilizer samples available in the market. AINP should develop simple methodology for use by farmers in respect of testing biofertilizers for their viability.

- Bioremediation technology should be developed for sites contaminated with various organic pollutants particularly in municipal and industrial effluent irrigated areas.

- VAM fungi are efficient in mobilizing plant nutrients through extended hyphae; however, production of VAM fungi is difficult and as such simple method should be developed for multiplication of efficient VAM species.

Technology Transfer

- Demonstrations on biofertilizers have been conducted by some centers in tribal areas; however, at some of the sites the reported benefits were very high. The QRT recommends that such demonstrations may be conducted through KVKs.

- Technologies developed on increasing shelf-life of biofertilizers should be validated by third party and then passed on to the manufacturers.

Administrative

- QRT recommends provision of one SRF to all centers to take up new research activities in cutting edge areas while the permanent technical staff (wherever available) may look after committed work.

- The universities should adhere to the MoU and not shift experienced scientists out of the scheme without consent of PC.

Financial

- Contingency may be enhanced for all centers since cost of experimentation (labour, chemicals, glassware etc) is rising. It should be minimum Rs 5 lakhs per centre per year for operational expenses.

ANNEXURE 1: TERMS OF REFERENCE

1. To critically examine and identify research achievements and impact.
2. To examine objectives, scope and relevance of research programmes and budget allocation.
3. To evaluate relation/collaboration with SAUs and other stake holders.
4. To examine the kind of linkages with clients/end users.
5. To suggest changes in organization, programmes and budget.
6. To examine constraints hindering the institute in achieving objectives and recommend.
7. To suggest for future program development, research prioritization and management changes.

ANNEXURE 2: SCHEDULE OF REVIEW MEETINGS OF QRT

<table>
<tr><td colspan="4">Venue: ICAR- Indian Institute of Soil Science, Bhopal Date: September 19-20, 2017</td></tr>
<tr><td colspan="4">Presentation of Significant Achievements by Head of the Divisions and Project Coordinators</td></tr>
<tr><td colspan="2">ICAR- Indian Institute of Soil Science</td><td colspan="2">AICRPs/AINP</td></tr>
<tr><td colspan="2">Program-I: Soil Health and Input Use Efficiency
Programme-II: Conservation Agriculture and Carbon Sequestration vis-à-vis Climate Change
Programme-III: Microbial Diversity and Genomics
Programme- IV: Soil Pollution, Remediation and Environmental Security</td><td colspan="2">AICRP on Long Term Fertilizer Experiment
AICRP on Soil Test Crop Response
AINP on Soil Biodiversity & Bio fertilizers
AICRP on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants</td></tr>
<tr><td colspan="4">Presentation of Significant Achievement by Centre In-charges of AICRPs and AINP</td></tr>
<tr><td colspan="4">Venue: ICAR NASC Complex New Delhi, Date: 24th to 25th October, 2017</td></tr>
<tr><td>AICRP on Long Term Fertilizer Experiment</td><td>AICRP on Soil Test Crop Response</td><td>AINP on Soil Biodiversity & Bio fertilizers</td><td>AICRP on Micro and Secondary Nutrients</td></tr>
<tr><td>PAU Ludhiana; GBPUAT, Pantnagar; HPKV, Palampur; IARI, New Delhi.</td><td>PAU Ludhiana; GBPUAT, Pantnagar; HPKV, Palampur; IARI, New Delhi; HAU, Hissar.</td><td>Delhi University center; YSPUHT, Solan; IARI, New Delhi GBPUAT, Pantnagar.</td><td>PAU, Ludhiana; GBPUAT, Pantnagar, HPKV, HPKV, Palampur; IARI, New Delhi; HAU, Hissar; Lucknow University, Lucknow; CSAUAT, Kanpur.</td></tr>
<tr><td colspan="4">Venue: UAS Bengaluru Date: December-19th to 21st, 2017</td></tr>
<tr><td>AICRP on Long Term Fertilizer Experiment</td><td>AICRP on Soil Test Crop Response</td><td>AINP on Soil Biodiversity & Bio fertilizers</td><td>AICRP on Micro and Secondary Nutrients</td></tr>
<tr><td>TNAU, Coimbatore; RARS, Jagtiyal; UAS, Bengaluru; RARS, Pattambi</td><td>TNAU, Coimbatore; UAS, Bengaluru; PJTSAU, Hyderabad; KAU, Vellanikkara; PJNCARI, Puducherry</td><td>ANGRAU, Amravathi; UAS, Dharwad; KAU, Thrissur; TNAU, Coimbatore</td><td>TNAU, Coimbatore; ANGAU, Hyderabad; UAS, Bengaluru; KAU, Thrissur; ICAR-NIANP, Bengaluru</td></tr>
</table>

Venue: AAU, Anand	Date: 5th -6th February, 2018		
JAU, Junagadh; MPUAT, Udaipur; PDKV, Akola; VNMKV, Parbhani	JAU, Junagadh; RAU, Bikaner; MPKV, Rahuri	DGR, Junagadh; MPUAT, Udaipur; MAU, Parbhani ;HAU, Hisar	AAU, Anand; PDKV, Akola; CSAUA&T, Kanpur; JNKVV, Jabalpur
Venue: OUAT, Bhubhneshwar	Date: 06th-09th March, 2018		
AICRP on Long Term Fertilizer Experiment	**AICRP on Soil Test Crop Response**	**AINP on Soil Biodiversity & Bio fertilizers**	**AICRP on Micro and Secondary Nutrients**
OUAT, Bhubaneswar ; JNKVV Jabalpur; IGKV Raipur ;BAU Ranchi ;CRIJAF Barrackpur; JAU Junagadh	RAU, Pusa; OUAT, Bhubaneswar; JNKVV, Jabalpur; IGKV, Raipur; BCKV, Mohanpur; CRIJAF, Barrackpur	RAU, Pusa; OUAT, Bhubaneswar; JNKVV, Jabalpur; AAU, Jorhat; BAU, Ranchi; CRURRS, Hazaribag	RAU, Pusa; OUAT, Bhubaneswar; JNKVV, Jabalpur; AAU, Jorhat; BAU, Ranchi; BCKV, Mohanpur; CAU, Imphal; CSAUA&T, Kanpur

ANNEXURE 3: ABOUT THE QRT MEMBERS

Dr. Vijay Singh Tomar, Chairman, QRT

Dr. Vijay Singh Tomar (DoB: 01 July, 1946), has served as Vice chancellor, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (2012-17) and founder Vice Chancellor, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (2008-12). Prior to this, he also served as Director Research, Dean Faculty Agriculture, Director Extension, Dean of the College, Sehore and Professor at JNKVV, Jabalpur. He also served GBPAU&T, Pant Nagar. His research focus was on Soil and Water Management with special with respect to climate resilient agriculture, conservation agriculture and management of soil resources for sustainable agricultural production. He has authored/ co-authored ~200 publications including 19 International & 100 scientific research papers, 11 books/manuals, 72 technical popular entrepreneurship articles, 7 chapters in books and delivered several keynote/ inaugural addresses. He is recipient of Jawaharlal Nehru Award-1974 (ICAR), Best Agriculture University Vice Chancellor Award-2015 (AIASA, New Delhi), Life Time Achievement Award-2015 as best mentor (Pantnagar Clan- GBPUA&T, Pantnagar), Biennial Best KVK Award-2002 (ICAR), Golden Jubilee Best Agri. Scientist Honour-2000-01 (GoMP) and others. In his leadership JNKVV, Jabalpur received the Best Agricultural University- JNKVV National Award winner – Krishi Shiksha Samman- 2015 (Mahindra Samridhi India Agri. Award).

He has served as member on the General Body of the ICAR; Secretary General, Indian Agri. Univ. Assoc.; Governing Body/ General Body& Board of several Universities of India; and as chairman of QRT-ICAR-IISS, Bhopal; QRT-ICAR-IIPR, Kanpur; RAC-ICAR-IISS, Bhopal; RAC-ICAR-DSR, Indore and several others.

Dr. Masood Ali, Member QRT

Dr. Masood Ali (DoB: 18 July 1947) is a renowned Pulse Agronomist. He served various reputed organizations like CSIR, GBPUAT Pantnagar, HPKVV Palampur, IGFRI Jhansi, IARI Regional Station, Indian Institute of Pulses Research, Kanpur. He retired as Director of IIPR Kanpur in July, 1999. After superannuation, Dr. Ali served as Technical Advisor (Pulses) in National Seeds Corporation, New Delhi and as Team member of QRTs /External Reviewer of ICAR institute/AICRPs and ICARDA. Presently, he is an Expert Member of the Executive Committee of the National Food Security Mission, Govt. of India. Dr. Ali has a long (38 years) and rich experience in research (Pulse agronomy, Cropping System and Dryland Agriculture) and research management.

Dr. Ali has published over 335 research/scientific papers, and edited/authored 14 books and 14 research bulletins. In recognition of his outstanding contribution in research and development, he has been honored with several national and international prestigious awards (Life Time Achievement award by ICARDA-2009, ISPRD Gold medal-2007, Dr. Rajendra Prasad Puraskar-2006, ISA Gold medal-2004, PPIC-FAI award-1991, Krisak Bharti Barani Kheti award-1989, etc.). He served as President of the Indian Society of Pulses Research and

Development for 7 years. Dr. Ali is Fellow of several academies/societies including the National Academy of Agricultural Sciences.

Dr. H.K.Senapati, (Member, QRT)

Dr. H.K.Senapati (DoB: 1951) is a renowned soil scientist having specialization in soil fertility & fertilizer chemistry, Agricultural chemicals and soil microbiology. Dr. Senapati served OUAT Bhubaneswar and its regional stations in various capacities, like Scientific positions, Dean Post Graduate Studies, Dean Students' Welfare and Dean College of Agril. Engg. & Tech (I/C) in OUAT Bhubaneswar. Dr. Senapati has published 133 research, scientific papers, books and bulletins and also guided 13 M.Sc (Ag) and 5 Ph.D students.
He was chairman and member of various committee of OUAT, in Board of Directors of The American Biographical Institute (USA),. He has been honored with Foremost Scientists of the World-Cambridge, England, and "Margadarshan Samman" (2010) as dedicated Educationist and Educational Administrator. He is also member of selection committee of different Universities and organizations, member of QRT, Chairman NICRA (ZMC) of Eastern Zone.

Dr. Biswapati Mandal, (Member, QRT)

Dr. Biswapati Mandal (DoB: 4 August 1957), is Professor at Bidhan Chandra Krishi Viswavidhyalaya, Kalyani. His field of specialization is chemistry of micronutrients and mechanisms of C stabilization in soils. He served as a Pro Vice Chancellor at BCKV, Kalyani. He is Member of different Task Forces constituted by DST, Govt. of India and a large number of committees for managing natural resources in the country including West Bengal. He is Editor-in-Chief, Editor and Reviewer for a large number of journals. He published more than 75 scientific articles in high impact journals of the world. He was Supervisor of >35 Ph.D. students. He is sanctioned with more than 30 research projects funded by a large number of National and International agencies and recognized with 11 national-level awards and 4 fellowships from National Academies/Societies. Professor Mandal has published almost in all the leading professional journals relating to soil science, including Global Change Biology.

Dr. M C Chinnadurai, Ph.D, (Member, QRT)

Dr. M. Chinnaduari (DoB: 01 April 1960), is Director of Centre for Agriculture and Rural Development Studies in Tamil Nadu Agriculture University, Coimbatore. He has completed Ph.D in Agricultural Economics in 1997. His areas of expertise are Agricultural development and Policy Analysis, Project Evaluation, Impact assessment and Macro Economic Modeling. He received FAO Fellow from Food Policy Planning Research Institute (IFPRI) Washington D.C, USA during 1997. He participated several short courses trainings at International Food Policy Research Institute, Washington D.C, USA, University of Maryland, Maryland, USA and International Rice Research Institute, Las Banoes, Philippines.

He has 34 years of professional experience in teaching, research and extension. He has published 26 popular articles, 8 books with ISBN number, 9 technical bullets/booklets, 76 research reports in various National and International Journals. He received seven Awards and Medals in his service for contribution to agriculture. He completed 35 schemes / projects funded by various organizations including, Union Planning Commission, GOI, State Planning Commission, Government of Tamil Nadu, Indian Council for Agricultural Research, New Delhi, Winrock International, USA and other private agencies.

DR. Ashok Laxman Pharande (Member QRT)

Dr. Ashok Laxman Pharande (DOB: 31 August 1959) is Dean (F/A) & Director of Instruction at, M.P.K.V. Rahuri. He completed his B.Sc and M.Sc from MPKV, Rahuri, Ph.D from New Delhi and Post Doctoral Research from Aberdeen UK. He served as Assistant Professor, Chief Scientist, Professor, and Head in different various reputed organizations like PGI Rahuri, MPKV Rahuri, Ag. College Kolhapur and Ag. College Pune. He acted as member of different management and departmental committees of College of Horticulture, Wadala and CRIDA, Hyderabad. He was honored by University Court, University of Aberdeen, Scotland, UK as a 'Research Fellow' in the Department of Plant and Soil Science during 1999-2000. He was also honored with prestigious awards like 'Commonwealth Academic Staff Fellowship for Post Doctoral Research', Teacher Fellowship under faculty improvement programme; and won several prizes at National and State Level Seminars, and Agril. Science Congress for presentations, writing popular articles as well as for the commendable services for the society. Dr. Pharande has published 194 research/scientific papers and authored 5 books and 19 bulletins with 94 radio talks and 15 TV programmes.

Dr. Jayanta Kumar Saha, Member Secretary, QRT

Dr. Jayanta Kumar Saha (DoB: 04 April, 1963), is Principal Scientist and Head of Division of Environmental Soil Science, ICAR-Indian Institute of Soil Science, Bhopal, India. He did his M.Sc. and Ph.D. in Agricultural Chemistry and Soil Science from BCKV, Mohanpur (West Bengal), India. His major research areas are soil pollution impact assessment, food contamination and soil biological activities, and toxicity amelioration. He has worked under various capacities in national and international forums. He has published several original research articles (45) in renowned National and International Journals, technical bulletins and books (9) and book chapters (12) and serves as reviewer of several international journals. He has authored a widely popular book 'Soil Pollution – An Emerging threat to Agriculture' published by Springer Inc. He is the recipient of S.N. Ranade Memorial Junior Scientist Award for Excellence in Micronutrient Research. Dr. Saha is Member of Technical Expert Committee constituted by Ministry of Environment, Forest and Climate Change, Govt. of India for developing soil standards and Member of 'National Network of Experts and Resources for Subsurface Investigations and Remediation of Contaminated Sites (NERCS)' at IIT, Delhi.

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F.No.NRM-4-1/2019- SW&DF

Dated 23.04. 2019

To

The Director
ICAR- Indian Institute of Soil Sciences,
Nabi Bagh, Berasia Road,
Bhopal-462038 (MP)

Subject: ***Minutes of the 246th Meeting of the Governing Body of the ICAR Society held on 12th February, 2019 - reg.***

Sir,

Please find enclosed herewith the decision taken by the Governing Body of the Indian Council of Agricultural Research Society in its 246th meeting held on 12th February, 2019 on the recommendation of the QRT in respect of ICAR-IISS, Bhopal during the period from April 2012 to March 2017 (Item No.8) for implementation.

Yours faithfully

24/4/19

(S. K. Chaudhari)
Assistant Director General (S&WM)

Encl: as above.

Minutes of the 246th meeting of the Governing Body of the ICAR Society held on 12th February, 2019

Item No. 8: Recommendations of the Quinqennial Review Team (QRT) in respect of the Indian Institute of Soil Science (IISS) including three AICRPs (Long Term Fertilizer Experiments, Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants, Soil Test Crop Response) and one AINP on Soil Biodiversity-Biofertilizers for the period from April 2012 to March 2017.

The recommendations of the QRT in respect of the ICAR-IISS including three AICRPs (Long Term Fertilizer Experiments, Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants, Soil Test Crop Response) and one AINP on Soil Biodiversity-Biofertilizers for the period from April 2012 to March 2017 were perused and noted. Further, while the ongoing programmes shall be continued with the timeline, budget allocation for new programmes need to be factored in at the time of preparation of the EFC document and action for the same should be initiated right now so that implementation can commence next year.

Salient QRT Recommendations of Indian Institute of Soil Science, Bhopal including AICRPs on STCR, MSN, LTFE and Network Project on Biofertilizers (2012-2017) agreed by ICAR Governing Body during 246th Meeting on 12th February, 2019

Sl. No.	**Recommendations**	**Comment of ICAR Governing Body**
IISS, Bhopal		
1	All available georeferenced databases at IISS, NBSS & LUP, CSSRI etc. on soil fertility and soil quality should be placed in IISS database portal for use by all stakeholders. Linkage may be established with institutes such as NRSA for this.	Agreed
2	The institute should make efforts to improve fertilizer use efficiency at least by 7-10% of the existing levels through developing new fertilizer formulations /products through institutional collaboration / PPP mode; mobilizing soil-fixed plant nutrients like P and Zn, and nano-technological tools may be exploited through collaborative research to utilize indigenous minerals.	Agreed
3	The IISS should conduct basic research on impact of climate change on various chemical and biological processes operating in soil including C sequestration in soil. For this, collaborative research may be taken up with AICRP on LTFE. Technology should be developed for increasing stabilization of soil C.	Agreed
4	In order to prevent crop residue burning in agricultural land, the institute should develop appropriate technologies for *in-situ* decomposition of rice and wheat residues from existing 30 days to 15-20 days. Develop and demonstrate accelerated decomposition technology for urban wastes.	Agreed
5	In view of 'Swachh Bharat Mission', initiate research for safe use of sewage sludge, and city / industrial wastes including appropriate phytoremediation technology for the contaminated soils. Also establish safe critical limits of heavy metals for different soil types.	Agreed
6	A centre of excellence for advanced research and training on "Soil pollution and remediation" to be initiated at IISS by strengthening laboratory.	Agreed
7	A rigorous analysis on economic and environmental impacts of NRM technologies and practices in all the programs is required.	Agreed

8	One time catch-up grant of Rs. 25 crore along with additional manpower may be provided for replacing old outlived instruments and repairing of residential and Institute buildings.Institute should initiate Certificate courses on Soil testing, Compost making and Biofertilizer preparation for the youths having appropriate level of education.	Agreed depending on the fund availability.
9	Long pending vacant positions in administration section may be filled up at the earliest. Additional contractual manpower may be provided for specific research	Agreed
AICRP on LTFE		
10	AICRP on LTFE should perform comprehensive synthesis of available soil and plant data from different years of experimentation to understand the reasons for deterioration in soil quality and crop productivity. It should also identify Soil Quality Indicators for sustainable soil productivity in different agro-ecological zones. Soil resilience study may be initiated at a few sites where significant deterioration in soil functions is observed.	Agreed
11	The project should investigate impact of climate change on soil processes through robust protocol.	Agreed
12	The AICRP should investigate the impact of intensive use of agrochemicals on residue build-up and their impact on soil biodiversity in collaboration with DWR and AINP-SBB.	Agreed
13	The AICRP should revisit general recommended doses in tune with changing varieties of different crops/cropping systems in order to make recommendations relevant.	Agreed
14	For improving efficiency, AICRP on LTFE should prepare standard manual for conducting the trials and analysis of samples for all the parameters; and archive soil samples year-wise and treatment-wise for future use in each of the centers. Separation of plots with permanent concrete *bunding* may be done to avoid lateral movement of nutrients and water.	Agreed
AICRP on STCR		
15	AICRP on STCR should revisit / refine RDF in view of changing crop cultivars and develop fertilizer prescriptions for all the soils and crops through analysis of available data within two years. Fertilizer prescription equations for different application methods of fertilizers (e.g. fertigation) and irrigation should also be developed indicating saving in cost of fertilizers in the advocated method.	Agreed

16	AICRP on STCR should develop multi-nutrient extractants for major agroceosystems for rapid soil testing and fertilizer recommendation as well as protocol for testing soils for manure recommendation in organically raised farms.	Agreed
17	AICRP on STCR centers should conduct training to Soil Testing Lab personnel and KVK scientists regularly. Besides the centres should come out with the economic impact of adoption of soil health card based recommendation.	Agreed
AICRP on MSNPE		
18	AICRP on MSNPE should develop models for predicting micronutrients status in soils of uncovered/unexplored areas using analyzed soil properties.	Agreed
19	AICRP on MSNPE should make efforts to enhance use efficiency of micronutrient fertilizers by 7-10% over the existing levels. Also it should consider antinutrients, promoters and Zn bioavailablity in processed foods as well as economics in ongoing Zn biofortification studies.	Agreed
20	Impact assessment study of critically polluted areas may be limited toonly those centres having appropriate instrumental facilities.	Agreed
21	A monograph for standard protocols for laboratory analysis and field experimentations may be prepared and followed by the centers.	Agreed
AINP on SBB		
22	AINP on SBB should investigate changes in soil biodiversity under different stress regimes under AICRPs on LTFE & Dry land Agriculture experiments to develop site specific microbial formulations	Agreed
23	AINP on SBB should develop crop and soil based microbial consortium for different agro-ecoregions of the country. It should also develop biofertilizer formulations to exploit the accumulated fixed P and Zn from soil and for solubilization of applied rock-phosphate in soil	Agreed
24	AINP on SBB should develop simple methodology of testing biofertilizers for use by farmers. Increase shelf-life of both for powder and liquid biofertilizers by at least another 6 months.Simple method should also be developed for rapid multiplication of efficient VAM species	Agreed
25	Collaborate with other institutes/AICRPs involved in *Rhizobium* and PGPR research to avoid duplication	Agreed

26	One SRF may be sanctioned to those centers not having permanent position. Amount under contingency may be increased 2-3 times depending on nature and quantum of research work	Agreed
27	Mechanism should be developed to promote strong coordination among all the AICRPs to develop a single package of soil and nutrient management technology for a region; and effective linkages with KVKs and State Department of Agriculture for faster technology dissemination	Agreed