



ICAR-CGIAR
AGRICULTURAL COOPERATION



Agriculture Minister's Meeting with the DG, IWMI

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MINISTER OF AGRICULTURE
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GOVERNMENT OF INDIA

6th October, 2017

MESSAGE

There has been a long association between the Consultative Group on International Agricultural Research (CGIAR) institutions and the Indian National Agricultural Research and Education System (NARES) and their mutual collaborative efforts have contributed immensely in achieving a remarkable growth in food production in India. The Indian Council of Agricultural Research (ICAR) joint activities with CGIAR Institutions in the areas of germplasm and technology exchange, capacity building etc. However, the changing climate and the human needs for food present newer and growing challenges of regular advancement of technologies and further to take them to the farmers.

I am pleased to know that the ICAR is bringing out, for the first time, a document "ICAR-CGIAR Agricultural Cooperation". The effort of summarizing the past achievements and identifying the future requirements of collaborative research is commendable for not only deepening of meaningful collaboration for strengthening food and nutrition security in India, but also in sharing our successes and knowledge with rest of the world, particularly, for bringing livelihood security through cooperation.

(RADHA MOHAN SINGH)



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Foreword

Technology enabled development of agriculture is evidenced by the ushering of green revolution followed by the yellow, white and blue revolutions in India. The Indian Council of Agricultural Research (ICAR) along with its partners in the National Agricultural Research and Education System (NARES) and in collaboration with the Consultative Group on International Agricultural Research (CGIAR) for research and technology developments, has led to achieve the all time high production of 275.7 million tonnes of foodgrains, 22.95 million tonnes of pulses and 299.5 million tonnes of fruits and vegetables during 2016-17. Similarly, many fold increase in production and productivity of rice, wheat, maize, pearl millet, oilseeds, cotton, sugarcane, jute, milk, fish, eggs and meat since 1950-51, has made a visible impact on the national food and nutrition security.

The CGIAR is a global research partnership for a food-secure future. It works through 15 research centres located world-wide. ICAR, as the nodal body, has signed Memorandum of Understanding or Agreement with 12 of them. Agricultural research and education in the country is precisely undertaken in the areas of mutual interest identified in the Work Plans which are developed for three to five years. An annual meeting of the Heads of CGIAR centres in India is held with the senior officers of the ICAR in which all the ongoing programmes are discussed and priorities are decided considering the national requirements and the areas where the CGIAR centres could assist the ICAR institutions and agricultural universities to address the existing as well as the emerging issues. ICAR acknowledges the importance of partnerships

and synergies of CGIAR centres in providing technical solutions for agriculture through exchange of germplasm, technologies, technical cooperation, joint experimentation, joint publications and capacity enhancement in several frontier areas of research.

Growing population, changing lifestyles, expanding urbanization and accelerated climatic changes are posing new challenges to the agricultural research system both nationally as well as globally. The food requirement will shift from adequate food to adequate nutrients to promote health and then, to meet the optimal nutrients based on individual's genetic profile. This will require periodic monitoring of progress and reorienting our approaches. Collaboration with CGIAR centres which have the global experience will assist in addressing these and related issues in India. This productive association might also help India to be a pro-active partner in south-south cooperation.

This publication provides a glimpse of activities of CGIAR centres along with their contribution. It has been ably compiled by Dr. R.K. Mittal, OSD (International Relations), ICAR. I do hope that the document will excite more precise and action oriented ICAR-CGIAR joint research efforts in order to solve specific problems afflicting Indian agriculture.



(TRILOCHAN MOHAPATRA)

ICAR - CGIAR Agricultural Cooperation— A Perspective

The Indian Council of Agricultural Research (ICAR) is an autonomous organisation of the Department of Agricultural Research and Education (DARE), Ministry of Agriculture and Farmers Welfare, Government of India. Formerly known as Imperial Council of Agricultural Research, it was established on 16th July, 1929. The Council is the apex body of the National Agricultural Research and Education System (NARES) which is one of the largest systems in the world with respect to human resource, infrastructure, research, education and extension network. The ICAR with its headquarters at New Delhi, coordinates, guides and manages research, education and extension in agriculture and allied sectors in the country with a vast network of 103 ICAR institutes including four deemed to be universities and one National Academy, three Central Agricultural Universities and 680 Krishi Vigyan Kendras (KVK). ICAR also provides support to 66 State Agricultural Universities. ICAR envisions ensuring food and income security for all through technological innovations and sustainable agriculture.

ICAR played an enabling role in ushering green revolution followed by yellow, white and blue revolutions in the country. The production of different commodities has increased many times during the past 65 years: food grains by 5.4 times, oilseeds by 6.2 times, milk by 9.6 times and fish by 14.4 times since 1950-51. Similarly, rice production by 3.6 times, wheat 4.3 times, maize 4.7 times, pearl millet 4.4 times, pulses 2.7 times, cotton 10.9 times, sugarcane 5.36 times, jute 2.4 times and eggs 47.6 times since 1950-51 and meat 3.88 times since 1998-99 are the glaring examples of technology led agricultural development in the country. India has emerged as the second largest producer of fruits and vegetables in the world and their production has touched a record 299.5 million tonnes during 2016-17 which is about 3 times as compared to 1991-92 production. This sterling progress in production and productivity in

a variety of agro-climatic zones (128) of the country, has made a visible impact on the national food and nutrition security. ICAR has also played a major role in promoting excellence in higher agricultural education.

2. Cooperation with CGIAR centres

Consultative Group on International Agricultural Research (CGIAR) is a global research partnership for a food-secure future. CGIAR science is dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources and ecosystem services. It works through 15 research centres located world-wide. ICAR as a nodal body has signed Memorandum of Understanding or Agreement with 12 of them. The first such Agreement was signed with the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) in 1972, which was followed by International Rice Research Institute (IRRI) and International Maize and Wheat Improvement Centre (CIMMYT) in 1974, International Potato Centre (CIP) in 1975, International Centre for Agricultural Research in the Dry Land Areas (ICARDA) in 1986, International Centre for Tropical Agriculture (CIAT) and International Food Policy Research Institute (IFPRI) in 1988, World Agroforestry Centre (ICRAF) in 1995, Bioversity International (BI), International Water Management Institute (IWMI) and International Centre for Living Aquatic Resources Management (ICLARM, now WorldFish) in 1996 and International Livestock Research Institute (ILRI) in 2004.

Out of the 12 CGIAR centres with whom MoUs have been signed, ICRISAT has its headquarters in Hyderabad with Liaison Office in New Delhi, while nine others are having their Liaison/Branch Offices in New Delhi. ICAR has also supported establishment of the Borlaug Institute of South Asia (BISA) at New Delhi with field locations at Pusa, Bihar; Jabalpur, Madhya Pradesh and Ludhiana, Punjab under the overall purview of CIMMYT. Recently, the Government of India has approved establishment of Food Legumes Research Platform (FLRP) of ICARDA at Amlaha, Sehore, Madhya Pradesh with Satellite Hubs in West Bengal and Rajasthan on 15th February, 2017.

Agricultural research and education in the country is precisely undertaken in the areas of mutual interest identified in the Work Plans which are developed for three to five years through interactions. An annual meeting of the Heads of CGIAR centres in India is held with the senior officers of the ICAR under the chairmanship of the Secretary, DARE and Director General, ICAR. In this, all the ongoing programmes are discussed and priorities are decided considering the national requirements and the areas where the CGIAR centres could assist the ICAR institutions and agricultural universities to address the existing as well as the emerging issues. Also, for the first time, in the last meeting held in January, 2017, an extended discussion followed on some common issues pertaining to Indian agriculture, like rainfed/dryland agriculture and water management, utilization of rice fallows, wasteland development, developing roadmap for taking new technologies to farmers and joint research and education efforts for the development of African countries.

ICAR has been a donor member of CGIAR system and provides annual grants under Window 1 and 3; about Rs 48 cr provided in 2016-17. This is in addition to the land, necessary facilities/logistics and tax and custom duty exemptions etc. provided

for establishment of institute/centres/offices and the grant extended for some specific projects developed outside the work plans. Secretary, DARE & Director General, ICAR is Vice-chairman of the Governing Board of ICRISAT and a member in some others. CGIAR centres have also entered into Agreements with the State Governments of India and developed certain collaborative projects on their funding support.

ICAR has become a part of the newly restructured Consultative Group on International Agricultural Research (CGIAR) System Council as a voting member and represents South Asia constituency. It also represents as a member of its Strategic Impact Monitoring and Evaluation Committee (SIMEC) of the System Management Board of CGIAR.

The Council acknowledges the importance of partnerships and synergies of CGIAR centres in providing technical solutions for agriculture. Technical cooperation between the NARES and CGIAR centres includes several areas of commonality, synergy and priority which provide various opportunities for exchange of germplasm, technologies, technical cooperation, joint experimentation, joint publications and capacity enhancement of scientists and students in several frontier areas of research.

3. Highlights of CGIAR contribution to Indian agriculture

CGIAR's biggest contribution is in providing or facilitating transfer of genetic material of different crops from various parts of the world which has been utilized for breeding new and improved varieties of the crops. Faced with food grain crisis, India realized the benefits of dwarf wheat varieties and production was doubled within five years (1966-1971), leading to the world famous event of "Green Revolution". This had a great impact on income of farming community in India. Since then, many wheat varieties comprising of durum and bread wheat have been released in the country possessing CIMMYT parentage. According to the records available with the ICAR-NBPGR, New Delhi, during the period 1976 to 2017, about 329,703 germplasm accessions of different crops were imported through CGIAR centres by ICAR, and about 7,423 germplasm accessions of different crops were exported to CGIAR centres from ICAR.

Contribution of IRRI to Indian agriculture is in the development of the first flood tolerant rice variety, Swarna-Sub 1 and several high yielding rice varieties which are tolerant to biotic and abiotic stresses suited to various environments, hybrid rice, stress proof rice (tolerant to flash flood, stagnant flood, drought and salinity etc.), improved crop and nutrient management practices including conservation agriculture in rice-wheat systems, improved post harvest technologies for enhanced storability and productivity, and building capacity of about 1600 Indian scientists. These varieties have reached millions of farmers covering over 2 million ha rice area.

With ICRISAT, the NARS developed about 316 improved varieties/hybrids which include sorghum (41), pearl millet (170), chickpea (45), pigeonpea (29) and groundnut (31). Besides they repatriated 41,796 national germplasm accessions to the NBPGR. Many of these varieties are first of its type and have covered a lot of area under crops in the country. Groundnut variety ICGV 91114 in Odisha and Andhra Pradesh, early maturing chickpea variety in Andhra Pradesh, pigeon pea cultivar ICPH and pearl millet early maturing hybrid HHB67 in Rajasthan and Haryana yielded significantly higher, therefore, covered greater area and provided more financial benefit to the farmers.

Collaboration with ICARDA works on basic, strategic and applied research on genetic enhancement of pulses (lentil, grasspea, Kabuli chickpea, faba bean), cereals (barley, durum wheat, bread wheat), forages including spineless cactus. Ten lentil varieties were developed and the work on Fe and Zn rich varieties for short season environment is in progress. In Kabuli chickpea, six and in barley nine varieties were developed and 67 spineless cactus varieties were introduced by using ICARDA germplasm.

Under the CIP-CPRI collaboration, eight potato varieties were developed out of which two of the processing varieties are occupying over 100,000 ha area in country. In potato, 33 germplasm accessions including six accessions rich in nutrients (Fe, Zn and Vitamin-C) were imported and established at Shimla, which are being utilized for developing indigenous nutrient rich varieties. Potato cultivation in dryland system of Rajasthan and non-potato growing areas in rice-fallow system in North Bengal would augment the increase in farmers' income.

The Bioversity International collaborative research provided support of technological innovation, targeted the poor farmers in priority regions and developing institutional innovations in farming systems to improve access to seed and other inputs and services especially for small and marginal farmers. Involvement of women in strengthening the Community Seed System would result into self reliance in seed related primary requirement.

Our collaborative approach with IWMI and ICRAF complemented and added value to ongoing research priorities of natural resource management. It resulted in developing/ standardizing the technologies including multiple use of water for raising crop-water productivity in Indo-Gangetic plains, use of geo-informatics in mapping agro-forestry, formulation and approval of National Agro-forestry Policy-2014, and capacity development through seven international trainings on Carbon Finance Market, Carbon Stock Assessment, and Carbon Trading Options, benefitting 62 participants.

IFPRI played important role in the development of Indian agriculture through its policy research. Its studies with ICAR-NCAP and other partners on agricultural diversification and market linkages, led to sequence of reforms in agricultural marketing, and accelerated institutional innovations, such as contract farming, formation of self-help groups and FPOs. IFPRI recommended the beneficial impacts of agricultural research and development on growth and poverty alleviation and therefore, advocated increased investments in agricultural research institutions. IFPRI also provided policy support to ICAR in developing 'ICAR Vision 2050' which was released by the Prime Minister of India. A 'Food Security Portal' is launched in India by IFPRI which aims to share knowledge on the best practices related to food security, monitor and analyse prices

of key agricultural commodities for taking informed decision, and interact with the policy makers to improve food and nutrition security. On nutrition, POSHAN (Partnership and Opportunities to Strengthen and Harmonize Action for Nutrition in India) examined the state of inter-sectoral convergence in the states of Odisha and Madhya Pradesh, and assessed its implications for scaling up nutrition based interventions. Recently, the team with partners launched 'India Health Report 2015'.

4. Current collaborative targets and activities

All the CGIAR centres working in India and located in New Delhi have an annual meeting with the senior officers of the ICAR under the chairmanship of the Secretary, DARE and Director General, ICAR. In this, all the ongoing programmes are discussed and priorities are decided considering the national requirements and the areas where the CG centres could support the ICAR institutions and agricultural universities to address the existing as well as the emerging issues. In the recently concluded such meeting, following areas were identified for them.

ICRISAT to have enhanced collaboration with ICAR-CRIDA to enhance cross-learning in modelling to adapt to climate change in responding to rapid variations in weather patterns in rain-fed agriculture. To have common frame work for data information frequent interaction and development of a road map for large scale implementation beyond pilots, strengthen coordination on Climate Resilient Villages (151 KVks)/Climate Smart Villages (2 + AP/Karnataka), digital agriculture, livestock sector in dry land agriculture, development of genetic and genomic resources of finger millet and its application in crop improvement, enhancing genetic gains for priority traits in grain legumes and dry land cereals (chickpea, pigeon pea, groundnut, sorghum and pearl millet), digitalization of breeding database through Breeding Management System (BMS) of Integrated Breeding Platform (IBP), transgenic pigeon pea and chickpea for insect resistance, smart food initiative and pulse production in rice fallows will be focussed.

IRRI has made significant push in promoting STRVs under STRASA in eastern and other parts of India and made impressive progress of projects on increasing yield potential., Marker assisted breeding for multiple stress tolerance and developing new rice varieties that suit DSR etc would be continued. There is a need for accelerated research work in collaboration with the ICAR institutes on C3-C4 project and focus to achieve targets in rice breeding such as heterosis beyond 30%, yield 10 t/ha, multi-stress (biotic and abiotic) tolerance, low GI-quality, combining high zinc and high protein traits and upgrading rice value chain.

Biodiversity International would be continuing the work on Seeds for Needs and Community Seed Bank projects, management and mitigation of the spread of Tropical Race 4 of *Fusarium* wilt in banana, facilitation of germplasm import of the selected crops (wild species of cotton, winter wheat, temperate fruits, trait specific soybean, cocoa, oil palm, olive and other identified germplasm), developing protocols for cryopreservation and regeneration of difficult-to-store species and developing human resource in this technology and establishing mother clone orchards, exploration, collection, *ex-situ* conservation, evaluation, chemical profiling of Neglected and Underutilized Species (NUS) of promising fruits, vegetables, root and tuber

crops and the wild relatives of crop plants, establishment of “Community Germplasm Banks” involving custodian farmers, studies on ecosystem services and project on mainstreaming agro-biodiversity conservation and utilization in agricultural sector to ensure ecosystem services and reduce vulnerability will be taken up.

ICARDA has made good efforts for bringing germplasm to India for use by the national program. A need has been highlighted to define heat stress and to develop new varieties of wheat with specific traits for the country. Besides this, introduction of disease resistant (*Stemphylium* blight) and high yielding lentil varieties from Bangladesh to India and their testing, interventions both on mapping of rice fallows and technical interventions of growing pulses like lentil and grasspea, bringing grasspea lines having less ODAP from ICARDA HQ to the Indian program for growing in barren areas and introduction of better varieties of date palm for multiplication and large scale demonstrations will be taken up.

IFPRI will focus on estimating returns on agricultural research investment and mapping adoption of improved technologies, strategies to enhance pulse production and to stabilize prices, developing transparent performance indicators for KVKs, developing mechanisms to implement innovative institutional arrangements (such as e-NAM, farmer producer organization and PMFBY) and to assess their impact on smallholders, and constraints in adoption of improved varieties and technologies be given more emphasis, especially in eastern India, and it should include strengthening of seed chain and delivery of key inputs and resources to the farmers.

CIMMYT is providing germplasm of wheat for quite long, a comprehensive document on how we are getting benefits of this germplasm in release if varieties and status of use of this germplasm in ICAR programmes is to be prepared by ICAR-IIWBR, Karnal. Also, the genetic gain in the existing varieties is to be mentioned. Further, yellow rust identification, documentation of entries with 100% yellow rust resistance, development of yellow rust resistant varieties to rising temperature, documents on the impact assessment of rust resistance breeding towards enhancing the total wheat production and productivity in India and, on the Ug99 resistant varieties, the Zn and Fe bio-fortified lines being developed should possess the multiple traits, e.g. heat tolerance, investigation on terminal heat tolerance in wheat with proper time line and undertaking gene mapping an action plan to be developed by the ICAR-IIWBR in collaboration with CIMMYT to achieve 9 t/ha wheat yield in India, for drought and salt tolerance ICAR-IIWBR should get material from CIMMYT and the trials to be done together. Wheat blast in Bangladesh is an emergent issue which is a threat to Indian wheat also and therefore, an action plan to be developed for India viewing the work done last year and also to be undertaken this year.

In maize, temperate and spring maize be crossed for obtaining higher *Kharif* yield to the tune of 5 t/ha and keeping drought tolerance and disease resistance traits in programme, a note on mechanization in maize is to be prepared and technology packages which are developed and perfected should be promoted. There is a need for further evaluation/validation, up-scaling and field demonstrations of available technologies regarding burning of crop residues, initiation of work on aflatoxin in maize and studies on social impact of maize cultivation involving the ICAR-NCAP.

CIP would be concentrating on developing participatory approach for varietal improvement having tolerance to heat and drought stress, early maturing processing varieties and specialty potato varieties, the technology for seed production of potato in net house advanced in Bangladesh needs to be demonstrated in the fields in India, potato seed production and commercialization to be strengthened between CIP and CPRI and a plan is needed to scale up the potato seed production out of Punjab for example in West Bengal and Karnataka, ICAR-NCAP with ICAR-CPRI should study the water use efficiency in potato for sustainable intensification, and mini processing plants for making flour, noodles, starch etc. should be worked upon so that the products may find place in nutritional programmes.

In sweet potato, release of varieties of sweet potato should be through AICRP and there should be participatory evaluation, transfer of sweet potato value addition technologies to households and small and medium entrepreneurs to be undertaken by CPRI with assistance of CIP, and popularization of orange flesh sweet potato varieties should be given more emphasis in tribal areas.

IWMI would prepare an action plan for wetland management with financial outlay, a project about the post flood management in eastern India and strategic research plan under NICRA to be developed, and IWMI to collaborate with ICAR-CRIDA in real time weather modelling and contingency planning.

ILRI and ICAR-IVRI would work on capacity building in epidemiology and anti-microbial resistance and for designing feed that has low greenhouse emission, ICAR-IVRI in collaboration with ICAR-NCAP to have 2-3 models having livestock component for dry areas for example Maharashtra and Telangana for doubling food production, ICAR and ILRI should jointly work on semen sexing and if needed assistance of CSIR, IITs or others may be explored for designing the machine, and work on ethno-medicine/herbal drugs be taken up with greater focus which will reduce the antibiotic use and delivery.

With ICRAF, India to have national level guidelines and certification standards for planting material, there should be credit and insurance for agro-forestry like in crops and the total benefit should be time linked, for bio-fuels best germplasm of *Jatropha* may be procured from ICRAF, agro-forestry mapping is required to be done with collaborative efforts on MIR with IISS, Bhopal, strong collaboration with CAFRI in geo-informatics based agro-forestry species identification, supply of quality planting material through development of scientific nursery techniques, attending to the degraded areas which are not attended to by other agencies and a joint plan to be developed towards wasteland development through novel techniques like aerial seeding of pelleted seeds.

5. Way forward

The farm holdings in India are small and taking technology to farmers and its implementation at ground level to enhance profitability is indeed a big challenge. Besides enhancing productivity and profitability of farmers, the management of nutrition related issues need major research focus across institutions of both ICAR and CGIAR. There is a strong need of climate resilience in production of cereals and pulses, working on emerging problems (biotic stresses) in different crops, developing suitable processing varieties for value addition, livelihood security problem and social sector issues in conservation agricultural practices, etc. In animal science, there is need for focus on semen sexing, multi-effective vaccines and genomic selection. Some common issues pertaining to Indian agriculture like rainfed/dryland agriculture and water management, utilization of rice fallows, wasteland development, developing roadmap for taking new technologies to farmers, enhancing farmers' income etc. emphasize the need of synergy among all the CGIAR centres and ICAR institutions. The collaborative work is mutually beneficial and has become strength of each other. CGIAR centres' experience of working elsewhere in different environments will help India, and therefore, a stronger relationship is needed. Further, both India and CGIAR centres have priority of working in Africa where already some CGIAR centres have their well established infrastructure which could facilitate development of the joint road map for working in Africa.

Bioversity International

Bioversity International is a global research-for-development organization with headquarters in Rome (Italy). We have a vision – that agricultural biodiversity nourishes people and sustains the planet. We deliver scientific evidence, management practices and policy options to use and safeguard agricultural and tree biodiversity to attain sustainable global food and nutrition security. Bioversity International was established in 1974 as the International Board for Plant Genetic Resources (IBPGR) to coordinate an international plant genetic resources programme, including emergency collecting missions, and building and expanding national, regional and international gene banks. The Food and Agriculture Organization (FAO) of the UN acted as its secretariat. In 1991, the IBPGR became the International Plant Genetic Resources Institute (IPGRI). The IPGRI started its independent operation as a CGIAR centre in 1994.

The operations in India were started at the National Bureau of Plant Genetic Resources (NBPGR), New Delhi, in July 1988. However, the formal inauguration happened on 10 June 1989. A memorandum of agreement (MOA) was signed between IBPGR and ICAR for scientific and technical co-operation in plant genetic resources. Since 1987, the ICAR and Bioversity International have collaborated to undertake research in the field of conservation of plant genetic resources and creation of facilities for scientific exchange programmes for global capacity building. The contribution of Bioversity International (then IBPGR) emphasizes joint plant genetic resources research activities on selected priority crops of mutual interest as per the programme and project activities of the Bioversity International. There will be a greater focus on promoting and undertaking collaborative research involving the expertise and facilities of NBPGR, other ICAR institutes, State Agricultural Universities and other related research organizations in India.

2.i. Overall contribution to Indian agriculture

One of the primary novel idea that Bioversity International brought to the Indian system is the broadening the genetic base of crops to empower farmers for better adaptation (Seeds for Needs). This activity deployed a huge farmers' network (45000 trials) for crop diversification. Bioversity International through "Seeds for Needs" project is studying the impact of agricultural biodiversity in minimizing the losses occurring due to climate shifts by involving large number of smallholder farmers. A suggested pool of landraces and released varieties of different crops is tested under Participatory Varietal Selection trials by adopting scientific methodology. The better performing varieties subsequently become part of the crowd sourcing trials. Each farmer in the crowd sourcing network is provided with a combination of three random varieties from the selected list that are tested along with the varieties commonly grown in the location and feedbacks are received from the farmers about the comparative performance. Thus, the responses from individual farmers, rather than the groups are collected. This information is analyzed by software-ClimMob, developed by Bioversity International, to generate recommendations for individual farmers as well as for the region. Farmers' increased knowledge about various traits of the tested varieties helps them to select the varieties suitable for their local climatic challenges. Participant farmers are trained for quality seed production to strengthen the local seed supply system. Seeds4Needs is operating in eleven countries in Africa, the Americas and Asia-Pacific. The activity was initiated in India in 2011 and has been well received by the farmers of five states: Bihar, Uttar Pradesh, Odisha, Madhya Pradesh and Chhattisgarh. A strong network of more than 35000 farmers has been established by including oilseeds, legumes, vegetables and cereals in the trials which emphasizes the need of broadening the crop genetic base for climate-resilient agriculture. The diversity that's been so introduced are then conserved and stored in community seed banks, established and maintained by the farming communities with help from Bioversity

International. In these seed banks, an advanced low cost "zeolite beads' technology is used which prolongs the seed shelf life by drying the seeds to a low moisture content. So the conservation of traditional and improved varieties happen within a system in a novel *ex-situ* within *in-situ* type of conservation.

Bioversity International has also contributed towards making genebanks 'climate-ready' to meet challenges of the future. In Collaboration with ICAR-NBPGR focussing crops wheat, chickpea, pigeonpea, sorghum & pearl millet a web portal, called PGRClm was established, which is an interactive online information system



Women's group making pickles from mango in the project site

(<http://www.nbpgr.ernet.in:8080/climate/arcMap.aspx>). This is an easy-to-use interface and with geo-referenced accessions and climate change analysis-ready for current, 2020s and 2050s climate predictions.

2.ii. Contributions during last one year

Bioversity International has worked towards the sensitization, management and mitigation of spread of Tropical Race 4 of *Fusarium* wilt of banana with special reference to preventing future outbreak, managing existing infection and strengthening international collaboration.

The floods in J&K took some unfortunate turn and the centre had been instrumental in restoring the lost diversity of rice landraces through the Seeds for Needs project. This activity turned into success story of farmers preferred rice varieties. There was revival of local seed system in Kashmir valley in response to the Srinagar floods of September 2014 and seed kits were distributed and evaluated (50,000 affected farmers), in collaboration with Sher-e-Kashmir University of Agricultural Sciences & Technology for distribution and monitoring. As a contribution and success story, the Khudwani centre of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir has recently released two rice varieties namely SKUA-408 (Shalimar Rice-4) and SKUA-402 (Shalimar Rice-5) through State Seed Sub Committee on 23-03-2017. This is the biggest contribution of this programme.

The Centre has collaborated with the national system in facilitation of germplasm import, including exchange, regeneration and testing of germplasm. There was a special emphasis for import elite germplasm of temperate fruit crops from Central Asia and their evaluation and use for varietal selection and crop improvement programmes. As a contribution to the National System, scientists from ICAR and PPV&FRA visited Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan. The team went to 20 research institutions, agricultural universities, seed/field gene banks and held objective meetings / discussions to identify areas of strengths, gaps, and cooperation on possibilities of exchange and conservation of temperate fruits & vegetables. Sixty-one accessions were collected and submitted to NBPGR.

The 1st International Agrobiodiversity Congress was organized on 6-9 November, 2016 where participants from 60 countries attended the sessions which was inaugurated by the Prime Minister of India. Here, the Delhi Declaration on Agrobiodiversity Management universally adopted which emphasized Agro-Biodiversity Index (ABI) a global necessity and a "Year of Agro-biodiversity" proposed to United nations.

2.iii. Socio-economic impact/outcome

- i. Farmers becoming self reliant in making the right choice of varieties from the trials. They are now trained to do seed production and distribute the seeds of food crops within their village. They now have enough seeds of different

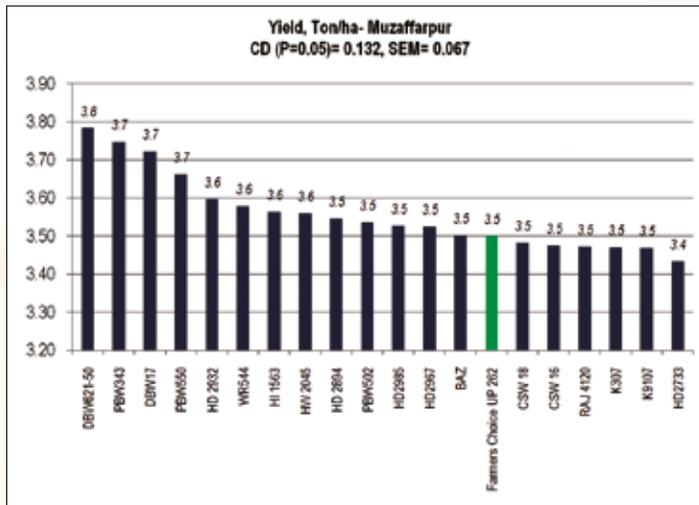
varieties available in their own community/village for their farming. They now have a choice to grow the varieties based on the climatic situation viz., late sowing, low water etc.

- ii. Community seed banks will serve as centers of rural activity. Starting from discussions on farming and current agro-climatic situations. The trainings on seed storage in community seed banks will be translated to regular seed storage and so the knowledge level in a certain community will be enhanced in terms of seed storage and conservation. The farmers will now have knowledge and infrastructure to safeguard the seeds that they will use for their farming. Farmers will interact and work towards making the CSB a solution giving enterprise and will have infrastructure of safe-keeping of seeds for long time which was otherwise not possible.
- iii. Involvement of women in the community seed banks will address the rural women's involvements and resulting into self reliance in seed related activities which is quite primary requirement.

3. Projects/activities in progress in India

Seeds for Needs: A Citizen Science Approach for Climate Change Adaptation: Broadening the genetic base of crops to empower farmers for climate change adaptation through a participatory approach

The programme commenced in 2011 in Vaishali district of Bihar, the site selected for climate-smart agriculture under the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). The experiment started with 30



A farmer selecting wheat varieties from 20 different wheat varieties in a PVS trial in Bihar

farmers. The results were so overwhelming that in the years 2013-2014, the number of farmers increased exponentially to 5,000. During Rabi 2014-15, approximately 15,000 farmers participated and provided their feedback for 43 varieties in different locations. Vegetables were provided in the areas where soil has high fertility and irrigation facilities are available. Other crops included in the programme were chickpea, soybean, cowpea, greengram, etc.

During Rabi of 2015-16, nine varieties of mustard were distributed to 1100 farmers in Satna. Mustard is not a prevalent crop but its cultivation was successful in the drought-affected region. Mustard was a good fit in the existing wheat-dominated cropping system due to its higher productivity under fewer irrigations and ability to tolerate frost.

To promote diversity in farmers' fields by involving horticultural crops and ensure a successful harvest, Bioversity International in collaboration with national partners is also developing sample nurseries in net houses for farmers in the moisture-stressed areas. An important aspect of this work is raising awareness among farmers on the importance of raising quality seedlings in the nurseries. The established nurseries acted as a prototype in the area. The success of this initiative is likely to encourage other farmers to start their own nurseries. Replication of the intervention will generate more income for growers and more diversity will be available in the farmers' fields. Talking about the impact, in a survey conducted in Bihar after 3 years of the initiative indicated that 96% farmers in Samastipur, 90% in Muzaffarpur and 73% in Vaishali districts who participated in the trials, agreed on the concept of crop diversification. In other words, they wanted to grow the varieties which were evaluated in crowdsourcing and PVS trials. Crowdsourcing varietal evaluation using farmers' network and looping in farmers as 'citizen scientists' is a new concept. The programme aims at mobilizing a very large group of farmers in a short time. The integration of IT tools with mobile technology, using Android devices and uploading the data directly from the farmers' field to the Open Data Kit (ODK) Aggregate server. Varietal evaluation linked to climate change and using genetic diversity as a tool to buffer abiotic stresses is another novel approach in this project.

Community Seed Banks

Bioversity works towards establishment of Community Seed Banks (CSBs) to conserve existing crop diversity in a region, supply seeds of traditional varieties not available in the formal seed systems, timely and affordable availability of seeds of improved crop varieties. Community Seed Banks are using 'Dry Store' storage technique by using absorbent desiccants to dry the seeds prior to storage to a very low moisture content and use of moisture proof containers to store the seeds. This technique protects against insects/fungi damage as well as seed deterioration since low levels of moisture slows down seed deterioration. In this aspect,



Training of farmers at KVK Majhgawan (Satna) on Community Seed Bank Management

Bioversity International with collaboration with 3 KVKs, had set up 11 community seed banks in April 2016. Capacity building of farmers and scientists on these new techniques are happening continuously and to mention a few, training workshop on the use of desiccants for seed storage in Community Seed Banks (Dec 2014), and the International workshop on Community Seed Banks and Farmers' Rights (November 2015) which had 30 participants from 18 countries. For this purpose a model Community Seed bank in Delhi was set up for training purposes.

Gene banks traditionally keep seeds under low temperatures to prolong their shelf life but this is expensive to run, and can be unreliable when power supplies are uncertain. In community seed banks, dry-storage method is used which offers a cheaper and more reliable alternative. The most serious threat to seed longevity is the high seed moisture content. This innovative solution entailing the use of desiccants (zeolite beads) to dry the seeds and use of airtight drums or polyethylene bottles for storage has been introduced by Bioversity International. There is in-depth research supporting the use of this technology and the importance of desiccated storage. The use of zeolite beads in seed drying enhances seed longevity. Since it is easy to use, it can be deployed in remote villages where power and other inputs are not easily available.



The Interior of the Central Repository of Seed Banks in Chitrakoot



Gaivinath Seed Bank in Satna district (MP)

Underutilized fruit trees conservation and utilization

In this activity, 16 species of Neglected and Underutilized Species (NUS) 60 varieties in 200 families was conserved in a genetic garden. Currently, 102 varieties of 74 species belonging to 47 genera of 26 families have been collected and planted in the ex-situ Genetic Diversity Park (Bioversity International Bengaluru project office). Along with this, a book entitled "Know the less known fruits of tropical & sub-tropical regions" is being published for increasing awareness and understanding for utilisation and conservation of these neglected and underutilized species/ crops.

4. Yearly action plan and collaborators from NARES

- i) Mainstreaming agrobiodiversity conservation and utilization in agricultural sector to ensure ecosystem services and reduce vulnerability. This is a UNEP – GEF funded project and jointly implemented by ICAR and Bioversity International.
- ii) Exchange of PGR: Oil palm Network and its activities
- iii) Management and mitigation of Tropical Race 4 of Fusarium in banana
- iv) Facilitation of germplasm import of the selected crops (wild species of cotton, winter wheat, temperate fruits, trait specific soybean, cocoa, oil palm, olive, and other identified species).
- v) Developing protocols for cryopreservation and regeneration with human resource development and establishing mother clone orchards.
- vi) Exploration, collection, ex-situ conservation, evaluation, chemical profiling of Neglected and Underutilized Species (NUS) of promising fruits, vegetables, root and tuber crops and the wild relatives of crop plants from all the important phytogeographical areas including A&N Islands. Jack and other potential fruits species, drought resistant legumes and vegetables shall also be included.
- vii) Establishment of Community Germplasm Banks in association with custodian farmers.
- viii) Studies on ecosystem services (including the direct and indirect services of pollinators, natural enemies of pests, soil arthropods etc.) and their economic valuation.



Genetic Garden at Bengaluru office of Bioversity International

5. Way forward

- Development of Agro-biodiversity Index and Sustainability Index.
- Implementation of two new projects with ICAR on Ecosystem services in mango and biodiversity studies in jack fruit.
- Establishment of Community Seed Banks in India. We plan to organize about 10 Community Seed Banks in India by the end of December 2017 in four agro-ecological zones of India. Expansion of the seed bank system to conservation of seeds of Crop Wild Relatives (CWR).

- Expansion of Seed for Needs programme including pulses, oilseeds and horticulture crops for climate change adaptation. This project will involve about 25,000 farmers across 125 villages in 5 states of India: Bihar, Uttar Pradesh, Orissa, Madhya Pradesh and Chhattisgarh.
- Expansion and strengthening of genetic garden based at Bangalore.
- Supporting oil palm network between India and West African countries (four countries). This will also include the collecting and characterization of oil palm germplasm by Indian scientists in west African countries.
- Enhancing genetic resources of soybean and its pre-breeding for soybean improvement programme in India.
- Implement of GEF project “Mainstreaming agro-biodiversity conservation and utilization in agricultural sector to ensure ecosystem services and reduce vulnerability” across 14 sites in India.
- Organization of training programmes in partnership with NBPGR. In vitro and cryopreservation training course and Gene bank Operations and Advanced Learning (GOAL) Master Class.

International Centre for Agricultural Research in the Dry Areas

Established in 1977, the International Centre for Agricultural Research in the Dry Areas (ICARDA) is a non-profit, CGIAR research center focusing on delivering innovative solutions for sustainable agricultural development in dryland production systems in the developing world. Headquartered in Beirut, Lebanon, with regional offices across Africa, Asia and the Middle East. ICARDA works in partnership with governments, civil society and the private sector to develop scalable agricultural solutions for the non-tropical dry areas that contribute to poverty reduction, food and nutritional security and ecosystem health.

The majority of smallholder farmers in the arid and semi-arid regions of the developing world grow crops and/or raise livestock as a key livelihood strategy. They face daunting challenges – from infertile and degraded land, water scarcity and frequent drought, to authorities and institutions struggling to support them, poor market intelligence and integration, and limited opportunities to access innovations and new technologies. The result is low agricultural productivity and limited livelihood opportunities that perpetuate a cycle of deep poverty and food and nutritional insecurity. To address these issues, ICARDA's targeted research is being operated under three major research programs with a decentralized research strategy located in contrasting agro-ecologies including India in South Asia region.

2.i. Over all contribution to Indian agriculture

ICARDA works with eight ICAR institutions and 12 State Agricultural Universities on basic, strategic and applied research on genetic enhancement of pulses (lentil, grasspea, Kabuli chickpea, faba bean), cereals (barley, durum wheat, bread wheat), forages including spineless

cactus. Additionally, management of rangelands and silvi-pasture, and developing models for improving water productivity in IGC Command area are also emphasized.

ICARDA has introduced several thousand landraces, wild species and newly developed breeding lines to India of the above crops and shared with its partner institutes. Pre-breeding research on lentil and Kabuli chickpea using wild relatives has generated promising genotypes with combination of desirable traits, which are under field trials.

Using ICARDA-supplied germplasm, 10 lentil varieties have been released: NDL-1, Moitree, DPL-62, DPL-58, IPL406, IPL-316, IPL-526, VL-507, L-4717 and VL-514). Identification and development of improved plant type of lentil rich in micro-nutrients (Fe and Zn) for short-season environments are in progress. Pusa Vaibhav, a high-iron lentil variety (102ppm) has been disseminated to farmers of Bihar & MP. In Kabuli chickpea, 6 varieties have been released: Virat-Phule G 95418, Vihar-Phule G 95311, Pusa 1108, Pusa 1053, Pusa 5023 and GLK 28127. Further 17 lines having high level of *Ascochyta* blight resistance are in field evaluation for future release. In barley, nine barley varieties have been released for food, feed and malt purposes in partnership with IIWBR. To enhance fodder availability, 67 spineless Cactus varieties have been introduced from Brazil and Italy and several nurseries have been developed. A total of 17,500 cladodes have been supplied to farmers in Janshi and Karnataka. Besides, promising lines of durum and bread wheat, grasspea and faba bean have enriched diversity for several traits including biotic and abiotic stress resistance.

Up-scaling of lentil, grasspea and Kabuli chickpea have been done in 10 states covering rice-fallows, and appropriate varieties and production technologies have been adopted by farmers. Mapping of rice-fallows is in progress in West Bengal and Odisha.

2.ii. Contribution during last one year

Based on requirements of genetic materials and requests from various partners, the following number of accessions were introduced in India during last one year-Kabuli Chickpea-1064; Grasspea-129; Lentil-1629; Faba bean-234; Barley-2100; Durum wheat-685; bread wheat-2781; and the total is: 8622. Besides, 2400 barley, 1434 lentil and 150 *Vicia* sp. were introduced as special nursery.



Lentil Variety "Moitree" in rice-fallows in West Bengal



Spine-less cactus in farmers' field in Karnataka introduced from Italy

Crop-specific crosses were commissioned using Indian parents, and segregating populations have been shared with partner institutions.

Seven *Stemphylium* blight resistant accessions, 19 rust resistant lines and 3 *Ascochyta* blight resistant cultures of lentil and 5 *Fusarium* wilt and *Ascochyta* blight resistant Kabuli chickpea lines have been selected.

11 lentil and 3 Kabuli chickpea lines developed from ICARDA genetic materials are in AICRP to test under varying climatic conditions 6,000 cladodes of spineless cactus have been distributed to farmers in Karnataka.

Release of L 4717 lentil variety (Pusa Ageti Masoor) by IARI using both parents from ICARDA. It is an early maturing variety with moderately resistance to wilt and yield potential of ca.1700 kg/ha. Mapped rice-fallows of two districts of West Bengal and one district of Odisha. 27 scientists took part in training and scientific visits organized by ICARDA

Out-scaling of improved lentil and grasspea technologies in rice-fallows in Chhattisgarh, Odisha, West Bengal, Tripura, Assam, Manipur, Meghalaya and Bihar under NFSM, OCPF, HarvestPlus and IFAD projects.



Extra-early segregants developed using ICARDA germplasm at IARI



A chickpea accession from Latvia is resistant to all races of *Fusarium* wilt



Tall and erect Kabuli chickpea landrace supplied by ICARDA has been selected at IIPR

2.iii. Socio-economic impact/outcome

To assess the technological impact and problems at farmers end for improving and further scaling-up of technologies, social scientists are working with multidisciplinary team of ICARDA scientists along with national partners in India. Jointly with Indian partners, promotion of lentil improved varieties and technologies has helped farmers to get increased yield of 39% in Assam, 36% in West Bengal, 53% in Bihar and 57% in Uttar Pradesh over farmers yield. Location specific technologies such as zero-tillage (ZT) gave 37-42% higher yields (up to 1.7 t/ha) and relay cropping gave 51-60% higher yields (up to 1.44 t/ha). In Rajasthan, demonstrations of improved production technologies of chickpea and barley gave yield advantage of 33 and 22%, respectively over local. CSJK 6 was better variety with low technology index and higher yield in chickpea and RD 2786 in barley gave higher net returns (43%), higher benefit cost ratio (14%) and economic efficiency (55%) over other varieties. Adoption of silvi-pasture on private land using ADOPT software revealed that it will take at least 19.3 years (14.3 years by scientists) in targeted villages for peak adoption. Predicted adoption level in 5 years from start will be 27.6% (48% by scientist's) and 78.4% (91.8% by scientists) in 10 years from start.

Overall, the major outcomes of collaborative research include: selection of accessions with desirable traits/genes/alleles (which were non-existence in Indian germplasm) and their use in genetic enhancement programs. Development of farmers-preferred varieties with higher and stable yields of lentil, Kabuli chickpea and barley. Spine-less cactus as an alternative animal fodder has a great impact to reduce feed shortage in India. Development of a model for improving water productivity in IGCC area in Bikaner is a notable outcome in scarce water research.

3. Projects/activities in progress in India

The following projects are operating in India with support from national and international donors. The major activities comprise of genetic enhancement of lentil, Kabuli chickpea, grasspea, faba bean, barley, durum and bread wheat, cactus and other forages, water productivity enhancement, mapping of rice fallows, impact studies, etc. Some of these activities are directly undertaken through a rolling work-plan operating with ICAR institutions and state agricultural universities.

- 5 projects (15 sub-projects) comprising of crop improvement (pulses, cereals, forages), resource conservation technology, water productivity, socio-economics, capacity development.
- Enhancing food and nutritional security, and improved livelihoods through intensification of rice-fallow system with pulse crops in South Asia.
- Variety, technology and seed system development for pulses in Odisha – Odisha Pulse Mission (OPM).
- Development of lentil cultivar with high concentration of iron and zinc.

- Increasing food legumes production by small farmers to strengthen food and nutrition security through adoption of improved technologies and governance within south-south cooperation.
- Application of Genomics to Innovation in the Lentil Economy (AGILE).

4. Yearly action plan and collaborators from NARES

The following yearly action-plan has been chalked-out to carry forward to achieve goal of ICAR-ICARDA collaboration.

- Genetic enhancement for the development of machine harvestable herbicide tolerant lentil cultivars for commercial production in India. Collaborators: IIPR, IARI, VPKAS, NBPGR, CSKHPKV, PAU, JNKVV, RAU.
- Breeding and selection for the development of small-seeded and extra short-duration lentil varieties suitable in rice fallows as relay (zero tillage) and sole crops in new niches of rice-based cropping systems of eastern India: Collaborators: IIPR, NBPGR, ICAR-NEH, BCKV, BAU.
- Introduction and use of exotic germplasm and development of large-seeded, extra short duration Kabuli chickpea varieties with resistance to wilt/root rots, Botrytis gray mold and Ascochyta blight and tolerant to heat. Collaborators: IIPR, IARI, NBPGR, CSKHPKV, PAU, JNKVV, MPKV, RAU.
- Multi-location testing and selection for high yielding and low-ODAP grasspea varieties adapted to rice based cropping systems for food and fodder production. Collaborators: IIPR, NBPGR, IGFRI, BCKV, IGKVV.
- Development of early high yielding, multiple disease resistant and drought tolerant Faba bean early varieties in India. Collaborators: IIPR, NBPGR, BCKV, ICAR-NEH, RAU.
- Development and deployment of climate resilient germplasm of barley and wheat for wide adaptation under climate change scenarios. Collaborators: IIWBR, VPKAS, PAU, RAU, CCSHAU, JNKVV, IARI, SKNAU, GAU, UAS.
- Development and deployment of appropriate varieties and technologies for improving farmers' income and livelihoods in rain-fed production systems through agricultural intensification and crop diversification. Collaborators: IIT-Kharagpur, BCKV, OUAT, ORSAC, IARI, CAZRI, IGFRI, IIPR.
- Research on development and dissemination of climate resilient and cost-effective technologies for rainfed regions for improved livelihoods. Collaborators: IARI, CIAE, IISS, WALMI, CAZRI.

5. Way forward

The effective collaboration between ICAR and ICARDA has led to introduction of legume and cereal germplasm from the Center of Origin and Primary Diversity of the Fertile Crescent conserved at ICARDA genebank in Syria. By utilizing them, several lentil, Kabuli chickpea and barley varieties have been developed and are being grown by farmers. Although a significant progress have been made, however, dryland production system further needs to expand R4D activities as follows:

- Strengthening Pre-Breeding Programs: acquisition of more wild relative accessions of legumes and cereals and their use in pre-breeding program.
- Introduction and growing of international and special nurseries at ICARDA's India Research Platform, and the selected materials (line/single plant) will be shared with national partners.
- Introduction of earliness and extra-earliness without yield penalty to address climate change effects (heat, drought).
- Bringing second/third crops in rice fallows needs a mission mode with fine mapping of fallow lands for suitability of various pulse/oilseed species, and demonstrating effective technologies.
- Development of site-specific varieties/production technologies based on edapho-climatic conditions and socio-economic conditions of farmers.
- As livestock is an important component, increasing availability of feed resources like Cactus, Vicia sp., pulses residues, etc. to be considered. Research on pulses should focus on high biomass.
- Training in the form of higher studies (MSc/PhD) to develop new generation of scientists under joint supervision to be strengthened.

International Centre for Research in Agroforestry

The International Centre for Research in Agroforestry (ICRAF), also known as World Agroforestry Centre (<http://www.cgiar.org/>), is one of the 15 research centers of CGIAR Consortium (<http://www.cgiar.org/>). ICRAF is headquartered in Nairobi, Kenya, with six regional offices located in Cameroon, China, India, Indonesia, Kenya and Peru. Research is conducted in over 36 countries in Africa, Asia and Latin America. As part of its global mandate, based in New Delhi, ICRAF established the South Asia Regional Program (SARP) in 2003. SARP covers Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. It focuses on four agro ecological environments, viz., mountainous regions of Afghanistan, Bangladesh, Bhutan, northeast India, Nepal; Indo-Gangetic Plains of Bangladesh, India, Nepal, Pakistan; humid coastal areas of Bangladesh, India, Maldives, Sri Lanka and semi-arid lands of India, Pakistan, Sri Lanka.

The vision of ICRAF is a rural transformation in the developing world where smallholder households strategically increase their use of trees in agricultural landscapes to improve their food security, nutrition, income, health and social cohesion, renewable source of energy and building material and environmental sustainability. The Centre generates science-based knowledge about the diverse roles that trees play in agricultural landscapes, and uses that research to advance the implementation of policies and practices that benefit the poor and the environment. As part of its work to bring tree-based solutions to bear on poverty and environmental problems, the Centre's researchers working in close collaboration with national partners, have developed new technologies, tools and policy recommendations for increased food security and ecosystem health.

2.i. Over all contribution to Indian agriculture

Scientific cooperation in the field of Agroforestry between ICAR and ICRAF started with signing of the first MOU between ICAR and ICRAF in 1985. Initially, the collaboration covered areas of climate change and restoration of degraded land which followed with the signing of collaborative work plans.

ICRAF contributed in the formulation and approval of National Agroforestry Policy (NAP) of India in 2014, and ICRAF's contribution was recognized by nominating it as one of the permanent members on the inter-ministerial committee that oversees the implementation of the policy. ICRAF continues its active involvement in the on-going implementations of NAP recommendations, and contributes to the development of the National Agroforestry Mission (Refer para 5.1.2 & 5.1.4 of National Agroforestry Policy, 2014).

ICRAF facilitated and supported the establishment of arboretum at Central Agroforestry Research Institute (CAFRI) for collection and evaluation of germplasm of Jatropha, Anogeissus, Acacia, Sisham, Neem, Karanj and other multi-purpose tree species (MPTS).

A protocol called "SMART-CDM" (Specific, Measurable, Achievable, Realistic, and Tangible – Clean Development Mechanism), developed by ICRAF'S team of scientists, was piloted through the National Agriculture Innovations Project (NAIP) on carbon finance, at four ecologies in India. A total area of 11, 678 ha, involving 5,492 small-holder families and 385 landless families contributed towards reduced emissions and sequestration of more carbon at the farm- house hold and community level by adopting climate change related interventions. Through the intervention of the project more than 390,790 trees were planted in the four grids (Almora, Mavli, Jaffergudum and Athagarh) with an approximate survival rate of above 75%. It is estimated that on average, farmers would realize more than Rs.100,000,000/grid at a conservative value of only Rs. 1000/tree, on harvest of the planted trees.

Taking into account the baseline emission levels and the accrued benefits of emission reduction and carbon sequestration interventions (as above), the potential certified emissions reduction (CERs) were calculated for the grid. As of now the calculated CERs in the respective grids range between 7,428 CERs for Almora to 25,378 for Mavli grid. Jaffergudum and Athagarh grids have similar levels of CERs, 11, 962 and 12,988 CERs, respectively. A prior consideration for all the grids was submitted, accepted and registered at the CDM / UNFCCC (United Nations Framework Convention on Climate Change).

The National Initiative on Climate Resilient Agriculture (NICRA) supported the fodder research project in Udaipur, Bhilwara, Chittorgarh, Churu and Fatehpur- Shekhawati districts of Rajasthan; and Allahabad district of Uttar Pradesh. Assisting natural regeneration of fodder trees and grasses in common lands through social fencing to avoid over grazing, seeding grazing lands with fodder grasses and legumes, and controlled harvesting sharing of fodder from these lands, regeneration of fodder trees in agricultural fields, significantly increased the fodder availability.

Under capacity development endeavour, 8 international trainings were conducted at Nairobi, Philippines and at India on Carbon Finance Market, Carbon Stock Assessment, and Carbon Trading Options, which were attended by 62 participants. A specialized international training on the use of Geoinformatics in mapping agroforestry was organized, at Nairobi, wherein 8 scientists from ICAR Institutes and State Agricultural Universities (SAUs) participated. Another international training on Research Methods in Agroforestry was organized at CAFRI, Jhansi, where 35 scientists (30 from India and 5 from SAARC Countries) received this much required training. Two trainings on Soil-Plant Spectroscopy were organized at IISS Bhopal in 2015. A total of 20 scientists from Indian Institute of Soil Science (IISS) and CAFRI attended these trainings. A scientist from CAFRI was sponsored to attend training on the Development of Communication Strategies for Adoption of Agri-biotechnology, at Bangkok. During October, 2015, an international training was organized on the Role of Gender in Agroforestry at New Delhi, was attended by 20 participants, including from Nepal and Bangladesh. In addition, following workshops/seminar/conferences were cosponsored:

- "3rd World Agroforestry Congress" during 10-14 february 2014 at New Delhi was organized by ICRAF, ICAR, ISAF and Global Initiative (GI). Over 1000 delegates from more than 80 contries participated.
- National Workshop on "Quality Planting Material Production & Supply" during January 16-17, 2015 at Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya (RVSKVV), Gwalior, which was attended by 150 scientists and other stakeholder including from SAARC Countries,
- National Seminar on "Holistic Development of Agroforestry: Potential and Policy Issues" during February13-14, 2015 at G.B. Pant University of Agriculture & Technology (GBPUA&T), Pantnagar, which was attended by about 200 scientists,
- A Regional consultation on "Agroforestry: The Way Forward" during Oct. 8-10, 2015 at New Delhi. This consultation was attended by 126 delegates, including 18 from Afghanistan, Bangladesh, Bhutan, Indonesia, Kenya, Malaysia, Nepal, Philippines, Sri Lanka Thailand, and Vietnam,
- Technically and financially supported organization of the International Grassland Congress during Nov. 20-24, 2015 at Delhi.

2.ii. Contribution during last one year

Soil Health measurement using MIR technology: In collaboration with the IISS Bhopal, Alpha MIR spectral processing and exploratory analysis of soil samples from Odisha, UP and Bihar States were completed. The 1st derivative was used for the development of the spectral library after joining with soil data of Odisha, Bihar and UP states and the results are given in figure 1. The available plant nutrients of black soils/Vertisols from central India by Mid-infra-Red (MIR) and wet chemistry method were compared to validate the results the MIR technology. In order to address large variability of Indian soils, 1450 soils samples from various agro-ecological regions of India were collected and analyzed using both the wet chemistry and MIR technique. Modeling of MRI data is in progress (Figure-2).

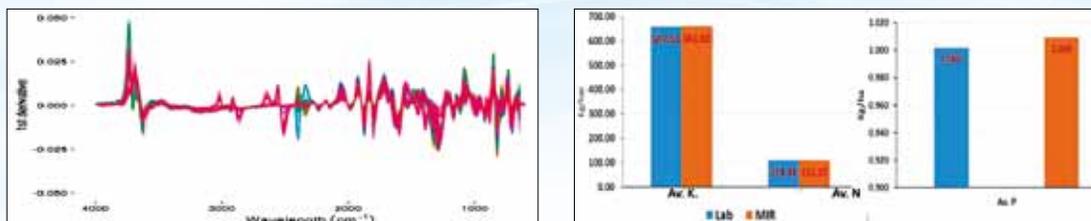


Figure 1: Result of MIR technology (a). First derivative spectral library after joining with soil data (b). Available Major Plant Nutrients (Kg/ha) by MIR and with traditional analyses (Black soil, Central India)

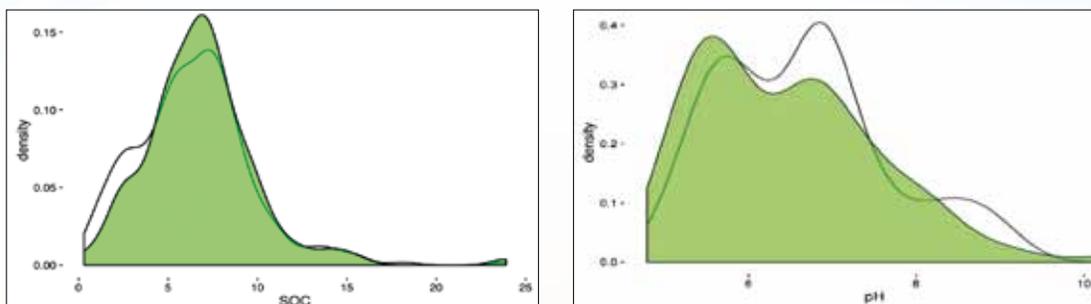


Figure 2: Plots showing the distribution of SOC and pH in the calibration and validation datasets (Prediction values white, Recorded data- green)

Geoinformatics: Use of Geoinformatics in mapping agroforestry was taken up in collaboration with CAFRI, Jhansi during 2016. High resolution/ hyper-spectral multi-temporal remote sensing data for Unnao, Lucknow, UP were collected for analysis. Temporal spectral reflectance pattern of agroforestry systems/ tree species was studied and spectral reflectance values in different spectral bands for different periods was recorded and analysed. These signatures are used as digital spectral library to map similar agroforestry species/systems. The technique was also tested to map specific agroforestry species (mango) to develop a technology for qualitative mapping of agroforestry figure 3. The work will jointly continue by ICRAF and CAFRI to fully develop the technology.

Develop skills in quality planting material production and supply systems of agroforestry species: Ten priority fruit, timber and medicinal plant species of national importance were identified and the collection and characterization of germplasm of priority agroforestry tree species (specially, *Psidium guajava*, *Litchi chinensis*, *Dalbergia sissoo*, *Azadirachta indica*, *Eucalyptus*

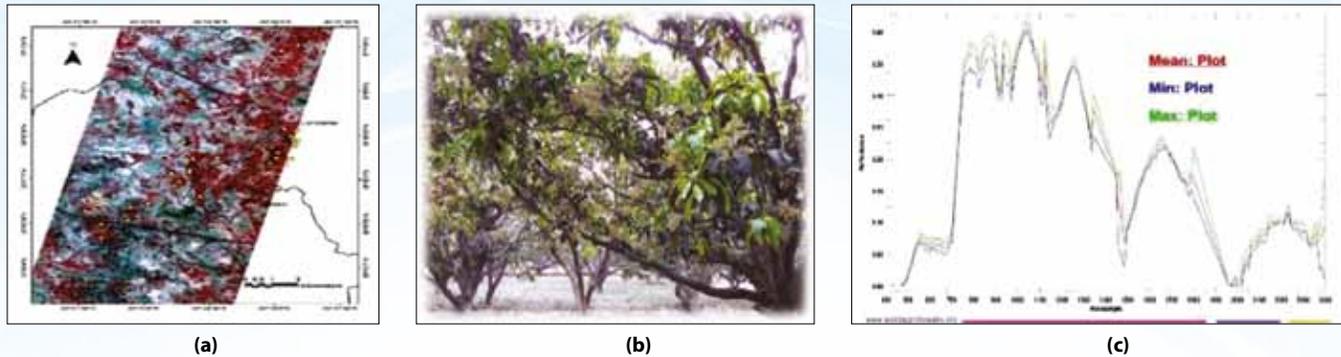


Figure 3: Identification of mango plantation using hyperspectral remote sensing (a) ground truthing, (b) mango tree on farmer field and (c) spectral signature of mango, Unnao, UP

sp., *Jatropha curcas*, etc.) were undertaken by the collaborators (CAFRI and GBPUA&T). About 1,30,000 Quality Planting Material (QPM) were produced and distributed to farmers by CAFRI, RVSKVV and GBPUA&T. ICRAF is analysing the value chain using the above interventions. Ministry of Agriculture & Farmers Welfare, Government of India and ICRAF initiated the action on following in association with above partners:

- Value chain analysis of QPM production and distribution of agroforestry species to identify required interventions.
- Facilitated formulation of guidelines to establish a “Production, Quality Control and Certification System for QPM” for agroforestry species.
- With collaboration of CAFRI, AICRP-AF, SAUs and other actors enabled private sector (nurseries, youth, women) to produce QPM.

Agroforestry species domestication with intensification and diversification of agroforestry production systems: The socio-economic analysis of three systems, in a multi-layer/inter-cropping system with pineapple in Orissa was found to be most remunerative. Inter-cropping with (*Ananas comosus*, *Curcuma amda*, *Curcuma longa* and *Maranta arundinacea*) were tested in mango based (mango + *Dalbergia sissoo* and mango+ *Gmelina arborea*) agroforestry system. It was observed, pineapple was the best suitable crop to be included in the mango based agri-horti-silvicultural system. In collaboration with OUAT, ICRAF is further examining these results to upscale in larger areas.

Enabling tribal communities of India to improve their livelihoods through agroforestry systems on a sustainable basis: The interventions were studied at two places, Ranchi (Jharkhand) and Nayagarh (Orissa) where maximum tribal farmers may be benefitted. Multi-tier horti-lac system comprising of lac as host plants and others like, semialata (*Flemingia semialata*)

and ber (*Ziziphus mauritiana*) and fruit trees aonla (*Emblca officinalis* syn. *Phyllanthus emblica*), guava (*Psidium guajava*) and lime (*Citrus aurantifolia*) initiated to test their potential for enhancing the livelihood. This will continue as a collaborative work with IINRG, Ranchi.

Agroforestry as a malnutrition remedy in India: Few farm sites on poor tribal farmers' fields in collaboration with partners were selected where *Acacia mangium* and *Tectona grandis* were planted as main agroforestry trees in village Kandupali, Badajorada Gram Panchayat, Block Talchar, Angul district. With a view to provide extra nutrient and vitamins to poor farmers in addition to financial gain trees species (*Acacia mangium* and *Tectona grandis*), short duration fruit crops (pineapple and papaya) and seasonal vegetables (brinjal-cowpea, okra-french bean and cowpea-potato) vegetable were intercropped.

The present results indicate, brinjal –cowpea intercropped with teak + papaya recorded the highest net return of Rs. 196020/- and Benefit Cost Ratio (BCR) 2.40. Farmers' consumption of papaya from market purchase was nil as papaya are produced on their own farms and their consumption was also increased up to 18%. While the vegetable consumption on an average was 5% through purchasing from the market was increased to 30-35%.

Rehabilitation of degraded lands through agroforestry systems: With the aim to select sites in some major ecologies of the country for rehabilitating the degraded land through agroforestry, reconnaissance of degraded lands were undertaken in Rajasthan. The preliminary survey revealed that a majority of the lands in these areas are found to be severely degraded and have very low biodiversity, plant density, soil fertility and productivity. Kalikhhol, Singoli, Amartia, Kekadia and Barundini village clusters in Bhilwara district as representative sites were selected for characterizing and mapping land degradation. The vegetation, soil, hydrological parameters and land productivity of the area are being sampled and analysed.

Accelerated implementation of National Agroforestry Mission: Worked with AF-Mission to convince states to de-notify agroforestry species from felling and transit regulations enhancing adoption of agroforestry. Few states are already in the process of de-notifying agroforestry tree species for planting to harvesting without any restriction.

- Supported states to develop their own agroforestry policy and mission which will accelerate the adoption of agroforestry. Uttar Pradesh has already constituted the committee for these purposes where ICRAF is one of the members.
- Dialogue and engagement with public and private sector to support agroforestry through CSR programs
- ICRAF-South Asia is a member of the Inter-Ministerial Committee to oversee the implementation of the National Agroforestry Policy,
- Contributes as a member of the Technical Group (Ministry of Agriculture) which supports Agroforestry Mission.

Capacity development: Following capacity development activities were undertaken and successfully completed.

- A training on Soil health analysis using MIR Spectroscopy was organised at IISS, Bhopal. Topics like, instrument calibration & trouble shooting; analysis and robust modelling for wide soil variability in India and spectral data analysis using different approach (other than Random Forest) were covered,

- A training on Spectroscopy and Data Analysis using Infrared (IR) spectral techniques was organized at Nairobi, Kenya. Participants had hands on training on the topics of integrating / predicting soil quality from spectroscopic data; developed models that explain the soil parameters with great degree of reliability,
- A National Symposium on “Agroforestry for environmental challenges, sustainable land use, biodiversity conservation and rural livelihood options” was jointly organized with CAFRI, where more than 200 delegates participated. The symposium successfully deliberated on agroforestry systems for climate resilient agriculture; agroforestry for food security & rural livelihood options; bio-resource & energy management; and socio-economic and policy issues in agroforestry, and
- An International Training on Ecosystem Services and Carbon Sequestration by Agroforestry: Concept, Theory and Practice was organized at ICAR-CAFRI, where thirty four scientists from CAFRI, Indian Grassland and Fodder Research Institute, Indian Institute Soil and Water Conservation and state govt. officials participated where the topics of ecosystem structure, function, service, human benefits and value derived were covered.

2.iii. Socio-economic impact/outcome

Formulation and implementation of the agroforestry policy, and accelerated promotion of agroforestry through the mission has huge socio-economic impacts. Change in policy is creating favourable atmosphere for farmers to grow trees of their choice to get the desired benefits, and also increasing the much required tree cover by the country. There is a gap of about 6% tree covers as compared to the required 24%. Further, Government of India through INDCs (Intended Nationally Determined Contributions) has committed for restoring/ new tree plantations in 5 million ha. Both the mission and the policy are highly contributing towards the socio-economic and environmental needs of the country. These initiatives of the Government where ICRAF is closely associated are also increasing the impact of India in the region. Bangladesh and Nepal, both are following India’s model and success to develop their own policies to enhance the adoption of agroforestry. Under rehabilitation of degraded lands through agroforestry, at pilot sites in Bhilwara and Udaipur districts, Rajasthan, the villagers had constructed 64160 running meters of graded bunds and contours within and outside the village. The villagers cooperatively managed blocks of land ranging from 30 to 50 ha and planted tree species, which included bamboo, sisso, acacia and amla in the area along with fodder legumes (stylo) and grasses (*Cenchrus* sp). They were able to produce high quality fodder for the entire year requirement for their livestock from these lands. Supplemented with the on- farm fodder production, they were able to market out excess fodder to other areas while maintaining the same species and same or higher number of livestock per house hold in the community. For example, Cheetrawas community in Udaipur has been consistently selling excess fodder to the tune of Rs 10 Lacs /annum since 2009.

In addition, 21% reduction of the waste land was recorded in the pilot watershed areas with rise of 1.5 meters in the water level of the wells, and the double cropped area at the pilot sites increased by 84%. The community moved to self-sufficiency from a 60% scarcity of fodder in the prior project phase.

Besides filling the gap in fodder supply, the project model has indirectly contributed to the enhanced environmental services, such as the biodiversity regeneration, conservation and increase, enhanced profile recharge, increased water supply and reduced soil erosion in quantified terms.

Increased cropping intensity and sale of extra fodder has created opportunities for employment and raised the income as well as the nutritional status of the community. The distressed sale of livestock due to lack and high cost of fodder has stopped at Rajasthan site, which was a regular feature before, and there is a significant increase in livestock population and milk production at Uttar Pradesh site; e.g. 6000 liters of milk is sold daily from Kaurihar block, Allahabad, UP.

3. Projects/activities in progress in India

The projects/activities initiated through approved ICAR-ICRAF work plan (2016-2020) in collaboration with NARES institutes. Activities in the following thematic areas will continue based on the recommendations of ICAR-CG review meeting of 2017:

- Germplasm exchange, Geoinformatics, and Environmental Services & carbon sequestration.
 - Quantitative and qualitative mapping of agroforestry using Geoinformatics.
 - Develop skills in quality planting material (seed and seedlings) production and supply systems of agroforestry species and development of guidelines of quality planting material.
 - Climate change adaptation options for stable and improved livelihoods of small holder farmers.
- Monitoring soil health using MIR technology.
 - Introduction and fine tuning of soil-plant spectroscopy technology to monitor soil health and targeting agroforestry interventions to enhance land productivity.
 - Assessment of important soil properties of India using mid-infrared spectroscopy.
- Improving food and nutritional security & restoration of degraded lands through agroforestry.
 - Agroforestry species domestication with intensification and diversification of agroforestry production systems.
 - Enabling tribal communities to improve their livelihoods through agroforestry systems on a sustainable basis.
 - Agroforestry systems as remedy for malnutrition.
 - Increasing fodder production to improve livelihoods of rural communities.
 - Rehabilitation of degraded lands through agroforestry systems.
- Accelerated implementation of National Agroforestry Mission.
 - Accelerating the implementation of National Agroforestry Policy recommendations in India, supporting State Governments to up-scale Agroforestry through state policies. Facilitating development of such policies in other South Asian countries (SAARC region) to highlight the profile of India.

- Promoting India as a technical hub for South Asia, & Capacity development. Strengthening the agroforestry capacity of individuals, and of research, development and educational institutions and systems (South Asian Association for Regional Cooperation-SAARC + Africa).

4. Yearly action plan and collaborators from NARES

In addition to approved activities for 2017 (mentioned above), following additional activities will also be taken up under the overall approved ICAR-ICRAF work plan (2016-2020).

- *Enabling small holders to improve their livelihood, food, nutrition and environmental sustainability through agroforestry:* This project is to be implemented in Rajasthan for degraded land rehabilitation in collaboration with CAFRI, Central Arid Zone Research Institute (CAZRI) and Oil and Natural Gas Commission (ONGC) Jodhpur under Corporate Social Responsibility (CSR) initiative with following objectives:

To design /develop/ compose sustainable agro-silvi-horti-pastoral models that increase productivity, food & fodder security, and environmental sustainability,

To demonstrate the above models in 30 ha block pilots in small holder farming operations,

To organize the community of small holder farmers into a unit of 30 ha blocks for demonstrating the pilot models,

To build capacity of the team of stakeholders to be able to deploy such a framework and strategy (as above) at scale in other areas as an exit strategy of the proposed project, and

To provide a template of the proposed project to the ONGC for a wider application and scaling up purposes elsewhere.

- *Enabling small holders to produce and consume more nutritious food through agroforestry systems in Odisha (under pipeline):* This project is to be implemented in collaboration with Government of Odisha (Department of Horticulture, Agriculture, Forestry, Watershed, Extension, Health and Rural Development), ICAR- CAFRI, and National Rice Research Institute (NRRI), Odisha University of Agriculture & Technology (College of Forestry, Home Science, Agriculture, Krishi Vigyan Kendra-KVKs). The objectives of the project are:

Create awareness about and improve community level consumption of diversified nutritious farm produce, including fruits, vegetables, and other tree based produce, such as the flowers, pods, leaves, etc.

Introduce and work for accelerated adoption of suitable agroforestry system by the communities for enhanced production of nutritive food.

Demonstrate the application of selected value addition aspects to the farm produce (sorting, grading, processing, storage for the off season use and collective marketing, etc.) at the community level.

Assess the impact of introduced interventions on food and nutritional security of the community, and the systems productivity to support better decision making for scaling up and scaling out.

Build capacity of all stakeholders and create a structure for sustainability of the activities and impacts.

- *Capacity building of agroforestry stakeholders in SAARC involving India as technical hub (in pipeline):* The objective of the project is to mainstream agroforestry and harness its full benefits through enhancing capacity development of policy makers, researchers, practitioners and the farmers of SAARC Countries.

5. Way forward

ICRAF in close collaboration with ICAR and its institutes will implement the above mentioned activities subject to availability of necessary funding. The ongoing collaboration will follow a “dynamic” approach enabling partners to add /drop activities to keep the collaboration aligned with provincial/ national/ and regional priorities; and address any changing/ emerging situation. Besides working with ICAR and its institutes, need and opportunities will be examined to broaden the partnerships with DAC, State Governments, Universities, and public and private sector companies through CSR initiatives. Besides research for development, ICRAF also aims to work with banks and insurance companies to assist develop specific and highly required credit and insurance products based on scientific data and realistic socio-economic considerations to protect the interests of smallholders.



Farmers' participation in implementation of agroforestry on their field

International Crops Research Institute for the Semi-Arid Tropics

The International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometres of land in 55 countries, the semi-arid tropics have over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT innovations help the dryland poor move from poverty to prosperity by harnessing markets while managing risks – a strategy called Inclusive Market-Oriented Development (IMOD).

We have specialized skills on crops of immense value to the nutrition and economics of the semi-arid tropics – dryland cereals (sorghum and millets) and grain legumes (chickpea, pigeonpea and peanut). We work across the whole value chain and have science-based solutions at all stages. Our Capabilities include:

- Multidisciplinary high class science from natural resource management, genetics, bioinformatics and phenotyping to economics and social sciences.
- On the ground in Africa and Asia with offices in Kenya, Ethiopia, Malawi, Mozambique, Mali, Niger, Nigeria, Zimbabwe and India.



Signing of work plan between ICAR and ICRISAT

- Strong networks as we work in partnership at all levels – local, national, regional and international.
- Participatory methods have been developed and are used as part of our work, involving the farmers through to the government and private industry where change is needed.
- Recognized as independent – as an international non-profit organization that has worked in Asia and Africa for over 40 years, our scientific and independent credibility are well founded.

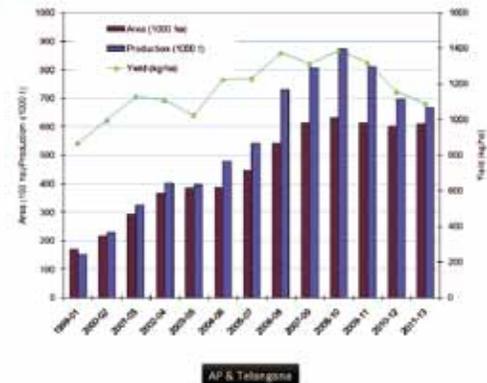
ICRISAT is headquartered in Patancheru, Hyderabad, India, with two regional hubs and eight country offices in sub-Saharan Africa. It is a member of the CGIAR System Organization.

2.i. Overall contribution to Indian agriculture

- From 1976 to 2016, 316 improved varieties/hybrids of sorghum (41), pearl millet (170), chickpea (45), pigeonpea (29) and groundnut (31) have been released by Indian partners (using breeding material from ICRISAT), raising production and incomes of millions of smallholder farmers.
- ICRISAT has repatriated 41,796 national germplasm accessions to the National Bureau of Plant Genetic Resources, New Delhi.
- Forty-five high-yielding chickpea varieties with early to medium maturity and high resistance to wilt have been developed and released in India through ICRISAT partnership with State Agricultural Universities in India. These varieties have shown high adoptions, particularly in central and southern India, and accounted for about 53% of the total indent of chickpea breeder seed in India during 2016-17. Efforts by ICRISAT and partners have led to a chickpea revolution in Andhra Pradesh, where production increased 8-fold in the past 15 years. ICRISAT-India partnership varieties (JG 11, JAKI 9218, KAK 2, and Vihar) were instrumental in the success. They cover over 90% of the chickpea area in Andhra Pradesh. The recently released machine

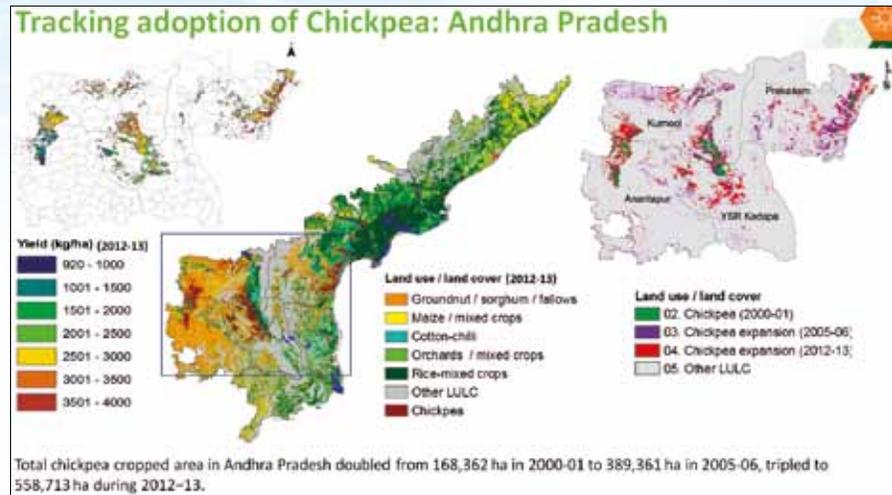
Impacts of short-duration chickpea varieties in Southern India

- 95% of chickpea area under short-duration varieties developed from ICRISAT-bred lines in Southern India (AP & Telangana) and Myanmar



harvestable chickpea variety (NBeG 47) in Andhra Pradesh will further benefit farmers from increased mechanization.

- ICRISAT and Indian NARS scientists developed pigeonpea hybrids (first in any grain legume in the world) based on cytoplasmic-nuclear male sterility (CMS) technology. The hybrids ICPH 2671, ICPH 2740 and ICPH 3762 have recorded 30% to 40% higher yields compared to local and improved varieties under rained conditions. Commercially viable seed production technology was also standardized for large scale seed production. Collaborative efforts of ICRISAT, the National Seeds Corporation, State Seed Corporations, ICAR institutes and State Agricultural Universities and State Agriculture Departments led to expansion of area under hybrid pigeonpea to 200,000 ha by 2016 and it is further expected to expand in coming years to the benefit of smallholder farmers.
- Drought-tolerant groundnut variety, ICGV 91114 is replacing the 60-year-old TMV 2, which dominated groundnut production in Anantapur district of Andhra Pradesh.
- Of the more than 30 sorghum hybrids cultivated during the rainy season on 3 million ha in India, 55% are based on ICRISAT-bred parental lines or derivatives. The first sweet sorghum hybrid CSH 22SS was released in 2005 by the National Research Center for Sorghum, Hyderabad which used the ICRISAT-bred female parent ICSA38.
- About 6 million ha area in India is under pearl millet hybrid cultivation, and 60% of about 100 pearl millet hybrids developed since 2000 by the NARS and seed companies in India are based on ICRISAT-bred material. ICRISAT in collaboration with NARS developed downy mildew resistant version (in 2011) of extra-early pearl millet hybrid HHB67, which was grown on about 875,000 ha in the most drought prone environment of north-western India. ICRISAT also bred the first biofortified cultivar of pearl millet 'Dhanshakti' with high grain Fe content of 72ppm. It was notified for release for all India cultivation in April 2014, and biofortified pearl millet hybrid ICMH 1201 is being marketed in north Indian states starting 2014.



- Work on watershed activities began in 2003 under the Sujala project covering 3,700 ha. Today the Bhoochetana project in Karnataka covers 7 million ha.

2.ii. Contribution during last one year

- ICRIAT maintains six crop improvement programs in India. These programs released elite lines into National Performance/Variety Trials in 2016 for pearl millet (62), finger millet (0), sorghum(1), pigeonpea (33), chickpea (75) and groundnut (228).
- ICRIAT and its partners (NARS scientists and extension staff, including NGOs and farmers' groups) produced and distributed over 16,000 t of seed for its mandate crops in 2016.
- Integrated soil, water, nutrient, seed and crop management practices in India were scaled up in partnership with the respective state governments across ~6 million hectares in two Indian states, Karnataka and Andhra Pradesh. Increases in crop yield and incomes ~10-50% were recorded in these states compared to traditionally managed farmers' fields.
- ICRIAT is working with national and international research institutes, NGOs and government departments and private companies under Corporate Social Responsibility initiatives to establish over 15 pilot watersheds (2000 ha to 5000 ha) in Uttar Pradesh, Karnataka, Telangana, Maharashtra and Andhra Pradesh covering ~70,000 ha with more than 50,000 farming families. The impacts of soil and water conservation practices are ~50-100% increase in groundwater recharge, ~30-60% increase in cropping intensity and 2-fold increases in crop yields.
- Farmer Producer Organizations (16) have been promoted in three states of India with the support of NABARD. FPO promoting institutions in Telangana state (40) were mentored to support sustainable establishment of 75 FPOs.
- Climate mapping of Telangana State was done by combining data from geo-spatial analysis, historical and future climate scenarios. A mandal (block) level mapping of vulnerability and climate risk and participatory prioritization has informed the government on the targeting and return on investment of climate smart agricultural practices.
- Mapping the shift of a cold season crop to warmer climate: A geospatial study revealed an increase in chickpea cultivation in warmer climatic conditions in south India (chickpea is traditionally grown as a winter crop in north India). The adoption area of chickpea tripled from 0.22 million ha during 2000–2001 to 0.6 million ha by 2012–2013 with nearly 98% improved cultivars, with an average increase in yield of 37% over yields achieved with unimproved varieties.
- 5000 small-scale vegetable cultivation (kitchen gardening) kits were promoted in the Indian states of Karnataka and Andhra Pradesh for mainstreaming women farmers and enhancing family nutrition.
- Weather-based advisories provided through a Sowing App was piloted with groundnut farmers in Kurnool, Andhra Pradesh, India. The app is based on long-period climate data, real-time observed rainfall and forecasted rainfall for the next five days. The advisories empowered farmers in taking suitable decisions on sowing at the right time to avoid crop failure and to take up proper crop management practices for enhancing crop yields and incomes.

- A mini dal mill was set up in the tribal areas of Adilabad district of Telangana as value-addition to help farmers process their produce and link them to markets. Livelihood opportunities are being created by introducing new varieties and cultivation practices of pigeonpea and sorghum and establishing processing centers.

2.iii. Socio-economic impact/outcome

ICRISAT groundnut variety ICGV 91114 was approved for release in Andhra Pradesh by the State Seed Sub-Committee in 2006. It was subsequently released as 'Devi' in Odisha. It results in 23% increase in yield, 36% higher net incomes and 30% reduction in yield variability. In Anantapur district, Andhra Pradesh ICGV 91114 is now replacing TMV 2 and occupied 25,000 ha of the 800,000 ha under groundnut in Anantpur district, Andhra Pradesh in 2010.

The adoption of early-maturing chickpea cultivars has brought a chickpea revolution in Andhra Pradesh. Over 80% of the chickpea area in Andhra Pradesh is now cultivated with the short-duration improved cultivars JG 11 and KAK 2, which were developed through a partnership between ICRISAT and the Indian NARS. Andhra Pradesh was once considered to be a low yielding state for chickpea because of its warm, short-season environment, but it now has the highest yield levels in India. Chickpea performance in Andhra Pradesh results into 9-fold increase in production (95,000 to 884,000 tons), 5-fold increase in area (102,000 to 602,000 ha) and 2.4-fold increase in yield levels (583 to 1,407 kg per ha).

Odisha released its first improved pigeonpea cultivar, ICPH 3762, in the name of Goddess Pārbati in March 2015. ICPH 3762 recorded 125% increase in yield over local types. This hybrid also possesses complete resistance against wilt and sterility mosaic diseases.

Three new varieties were released in Telangana in 2015: (a) ICPH 2740 – released under the name Mannem Konda Kandi – is the first pigeonpea hybrid for the state of Telangana. The hybrid possess resistance to wilt and sterility mosaic diseases and is suitable for deep black soils of the state. With a yield potential of 3.5 tons per ha it registered a 40% yield increase over the local cultivars. (b) ICPL 14003 (PRG 176) was released under the name Ujwala. The variety has yield potential of 2.5 tons per ha and matures in 130 days. It is resistant to terminal drought. (c) ICPL 332 WR (TDRG 4) was released by the name Hanuma. This variety has a yield potential of 3 tons per ha and is resistant to wilt and tolerant to Helicoverpa.

HHB 67, an early maturing (62–65 days from sowing to harvest) pearl millet hybrid was developed by ICRISAT in collaboration with the Indian NARS.

At the peak of its adoption in 2002, HHB 67 was grown on about 774,000 ha. By 2011, HHB 67 Improved had spread to 875,000 ha, with Rajasthan accounting for 768,000 ha (16% of the state's total pearl millet area) and Haryana accounting for 107,000 ha (21% of the state's pearl millet area). It results into \$13.5 million net additional benefits compared to local land race, \$1,460 per ha increased net income from hybrid seed production and \$6.4 million total net benefit from hybrid seed production.

Furthermore, these hybrids have facilitated the cultivation of winter season rotational crops such as mustard, wheat and chickpea, thus doubling cropping intensity and substantially increasing farm household incomes compared to those obtained previously by growing pearl millet landraces.

To date, more than 1.4 million samples of nearly 100,600 germplasm accessions have been shared with collaborators in 145 countries. NARS partners have released more than 800 varieties in 79 countries utilizing germplasm and breeding lines from ICRISAT.

Under the Bhoochetana project being implemented in Karnataka, 3.1 million farmers have benefited, 7.4 million ha of farmland covered, 3-14 : 1 benefit-cost ratio, 20-66% increase in crop yield and Rs 1,268 crore net benefits accrued in 4 years.

3. Projects/activities in progress in India

Since 1992, a Joint ICAR-ICRISAT Policy Advisory Committee was formed to oversee collaboration and initiate formal ICAR-ICRISAT Joint Research projects that are renegotiated in a three-year cycle. Ten research projects were undertaken during 2010-12 and eight joint research projects conducted in 2013-15. For 2016-18, following joint projects are undertaken

- i. Integrating systems modelling tools enabling informed decisions for upscaling climate resilient agriculture.
- ii. Development of genetic and genomic resources of finger millet and its application in crop improvement.
- iii. Enhancing genetic gains for priority traits in grain legumes and dryland cereals.
- iv. Digitalization of Breeding Database through Integrated Breeding Platform (IBP) for National Agriculture Research System.
- v. Transgenic pigeonpea and chickpea for insect resistance.
- vi. Smart Food Initiative.
- vii. Interim support for the core breeding programs of ICRISAT grain legume and dryland cereal crops.

4. Yearly action plan and collaborators from NARES

- For all six mandate crops, the BPAT (Breeding Program Analysis Tool) is being operationalized for enhancing the efficiency of ICRISAT breeding programs to achieve higher genetic gains through targeted breeding initiatives. Learning from this process will be shared with NARES partners.
- New markers for prioritized traits across ICRISAT mandate crops will be developed and validated. Validation and deployment of markers for at least one additional high priority traits in each crop (except finger millet) will be made available for forward breeding.
- Additional transgenic events expressing higher levels of CRY toxin in both chickpea and pigeonpea will be developed. Progenies of promising events will be advanced and evaluated in insect feeding assays. A field trial for existing cry1ac pigeonpea events will be carried out in Kharif 2017 following permission from Regulatory Authorities.
- ICRISAT will continue to support the Government of India for the doubling of farmers' incomes and will contribute to its strategy of a holistic livelihood ecoregion-based approach with appropriate institutional mechanisms for achieving the goal of doubling the farmer's income by 2022.
- Effort will continue on popularizing pigeonpea hybrids, evaluating short duration pigeonpea hybrids as well as machine harvestable chickpea, high oil content lines of groundnut, and high-yielding dual purpose sorghum.
- ICRISAT will continue to popularize and demonstrate sustainable intensification of rice fallows using pulses and also sweet sorghum in target states in India and contribute to the Government of India's target of achieving 3 million hectares cultivation of rice fallows.
- In partnership with Ministry of Petroleum and Government of India, will support the development of a 2G ethanol production strategy. The 2G Renewable Biomass Availability Study in the states of Andhra Pradesh and Bihar will be completed and submitted to Hindustan Petroleum Corporation Limited (HPCL).
- Biogas production pilot plant will be established on ICRISAT and be in use for producing the clean and renewable energy using agricultural residues, food wastes generated on campus in an environment-friendly manner.
- In partnership with DBT, ICRISAT will participate in the University of Cambridge, UK, Government of India initiative on enhancing research in crop sciences, promote knowledge exchange and develop resilience in food security.

5. Way forward

ICRISAT is the only CGIAR Centre to be headquartered in India; 2017 is the 45th anniversary since its establishment at Patancheru. Over these four and half decades, ICRISAT has established strong collaborative relationships with Indian public and private sector partners to help meet its vision of securing a prosperous, food-secure and resilient dryland tropics in India. Looking forward, ICRISAT will continue undertaking research for development that leads to reduced poverty, hunger, malnutrition and environmental degradation in the semi-arid dryland tropics of Africa and Asia. Partnerships that embody demand-driven innovation will continue to be ICRISAT's approach in fulfilling its mission.

In 2018, ICRISAT intends to lead a new five-year CGIAR Research Program on Grain Legume and Dryland Cereal Agrifood Systems. The objective of the CRP is to increase the productivity, profitability, resilience and marketability of critical cereal and grain legume crops grown within the semi-arid and sub-humid dryland agro-ecologies of sub-Saharan Africa and South Asia. This program will support research for development on three cereal (sorghum, pearl millet, finger millet) and six legume (chickpea, cowpea, groundnut, lentil, soybean, pigeonpea) crops, all of which are important in Indian agriculture. The CRP will marry the traditional strengths of crop improvement science and farming systems research along with research that fosters wider market and policy opportunities within the targeted agrifood systems. This CRP can only deliver on its R4D agenda through strong, broad and active partnerships. In India, such partnerships exist in strength. ICRISAT looks forward to the CRP's approval and its implementation in complimenting Indian institutions in supporting Indian agriculture and Indian farmers.

International Food Policy Research Institute

Achieving food and nutrition security is a complex challenge. This is especially true in South Asia, where 40 percent of the world's poor—who survive on less than US\$1.25 a day—live and 21 percent of the population is undernourished. Yet countries in South Asia have seen marked improvements in socio-economic developments in recent years. While agriculture is a critical component of food and nutrition security, it is interlinked with water, energy, infrastructure, and policy challenges. Apart from this, natural resources are under additional pressure from population growth, income growth, urbanization, changing consumer preferences, and climate change.

Against this backdrop, the IFPRI South Asia Office (SAO) in New Delhi engages in evidence-based policy research and capacity-building activities related to food and nutrition security in the region. This research focuses on agricultural diversification, climate change, markets and trade, nutrition and health, science and technology and governance. IFPRI's strategy identifies six research areas focussed on:

- i. Ensuring Sustainable Food Production
- ii. Promoting Healthy Food Systems
- iii. Improving Markets and Trade
- iv. Transforming Agriculture
- v. Building Resilience
- vi. Strengthening Institutions and Governance

IFPRI is based in Washington DC, USA but has a strong presence throughout the developing world, with regional offices and project offices across Africa and Asia. The offices provide local partners with broad access to IFPRI while allowing the Institute to better align its work with the needs of the regions and individual countries. In 2005, IFPRI established its South

Asia Office in New Delhi. Cutting the ribbon at the opening ceremony, the then Indian Prime Minister Dr. Manmohan Singh signalled the importance of IFPRI's collaboration with national agricultural research system (NARS) in addressing the region's development challenges. Hope for a world in which hunger, malnutrition, and poverty are distant memories is reflected in IFPRI's mission to seek sustainable solutions for ending hunger and poverty from the world.

Current research priorities of the South Asia Office include; agribusiness and smallholder farmers, food and nutritional security, climate change, governance issues, water use/scarcity, gender and malnutrition. IFPRI conducts all its researches in close partnership with the national agricultural research system with ample emphasis on capacity development of its partners.

2. i. Overall contribution to Indian agriculture

IFPRI played important roles in the development of Indian agriculture through its policy research. A few of the flagship contributions are mentioned here with.

Agricultural diversification: IFPRI's studies with NCAP and other partners on 'agricultural diversification and market linkages', led to sequence of reform in agricultural marketing. The studies emphasized for institutional innovations, such as contract farming, self-help group and FPOs. Research studies led to increased allocation to high value commodities for increasing their production.

Agricultural research and development: There was general consensus that IFPRI's findings regarding the beneficial impacts of agricultural research and development on growth and poverty alleviation have been part of the wider policy conversation, particularly in the run-up to the Eleventh Five-Year Plan (2007-2012). In fact IFPRI's research was "central" to the Steering Committee on Agriculture and Allied Sectors group's recommendation of increased investments in agricultural research institutions (India Planning Commission 2007).

Impact evaluation of the national rural employment guarantee scheme in India: The study aims to thoroughly evaluate the impacts of India's National Rural Employment Guarantee Scheme (NREGS), the largest public works project in the world. IFPRI's research results already suggest that the program is well-targeted in Andhra Pradesh and, while short-term effects are greater in terms of participants' nutritional intake, in the medium-term, researchers see an increased accumulation of nonfinancial assets. Both short- and medium- term benefits seem to accrue more to participants in the scheduled castes and tribes, as well as to those who would otherwise rely on casual labour. Studies were also undertaken to assess the role of MG-NREGA in changing demand for food commodities and its long-term impact on agricultural growth and poverty alleviation. Similarly, impact of prices and technologies on food grain supply helped in food management policy.

2.ii. Contribution during last one year

Through its extensive policy research, IFPRI has played significant roles at various policy platforms in the last one year. Some of the key highlights are:

The Chief Economic Advisor to the Government of India prepared a new strategy report titled “Incentivising Pulses Production through Minimum Support Price (MSP) and Related Policies” in September 2016 that laid out policy recommendations emerging from IFPRI’s research on pulses. This report acknowledges contributions by IFPRI research team. The report was aimed to incentivise pulse production in the country through price support and other related policies. It led to i) increase in minimum support price (MSP) for pulses; ii) beginning of procurement of pulses at MSP and iii) creation of a buffer stock of pulses to ensure stable prices. These policies will secure assured prices for their pulse productions and make pulses more affordable to consumers. Producers and consumers across India will benefit from this outcome.

During the International Year of Pulses-2016, we undertook several studies on increasing production of pulses and organized several events. A new methodology was developed to compute MSP for pulses by incorporating risk in pulses and their contribution in eco-system services. One book on ‘Pulses for Nutrition Security: From Farm to Fork’ has been approved by the IFPRI’ Publication Review Committee. Two discussion papers were published; one on policies to increase pulses production in India, and another on global pulse outlook. Both the publications cover a range of issues concerning pulse sector in India and also global level.

To develop indicators for ranking KVKs two brainstorming sessions were organized with ATARI directors, KVK staff and professionals. The indicators have been finalized and data for verifying the methodology is under progress. Also, two studies were initiated (i) how repeal of APMC Act (especially in Bihar) contributed in better price discovery; and (ii) how agricultural insurance facilitate adoption of improved technologies. In the former study, data was used from different wholesale markets, while in later case it was from Situation Assessment Survey. Further analysis is under progress.

Country-wise agricultural research expenditure was collected for the last 15 years to compare India with other countries. This data is regularly updated to share with ICAR to seek more research resources. India is allocating much less resources than many Latin American countries, China and many countries in Africa. State-wise time series data on different expenditure heads and subsidies was also collected from 1980-81 to 2013-14 to assess how different governments are prioritizing agriculture sector. Some preliminary analysis has been done for entire country to prioritize investments and subsidies for increasing agricultural growth and reducing poverty. Early results show that investment on agricultural research was ranked high in increasing agricultural growth and reducing poverty. Other investment heads were education, health and irrigation development. The study will provide empirical evidence on rate of returns from investment in agricultural research for convincing decision makers to allocate more funds for agricultural research.

IFPRI-SAO completed three research projects under Technical Assistance and Research for Indian Nutrition and Agriculture (TARINA) in 2016. The first one focussed on the impact of reduction in price of food grains under the Public Distribution System (PDS) on household purchases. We found that the increased PDS subsidies do not benefit consumers unless there is a significant investment in controlling pilferage.

A related research project on PDS empirically tested if providing subsidized pulses through the PDS will increase household consumption of pulses and proteins. We found that subsidizing pulses prices only have a small effect on pulse consumption and a negligible effect on total protein intake. The scarcity of pulses in India and even the global market, consumer subsidies on pulses cannot be scaled up and are unlikely to be effective.

Another study on sweet potato value chain in Odisha suggests that input subsidies alone won't be enough to encourage production and consumption of orange flesh sweet potato (OFSP) in the state. We need to create a demand pull for OFSP by creating greater awareness about its nutritive value and benefits from its regular consumption.

As part of the ICAR-CG work plan, IFPRI and NIAP have undertaken research on Green Revolution in Eastern India and Impact assessment of agricultural technologies. Impact of capacity building under NAIP was also conducted and prepared a capacity building strategy for national agricultural research system. To institutionalize the priority setting, monitoring and evaluation (PME), two manuals (one of ICAR and another for SAUs) were prepared. The Agriculture Science and Technology Indicators (ASTI), developed by IFPRI are useful in planning financial and human resources in agricultural research, education and extension system across discipline, regions and commodities.

Specific studies were also completed measuring returns to research investment on rice, wheat, maize, and chickpea research. These studies have shown high rate of returns from agricultural research investment and argued for more research funding. The studies on impact of investment and subsidies on agricultural growth and poverty clearly justified that investment in R&D contributes relatively more in increasing agricultural growth and reducing poverty compared to subsidies and other investment options. IFPRI also supported ICAR in developing 'ICAR Vision 2050' which was released by the Prime Minister of India in Patna.

Women contribute 60–80 percent of the required labour in rice production in India. Direct seeded rice is a climate smart technology that requires less labour and has reduced carbon footprint, but offers higher yields and higher profits. We carried out an experiment in tribal areas of Maharashtra to understand women's and men's preferences for this labour saving climate smart way of growing rice. We also used the Women Empowerment in Agriculture Index (WEAI), developed by IFPRI, to collect self-reported data on the role and say of women in agriculture. Men have a greater say over how the family spends the cash. Accordingly, men tend to have a higher willingness to pay for attributes that increase income (increase in yield) or reduce cash costs (reduction in the seed rate). Women contribute a large share of the labour for transplanting rice, much of which is unpaid work on family farms. Women, therefore, seem to value labour saving significantly more than their male counterparts. Further, women in our experiment are significantly more interested in switching from transplanted to

direct-seeded rice and are on average willing to pay more for the drum-seeder than the men in their families.

Our finding of women having higher WTP for a new technology and more interest in adopting it suggests that both product designers and extension workers should also target women when designing and promoting a new agricultural technology or practice.

On nutrition, POSHAN (Partnership and Opportunities to Strengthen and harmonize Action for Nutrition in India) examined the state of inter-sectoral convergence in the states of Odisha and Madhya Pradesh, and assessed its implications for scaling up nutrition interventions. The team estimated the costs of delivering nutrition-specific interventions at full scale and prepared a review of strategies to support multi-sectoral actions for nutrition in India. Recently, the team with partners launched 'India Health Report 2015'.

Under CRP (CGIAR Research Program) on 'Agriculture for Nutrition and Health' (A4NH), several studies were completed on pulses, which included production, consumption, trade, prices, processing and technologies. Other study under A4NH was on changing pattern on diet diversity and its implications on nutritional security across different income groups. Some choice experiments were also conducted to assess the impact of several interventions (namely, changing production portfolio, entrepreneurial development, preventive measures, self-help groups, behavioural towards nutrition) to design better programs for improving food and nutrition security.

Under CRP on 'Policies, Institutions and Markets' (PIM), studies on smallholder agriculture and linkages with markets and service providers were initiated. Studies were related to contract farming, financing innovative value chains, energy and agriculture value chains, and role of rural business hubs for improving efficiency of service delivery were undertaken. Similarly, market linkages through supermarkets were studied to assess consumers' choices for prices and food safety issues.

As part of the capacity building programs, several activities were organized to enhance policy analysis capacity of researchers in ICAR institutes, and SAUs in area related to impact assessment, value chain analysis, priority setting, monitoring and evaluation, agricultural trade analysis, DERAM Model to assess impact. Some of the researchers visited IFPRI HQs in Washington DC to work with senior researchers in IFPRI under various programs.

2.iii. Socio-economic impact/outcome

The IFPRI's research had profound socio-economic impact. As mentioned earlier, its research on returns to public investment helped to launch the massive rural road programme, which helped millions to escape poverty. The persistent advocacy, backed by credible empirical evidences by IFPRI led to increased funding for agricultural research, which improved the farmers' economic welfare and contributed to reduction in poverty, under-nutrition and malnutrition. The IFPRI's research on nutrition has been instrumental to design the nutrition agenda of India.

3. Projects/activities in progress in India

IFPRI has been actively involved in research, capacity development and policy communication activities in India. While some projects have neared completion, some are in the research process and will produce outcomes this year. Some of the salient projects/activities are mentioned below.

Research: Several research studies were conducted by IFPRI and partners in India from ICAR institutes, SAUs, general universities, and selected professional think tanks. A gist of selected studies is given below:

Questions are often asked by the policy makers on returns to agricultural research investment. Some studies were completed to measure returns to research investment and changing investment patterns on agricultural research and extension.

The different types of public expenditure have shown positive impact on agriculture income and poverty reduction in India. However, the impact differs quite significantly among the social and economic heads of expenditure and also among different categories of states. The all India picture shows highest returns from investment on irrigation and agriculture R&D followed by education, health and energy. Returns to irrigation, education, Agril. R &D and health stood high at 9.72, 2.47, 2.39 and 1.84, suggesting for more investment in irrigation development and research system.

A study supported by ICAR will map adoption of improved varieties of seeds of the main food and cash crops across different states of India and identify that promote or hinder large-scale adoption of new and better seeds. Surveys will be carried out with farmers, seed dealers and extension agents to understand the seed value-chains of key crops.

Climate change is posing a serious threat to Indian agriculture. Few studies were initiated to address the issues related to climate change. Two foresight studies are related to (1) assessing impact of climate change by 2050 and 2080 under different climate change scenario using IFPRI's IMPACT Model, and (2) impact of drought on demand and prices of important food commodities. Other studies are related to (1) farmers' willingness to pay and prioritizing climate smart interventions, (2) bundling of agricultural insurance with stress tolerant varieties, and assessing modalities of their implementations, (3) impact of past policies on efficiency, sustainability, resilience, and climate change adaptation and mitigation, and (4) adoption and/or dis-adoption of climate smart technologies. The ultimate aim of these studies is to develop programs to up-scale climate smart agriculture.

Under the Sustainable and Resilient Farming System Initiative (SRFSI) project, the researchers will continue carrying out comparative studies in Eastern Gangetic Plain, with more emphasis in Bihar, West Bengal, Bangladesh and Nepal Terai along with focussing on identifying best practices in each state or country that others can learn from to improve their own policies. Led by IFPRI's EPTD division, the focus will be on assessment of risks and options for decision-making along the water-energy-food nexus in the EGP. Technical workshops will be carried out to develop causal risk models to support more resilient decision-making in the EGP.

Food inflation of key commodities is becoming a recurring phenomenon. To monitor prices of important food commodities, a 'Food Security Portal' is specifically launched for India. The aim is to share knowledge on best practices related to food security, monitor and analyse prices of key agricultural commodities for taking informed decision, and interact with the policy makers to improve food and nutrition security. Few demand-driven studies have been undertaken under this project: (1) projections of demand and supply of food commodities under different scenario, (2) cash vs. kind for food security, (3) food inflation and its drivers, (4) feasibility of pulses under PDS, and (5) gender and nutrition security.

Rising prices and declining consumption of pulses cause concern in terms of both nutrition and food inflation in India. We submitted a document on evidence based strategies to increase the availability of pulses at affordable prices in India to the Ministry of Finance, Government of India. It was strongly emphasized that there was no option but to increase domestic production of pulses in India. The global supply of pulses is limited compared with India's needs, and sizable imports by India are bound to increase world prices. Access to one or two protective irrigations during the growing season can possibly lead to sizable increases in pulse production and reduce the production risk. The "har khet ko paani" (assured irrigation) initiative under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) program should give priority to pulse-producing areas. We also drew attention to the fact that the minimum support price (MSP) for pulses, without direct government procurement, helps traders more than farmers because it acts as a focal point for tacit collusion among traders. Farmers will benefit from the MSP only if it is raised substantially from its current levels. The increase in farm gate prices due to a higher MSP will not necessarily lead to an increase in the retail price of pulses because much of the wedge between farm gate prices and consumer prices is traders' margin. Including subsidized pulses in public distribution systems can save households some money, but it has only a small effect on total consumption of pulses and almost no effect on total protein intake. We suggested that investing in research and extension for pulses, aggregating pulse growers into farmer producer organizations, and paying pulse growers or pulse-growing areas for the ecosystem services offered by pulses.

Two brainstorming sessions were organised with ATARI directors, KVK staff and professionals to develop indicators for ranking KVKs. While the indicators have been finalized, the data for verifying the methodology is under progress. Two studies on how repeal of APMC Act (especially in Bihar) contributed in better price discovery and how agricultural insurance facilitates adoption of improved technologies are in the stage of further analysis this year.

Under POSHAN, work will continue in thematic areas related to strengthening data for decision-making on nutrition and multi-sectoral actions for nutrition. The team will continue to work in the direction of preparing various POSHAN knowledge products under its four thematic areas: data, financing, strengthening implementation and working across sectors.

Under CRP on 'Policies, Institutions and Markets' (PIM), studies are also in progress on to assess the role of innovative institutional arrangements (self-help groups, contract farming, cooperatives and farmer producer organizations).

The SAO is also participating in a five-year program called the Bangladesh Integrated Food Policy Research Program (BIFPRP). By combining policy research with capacity strengthening to tackle all four aspects of food security—availability, access, utilization, and stability—the program intends to usher in a new phase of addressing food security in Bangladesh.

IFPRI-SAO is assisting IFPRI's Agricultural Science and Technology Indicators (ASTI) program which collects data on institutional developments, investments and human capacity in agricultural research in developing countries worldwide. The office in New Delhi will support in producing a number of interactive models depicting trends and challenges in agricultural research and development, investment and capacity in India, Bangladesh, Nepal and Pakistan.

To initiate further research opportunities from time to time South Asia office, interacts with policymakers, researcher and donors. IFPRI brings in ground realities from field, past and current regional experience and international perspective to list regions research priorities and policy directions. IFPRI office in South Asia also had active engagement participation at various levels with private sector by constant interaction with numerous associations.

Capacity building programs: Several capacity building programs have been and are in the process to be organized to enhance policy analysis capacity of researchers in ICAR institutes, and SAUs in area related to impact assessment, value chain analysis, priority setting, monitoring and evaluation, agricultural trade analysis, DERAM Model to assess impact.

4. Yearly action plan and collaborators from NARES

Numerous projects and activities will be in progress as part of this year's work plan.

The Technical Assistance and Research for Indian Nutrition and Agriculture (TARINA) project focuses in Bihar, Odisha and eastern Uttar Pradesh with high burden of malnutrition and relatively underdeveloped agriculture. While exploring the role of Public Distribution System (PDS) in improving access to nutritive food at affordable prices, the researchers will try to understand the households' preference for commodities to be included in the PDS basket of goods and their preferred mode of transfer (cash, kind or vouchers). A second piece of research in TARINA is trying to map the value chain of high-value nutritive commodities in the project sites.

The IFPRI SAO will also examine the impact of change in market regulations on farmers' returns from growing cash crops and households' access to nutrition rich food items. The focus will be on the impact of abolition of APMC Act in Bihar and changes in this act in Odisha and UP.

Under the Sustainable and Resilient Farming System Initiative (SRFSI) project, the researchers will continue carrying out comparative studies in eastern Gangetic plain, with more emphasis in Bihar, West Bengal, Bangladesh and Nepal Terai along with focussing on identifying best practices in each state or country that others can learn from to improve their own

policies. Led by IFPRI's EPTD division, the focus will be on assessment of risks and options for decision-making along the water-energy-food nexus in the EGP.

Our frequent interactions with the policy makers over the last year on issues related to pulse have given us a better sense of important policy questions where more research and better evidence is needed. Accordingly, in 2017, our pulse research will focus on a) understanding pulse seed value-chains to make them more efficient; b) estimating the monetary value of environmental services provided by pulse cultivation and c) improving our understanding of emerging patterns in demand for pulses in India, including demand for processing pulses for rising snacks consumption.

Understanding the threat posed by climate change to the food and nutritional security is evident, IFPRI- SAO aims to study the plausible penetration of climate-smart technologies and practices in the region with an eye towards understanding the patterns of adoption and dis-adoption of climate smart agriculture (CSA). We will develop policy proposals and program outlines for an efficient and sustainable adoption of CSA in South Asia.

Under the ICAR and Government of India collaboration, IFPRI SAO will focus on (i) Estimating returns to agricultural research investment and mapping adoption of improved technologies. (ii) Strategies to enhance pulse production and stabilize their prices. (iii) Developing transparent performance indicators for KVKs. (iv) Developing mechanisms to implement innovative institutional arrangements (such as e-NAM, farmer Producer Organization and PMFBY) and assess their impact on smallholders.

The on-going USAID project on Policy Reform Initiative Program (PRIP) in Nepal aims to bring policy reforms through credible empirical analysis, capacity development activities and policy advocacy. IFPRI activities will be undertaken to strengthen Nepal's seed policy, improve understanding on the impact of fertilizer policy, help in reorganizing Ministry of Agricultural Development governance structure, develop guidelines for implementing agricultural mechanization promotion policy, promote contract farming and agri-business opportunities, finalize national food safety policy, assess impact of Feed the Future interventions on farmer's welfare, and analyse agricultural trade and investment opportunities.

Under POSHAN, work will continue in thematic areas related to strengthening data for decision-making on nutrition and multi-sectoral actions for nutrition. The team will continue to work in the direction of preparing various POSHAN knowledge products under its four thematic areas: data, financing, strengthening implementation and working across sectors.

IFPRI SAO in collaboration with the International Fund for Agricultural Development (IFAD) and partnering with the South-east Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), will work on agricultural transformation and market integration in the ASEAN Region.

To broadly include possible collaborators; under ICAR institutes, NCAP, IARI, ATARI, CTCRI, IIPR, IIWM, IASRI and NAARM are included while under SAU's, there is TNAU and GBPUAT, among others.

5. Way forward

Eliminating hunger, poverty and under-nutrition will be the main focus for IFPRI's research in India. Doing so will pave the way for achieving multiple Sustainable Development Goals (SDGs) - the anchor of the post-2015 agendas. IFPRI will strive its best to serve as a knowledge and innovation hub to experiment, learn and share evidence for pragmatic, action oriented strategies jointly with ICAR and national partners. It will offer evidence based on current specific strategies to improve NARES, other institutions and initiatives for doubling farmers' income by 2022, and eliminating poverty by 2025. Sharing knowledge, supporting evidence based policies and experiments, mobilizing data revolution, facilitating country-led strategies and investments, and strengthening inclusive and accountable partnerships will be the *Mantra* for IFPRI's activities in India.



David Bergvinson, ICRISSAT presenting award to winners of the Pulses Painting competition. On the right: The board display the paintings submitted by the students



The launch of the Global Food Policy Report at the Pulses for Sustainable Agriculture and Human Health conference in New Delhi on 31 May, 2016.

International Livestock Research Institute

The International Livestock Research Institute (ILRI) works with partners worldwide to enhance the roles that livestock play in food security and poverty alleviation, principally in Africa and Asia. The outcomes of these research partnerships help people in developing countries keep their farm animals alive and productive, increase and sustain their livestock and farm productivity, find profitable markets for their animal products, and reduce the risk of livestock-related diseases. Supporting the many small-scale producers, processors, sellers and consumers of animal-source foods in low-income countries, ILRI works with partners to change practices, provide evidence to decision-makers and develop capacities in smallholder livestock development. ILRI is a CGIAR Research Centre which undertakes multi-partner 'CGIAR Research Programs' (CRPs) and these set the scope, direction, institutional partnerships and opportunities for ILRI research in India.

ILRI's corporate strategy articulates three strategic objectives and the underpinning five critical success factors that will be addressed to achieve the institute's mission: 'To improve food and nutritional security and to reduce poverty in developing countries through research for efficient, safe and sustainable use of livestock – ensuring better lives through livestock'. The recently completed science strategy further articulates the key elements of the critical success factor 'getting the science right', which includes different research areas that need to be addressed by the institute's research to different degrees depending on the trajectory in question. The science strategy also highlights the importance of ILRI's regional programs in implementing its research and ensuring that impact pathways are realised in local and regional contexts, whilst delivering global public goods.

2.i. Overall contribution to Indian agriculture

In last several years, ILRI has successfully implemented a number of collaborative projects in the region including Cereal System Initiative South Asia (CSISA), Enhancing livelihoods through livestock knowledge systems (ELKS), National Agricultural Innovation Project (NAIP), Milk India Tanzania (MilkIT) project, Farm Animal Genetics Resources (FAnGR), India Mozambique Goat (IMGoat) project, Climate change, Agriculture and Food Security (CCAFS) etc. and set a positive track record as a scientifically sound, honest, sincere, responsive and flexible research institute that is good to work with.

In the region, ILRI has demonstrated the use of its knowledge and skills in conducting multi-disciplinary research on livestock based livelihood, fodder innovation, zoonosis and food safety, participatory epidemiology, disease economics, informal milk market improvement, value chain assessment, research and identification of policy intervention and advocacy to complement the strong technical research capacities among the NARS especially in India. ILRI's research goes much beyond livestock technologies and based on ILRI's prevailing strengths and experience, ILRI complements NARS expertise by conducting research in the fields of food safety and zoonosis, gender, climate change, feed and fodder innovation, biotechnology, economic assessment of livestock systems, epidemiological studies, genetic studies and policy facilitation.

As a global research institute, ILRI can bring global knowledge to address local problems. ILRI has access to and understanding of global livestock knowledge and technologies and therefore, it can create a platform for knowledge sharing and cross learning within and between regions.

ILRI focusses on pro-poor livestock development policy which is very relevant for this part of the world. It develops, tests and pilots interventions that are affordable, acceptable and accessible to the poor livestock keepers. Other research systems including many national systems have a broader mandate to cover the whole agricultural or livestock sector and as a consequence often do not differentiate sufficiently the needs of poor smallholder livestock keepers from larger commercially oriented farmers.

ILRI's arguments and examples set by it in the field on pro-poor livestock development (for instance under NAIP or ELKS project, AIP) are well appreciated by policy makers and donor agencies.

For last several years, ILRI has been implementing projects in partnership with local R&D organisations and has been trying to build their capacity by jointly designing and implementing projects. This is being done to strengthen capacity of local partners in order to ensure sustainability of ILRI's initiative even after closure of the project.

The Food Safety Zoonosis team at ILRI has previously been working with improving milk hygiene in Assam, and has been successful in increasing awareness among farmers about diseases and the importance of hygienic practices. In addition, the intervention has been shown to increase milk yield and reduce mastitis.

The Policies, Institutions and Livelihoods program has previously worked on dairy systems in Bihar, Gujarat and Assam. This includes policy related issues in Bihar and the need to address the policy incoherence in the small holder dairy sector

through organization of a multi-stakeholder policy working group which focuses on ways of addressing policy gaps, enhances capacities for policy implementation and facilitates policy learning.

2.ii. Contribution during last one year

In 2016, ILRI implemented more than 10 bilateral projects including five ICAR funded ones. The list of projects are itemized below (project details in section 3):

- Improvement of basal diet of dairy animals (Govt. of Karnataka)
- Promotion of superior Sorghum and Pearl millet cultivars (OPEC)
- Deconstruction of Ligno Cellulose Biomass (USAID funded)
- Dairy Value Chain Improvement (Tata Trusts, World Bank)
- Pig Value Chain improvement (Tata Trusts, IFAD, World Bank)
- Promotion of health, livelihood and sustainable dairy system in peri-urban settings in India (IDRC-PHFI)
- Genomic selection (ICAR)
- Multi-dimensional crop improvement (ICAR)
- Brucellosis control (ICAR)
- Antimicrobial resistance (ICAR)
- Goat VC improvement (ICAR)

The above research for development projects mainly targeted and worked with livestock keepers in the field allowing ILRI to develop good understanding of the issues faced by poor livestock keepers. This also helps ILRI to raise the real issues suffered by poor livestock keepers in different forums. In addition, ILRI got direct access right from farmers to policy makers and therefore, it enjoyed strategic advantage of informing and influencing policy at different levels. In implementing the above projects, ILRI developed strong partnership with several national and local research institutes, government departments and non-government agencies (local, national and international). The approach allows ILRI to act as a catalyst/facilitator that can bring multiple stakeholders together for addressing common issues of interest.

Some of the key achievements of ILRI work in the past year are listed hereunder:

- Improved milk production in the project area (e.g. Assam, Uttarakhand, Vidarbha)
- Increased quality and quantity of crop residues through use of dual purpose food-feed crops (e.g. sorghum, maize, groundnut, millet, rice, wheat)
- Improved awareness level among farmers and stakeholders on food safety (milk, pork)
- Improved feeding practices leading to increased milk yield (20-30%) & reduced women drudgery

- Was instrumental in the development of National Classical Swine Fever Control Programme starting with North East India with improved access to vaccine and service delivery
- Facilitated development of Pig Breeding Policy for Nagaland

2.iii. Socio-economic impact/outcome

The ILRI research for development work in India also enhances the capacity of local actors and stakeholders in terms of providing global experience and expertise in the fields of food safety & zoonosis, participatory epidemiology, value chain development, multi-dimensional crop improvement, innovation platform approaches, evidence based policy influence etc. where ILRI has its strength.

ILRI connected the vital missing links such as research and development, public and private sectors, crops and livestock and forged inter disciplinary linkages. The value chain research helped to bring in a holistic perspective in development. Gender balanced approaches integrated the gender component in various projects and programmes so that the outcome became inclusive and positive. ILRI works gave high prominence to reach the unreached, namely resource poor farmers, women and farmers in remote rural locations.

3. Projects/ activities in progress in India

ILRI has an existing MoU with ICAR for joint Animal Science research activities on selected programmes of mutual interest, where collaboration can bring added value to the activities of both organisations building on and guiding the ILRI's project activities. According to this, there will be a focus on promoting and undertaking collaborative research involving the expertise and facilities of Animal Science Institutes of ICAR/State Agricultural Universities and other organizations in India. Currently there are five ongoing ICAR funded projects:

3.1. Genomic techniques to profile and improve productivity and resilience in buffalo: This project aims to use genomic techniques to profile and improve productivity and resilience in buffalo. Key collaborators are ILRI and ICAR (Central Institute for Research on Buffalo). The goal of the project is to increase buffalo productivity through the use of superior buffalo genetics that meets the needs and preferences of women and men smallholder buffalo. Activities completed / in-progress to-date include:

- Review the Murrah buffalo breeding program and make recommendations in relation to the best means for it to incorporate genomic selection.

- Test the suitability of the currently available buffalo genotyping tool for the Indian Murrah buffalo population, and (if required) develop a more informative and / or less expensive genotyping tool.
- Develop and implement a smart tool for capture of animal sample data and transfer to a biorepository database.

3.2. Multi-dimensional improvement of food-feed crops:

This project aims to improve feed quantity and quality without increasing land and water use through collaborations of livestock nutritionists and crop scientists to identify, select and breed major cereal and legumes (rice, wheat, maize, sorghum, pearl millet, small millets, groundnut, chick pea and pigeon pea) cultivars that provide superior grain yields and improved fodder quantity and quality in their crop residues than currently available cultivars. The following activities have already been completed:

- Collected crop samples from minor millet (IIMR) and rice breeding (CRRI) and sorghum and pearl millet forage breeding (IGFRI, IIMRI)
- Analysed all samples for a wide range of fodder quality traits and possible trade-offs at ILRI laboratory
- Shared crop (10) residue samples with NIANP to compare the impact of enzyme, fungal and AFEX (Ammonia Fibre Expansion) treatments (> 15% units in IVOMD)

3.3. Sero-epidemiological and molecular detection of Brucella infection and assessment of economic costs and control options: This collaborative project (ILRI, NIVEDI & IVRI) aims at assessing prevalence and risk factors of Brucella-infection in dairy cattle and buffalo in urban and rural areas and to do spatial mapping of geographical distribution of Brucella-infection in the surveyed areas (Assam, Bihar and Odisha), economic loss (direct and indirect) caused by brucellosis, knowledge, attitude and practices of farmers relevant to brucellosis and to identify risk management and control



A woman dairy farmer with Murrah buffalo



Traders chopping strow for marketing

options and to assess prevalence, risk, economic cost and control options in small ruminants and humans. The field work has now been finished and laboratory analyses is ongoing.

3.4. Assessment of antimicrobials and antimicrobial resistance (AM) in livestock with special emphasis on dairy animals: The objectives include understand use of antimicrobials at state and farm level in dairy and poultry sector (Haryana and Assam), screen dairy and poultry samples for presence (qualitative and quantitative) of AM residues, study the surveillance of antimicrobial resistance in dairy and poultry sector, screen probiotics & their metabolites as alternative therapeutics in the mitigation of AB resistance, identify innovations and incentives that could improve the use of antimicrobials and piloting them in the field and support the institutions and policy facilitation necessary for scaling out. The field work has now been finished and laboratory analyses is ongoing.

3.5. Development of goat meat /milk value chain in Bihar & UP: This project, in which ILRI is collaborating with the Central Institute of Research on Goats (Mathura), the Sanjay Gandhi Institute of Dairy Technology (Patna) and the National Dairy Research Institute (Karnal), aims at identifying suitable interventions for pro poor goat value chain development, starting with a value chain assessment at various nodes of the value chain. Both meat and milk value chains are being considered. The data collection is going on and data analysis has started concurrently. A stakeholders' workshop will be held in March 2017 to get a common understanding on the most promising interventions. Interventions will be assessed by their ability to provide improved market access for poor goat keepers in marginal areas, allowing investments in improved production technologies to be more attractive. Following the identification of the most relevant initial intervention opportunities, these will be implemented on a pilot basis with local partners in the second phase of the project.



Scientist collecting blood sample for analysis

4. Yearly action plan and collaborators from NARES

The work plan for the five ICAR funded projects for the next year is detailed below

Sl. No.	Project	Work plan 2017
1	Genomic selection in buffalo	<p>In 2017, the project will build on year 1 activities aimed at strengthening the buffalo breeding program, via the incorporation of genomic selection. Here, ILRI and ICAR-CIRB will jointly work to continue incorporation of genomic selection into the breeding program. The focus will be on:</p> <ul style="list-style-type: none"> • Develop a resource population for genomic selection of between 2000 and 3000 genotyped Murrah buffalo with appropriate trait records. • Digitization of buffalo records into a database. • Strengthen the field progeny testing scheme. • Develop and implementation an analytical platform for genomic selection. • Incorporate genomic selection into the breeding program, including potential changes to the breeding program structure for maximal benefit from the technology.
2	Multi-dimensional crop improvement including upgradation of LCB	<p>(i) Promising breeding lines for further genetic enhancement towards food-feed crop cultivars: Promising breeding lines will be identified by tracing parental lines of superior cultivars. In addition the genetic mode (additive, heterosis etc) of inheritance of fodder traits will be investigated by specifically designed key and proof-of-concept breeding trials including Conventional breeding such as recurrent selection as well as marker assisted selections approaches will be tested by integrating crop residue trait analysis in pertinent ongoing trials.</p> <p>(ii) Tools that assess economic viability of feed processing technologies that increase transport and storage worthiness of crop residues: The economy of feed interventions is often neglected by livestock nutritionists. The proposed ICAR-ILRI collaboration will develop a decision making tool that screens, supports and ranks options such as: 1) trading and transport of crop residues from surplus to deficit areas, 2) processing (for example chopping, baling, grinding) of crop residues for transport, 3) supplementation and processing (blocking, pelleting, mashing). The input requirements of these interventions will be compared with outputs (milk, meat in case of small ruminants) and related to information from farmers about their perception of non-acceptable, acceptable and attractive input to output ratios.</p>

Sl. No.	Project	Work plan 2017
		<p>(iii) Explore spin-off effects from second generation biofuel technologies for upgrading ligno cellulosic biomass for animal feed: The recent global interests in 2nd generation bio-fuel technologies with billions of US \$ investments from private and public sector offers ample opportunities for upgrading ligno cellulosic biomass for animal feed. For 2nd generation bio-fuel technologies to succeed, economically efficient and environmentally acceptable technologies were/are required for hydrolysis of plant cell walls and release of glucose and other sugars from the lignified matrix. Animal nutritionists have the same objective. In addition implementation of 2nd generation bio-fuel technologies is faced with optimizing collection and transport of low density widely dispersed biomass, processing the biomass in fermenter and distributing the produce. Animal feed processors and producers wanting to use cellulolytic biomass better, are facing very similar logistical and engineering problems. Second generation bio-fuel technology developments engaged a wide range of experts encompassing plant breeder and molecular geneticists, plant chemists, microbiologists /enzymologists, economists and manufacturing and process engineers. We argue that from these research investments potential spin-offs can be harvested for: 1) upgrading of ligno-cellulose biomass for ruminants; 2) making the boundaries between feed resources for ruminants and monogastrics and fish more permeable, thereby increasing the choice of feed material for these species and; and 3) reduce the competition between biomass use for food, feed and soil improvement. If ruminants achieve higher productivity on ligno-cellulolytic biomass, they will require less concentrates which will reduce competition with monogastric animals, including humans, and fish.</p>
3	Brucellosis control	<ul style="list-style-type: none"> • Sero prevalence of Brucella infection in small ruminants to understand the zoonotic nature of brucellosis • Assessed prevalence, risk, economic cost & control options of brucellosis in small ruminants under the principle of “One Health”
4	AMAR	<p>Identification of innovations and incentives that could improve use of antimicrobials by suppliers and farmers.</p> <ul style="list-style-type: none"> • Informed by literature and the survey in activity 1, develop innovations to improve drug use (e.g. information on diagnosis and treatment; vaccines; diagnostics to detect residues). • Test their uptake and use through field experiments. • Assess the costs and benefits of interventions to improve drug use. • Develop a customized package of information, extension and communication material for different groups (e.g. manufacturers, farmers) which addresses the motivation for behaviour change.

Sl. No.	Project	Work plan 2017
5	Goat VC	<ul style="list-style-type: none"> (i) Identify interventions to improve productivity, processing and marketing of hygienic goat meat and / or milk through participatory discussion in multi-stakeholder innovation platforms <ul style="list-style-type: none"> • Identification of constraints and what opportunities exist to improve efficiency of the chain based on data collected at previous step (may be shifted to Year 2) • Identification of potential interventions (technical, institutional and policy) for implementation (may be shifted to Year 2) (ii) Piloting of production, processing and marketing interventions in the selected sites and assessment of technical and socio-economic impact of the interventions for learning and action. <ul style="list-style-type: none"> • Prioritisation of interventions that can produce maximum impact within short time span • Formulation of objectives and activities of sub projects for technical/institutional interventions • Implementation of interventions through grass root level NGOs Monitoring and evaluation of outcome (iii) Application of dissemination tools for scaling out of innovations and best practices for large scale adoption by landless, small & medium scale farmers <ul style="list-style-type: none"> • Documentation of best practices and potential innovations that can improve the efficiency of goat value chain as a whole • Evidence based policy dialogue with policy makers and planners • Outreach workshop

5. Way forward

Articulated in the tagline better lives through livestock, ILRI will move from a focus on livestock as a pathway out of poverty to a broader agenda that addresses poverty and food security in ways that are environmentally sustainable, good for human health and nutrition, and equitable. Towards this, ILRI will broaden its target beneficiaries to include other value chain and civil society actors, and poor urban as well as rural consumers. ILRI will also pilot forward-looking interventions for the livestock farmers of the future and support more comprehensive food-system productivity and supply to consumers. In this venture, ILRI will work not only with the smallest scale farmers but also with more commercially oriented livestock producers and value chain actors.

International Maize and Wheat Improvement Center

Headquartered in Mexico, the International Maize and Wheat Improvement Center (known by its Spanish acronym 'CIMMYT') works to reduce poverty and hunger by sustainably increasing the productivity of maize and wheat based farming systems in Asia, Africa and Latin America. In 2016, we celebrated CIMMYT's 50th Anniversary. The ICAR-CIMMYT partnership in agricultural research is one of the longest and most productive in the world with a rich history of five decades. The collaboration started with the visit of Nobel Laureate Dr. Norman E. Borlaug to India in 1963 for ushering in "Green Revolution" in active partnership with the Government of India. In 2011, Borlaug Institute for South Asia (BISA), a joint initiative of CIMMYT and Government of India (ICAR), was established with 3 centers (Ludhiana, Jabalpur and Samastipur) to address food, nutrition, environment and livelihood security in South Asia. CIMMYT, and BISA, has currently more than 110 staff in India operating from 12 sites. CGIAR Research Programs (CRPs) on maize, wheat and CCAFS are the corner stone of the ICAR-CIMMYT collaborative work plan 2013-2017. Collaborative research in India is resourced by CRPs and funding sources from various donors including a contribution from ICAR. In addition to ICAR, as of 2016, CIMMYT was investing around 8 million US\$ in India through other funding sources.

2.i. Overall contribution to Indian agriculture

In just four short years after Borlaug's first visit, the India-CIMMYT partnership doubled India's wheat harvest to 20 million tons and the nation reached self-sufficiency in wheat. The success continued and in 2014, India harvested a record 95.9 million tons of wheat. But the drop to 90.8 million tons in 2015 was a reminder to continuously invest in wheat research. CIMMYT's Wheat Improvement Program in Mexico targets 60 m ha, about half of which is in India.

During 2010-2016, more than 60 CIMMYT germplasm derived wheat varieties were released with 34 being direct release in different parts of India. The first two biofortified (grain Zinc rich) wheat varieties were also released by CIMMYT. Each year more than 100 lines were promoted to various national and state trials including biofortified wheat for zinc and iron.

In maize, CIMMYT focussed on the development of climate resilient maize hybrids and also Quality Protein Maize (QPM) that have competitive yields under optimal conditions and superior yields under abiotic and biotic stresses. About nine QPM hybrids were developed in the last decade with extensive use of CIMMYT's maize germplasm. Germplasm resistant to Turicum leaf blight (TLB), downy mildew, and bacterial leaf and sheath blight were also developed and distributed to the national maize program. A strong germplasm base was created to combine drought, heat and waterlogging tolerance with high yield potential.

Conservation agriculture based sustainable intensification practices promoted by CIMMYT have achieved large scale adoption; these include zero tillage, direct seeded rice, precision land levelling, residue management, systems optimization & diversification, precision input management, scale appropriate mechanization and climate smart agriculture. BISA farms demonstrated the implementation of large scale rice straw management with no burning of residue.

Socio-economics program evaluated and prioritized wheat and maize interventions for achieving greater impact. Cross-cutting agricultural research was conducted to ensure social and gender inclusiveness. CCAFS and BISA introduced the concept of climate smart agriculture in more than 1000 villages of Maharashtra, Punjab, Haryana, Bihar and Madhya Pradesh.

Since 1969, more than 350 Indian visiting scientists and nearly 80 trainees have been hosted at CIMMYT. Between 1969 and 2015, more than 2,000 Indian scientists improved their knowledge and skills through various capacity building activities with CIMMYT. At present around two dozen international scientists from India are engaged in CIMMYT.

2.ii. Contribution during last one year

Seven CIMMYT derived wheat varieties were released for various parts of India. Of these varieties, two were biofortified varieties which are among the first grain Zinc rich wheat varieties released in South Asia. In 2015-16, 140 trials and nurseries from CIMMYT were sown by collaborators throughout wheat growing areas of India. More than 2000 germplasm lines were shared which carry resistance to major diseases, abiotic stress tolerance and high grain & quality. Screening of Indian wheat lines for wheat blast resistance was initiated at Bolivia. The International Maize Improvement Consortium for Asia (IMIC-Asia) entered its second phase. With support from ICAR, breeding for Quality Protein Maize (QPM) germplasm was strengthened and at least 100 QPM lines were shared with AICRP partners. Breeding for 'Heat Tolerant Maize' got momentum and 1st generation heat tolerant hybrids were formally licenced to partners for deployment and scale-out in their targeted geographies. Lines derived from CIMMYT germplasm with resistance to various diseases were shared with six AICMIP centers. The 2nd batch of 13 heat tolerant hybrids were licensed in 2016 to Indian maize program partners, including public and private sector, for release or registration.

The sustainable intensification program (SIP) continued to work with public and private sector to implement the SI activities under CRPs on WHEAT, MAIZE and CCAFS as well as bilateral projects. Significant outputs and outcomes were: Large scale impact of laser land leveling; accelerated uptake of CA based management (zero tillage, direct seeded rice); conceptualizing and implementing precision water and nutrient management; new tools for example “Nutrient Expert (NE) Decision Support Tool” for maize and wheat and Android phone based app for hand held GreenSeeker sensor for scaling precision nutrient management in smallholder wheat and maize systems; newly developed machines such as high clearance planter for cotton-wheat system and Turbo Happy seeder for eliminating rice residue burning.

CCAFS, a CRP of all CGIAR centers demonstrated climate smart agriculture in more than 1000 villages in India through scale-out adaptation (practices, technologies, institutions and policies), improved agriculture insurance, ICT services and crop growth monitoring and forecasting. In addition, several new insurance products were developed that have been used by the Agricultural Insurance Company of India and the Maharashtra Government.

BISA farms demonstrated the use of genomic selection in wheat breeding, prospects for hybrid wheat, practicality of implementation of conservation agriculture practices without any burning of rice straw and tools that save water and nutrients.

2.iii. Socio-economic impact/outcome

- i. The impact of CIMMYT’s wheat germplasm has been observed in sustained wheat production in last five years in the face of climate change. Despite warmer temperatures in last few years, the production continues to increase.
- ii. QPM maize varieties released using CIMMYT germplasm is contributing significantly to address human malnutrition issues.
- iii. A significant impact of QPM maize in bio-fortified maize (QPM with methionine and high oil) is seen on poultry sector.
- iv. SI program has supported the emergence of a robust service economy for sustainable intensification technologies with over 3000 service providers active in Bihar and Eastern Uttar Pradesh (EUP), constituting an increase of 34% compared to 2014-15. More than 47,000 farmers benefited from zero tillage wheat in 2015-16 in Bihar and EUP through low -cost access to capital-intensive machinery from service providers. Furthermore, there is evidence that the use of ZT has become more socially inclusive, with marginal farmers (farm size < 1 ha) constituting a more than proportionate share of new ZT users.
- v. Agro- advisory information delivered via mobile phone messages contributed to reducing the information asymmetry between women and men in farming families.
- vi. Pan-India analysis of GHGs emission from agricultural food production to supply and their implications for climate change mitigation has been done. Emission intensity for major food crops in India are generally lower than those in Europe and North America. GHG emissions for cereals are 2–3-fold greater in Europe (2000–3000 kg CO₂eq ha⁻¹ yr⁻¹).

Livestock (45.54 kg CO₂eq kg⁻¹ mutton meat) and 5.65 kg CO₂eq kg⁻¹ for rice production were found to be the main sources of GHG emissions in Indian agriculture. Production of cereals (except rice), fruits and vegetables in India emits comparatively less GHGs with <1 kg CO₂eq kg⁻¹ product.

3. Projects/activities in progress in India

Wheat: Breeding to develop more productive varieties that are climate resilient, durable disease resistant, and have good end-use and nutritional qualities is the major thrust for various projects. In 2016-17, 150 trials and nurseries from CIMMYT were sown by collaborators throughout wheat growing areas of India. The major on-going activities include:

- i. Development of high-yielding lines, resistant to all the three rusts with superior end-use quality under irrigated favorable environment of NWPZ.
- ii. Breeding early maturing, heat tolerance lines with high yield, disease resistance and desirable end-use quality for NEPZ. A special trial (HTWYT) is dedicated to such lines.
- iii. Development of abiotic stress tolerant aestivum and durum wheat germplasm for the central and peninsular zones.
- iv. Breeding for biofortified wheat with varied maturity.
- v. Borlaug Global Rust Initiative for developing wheat cultivars and promising germplasm from India and CIMMYT for resistance to Ug99 race of stem rust fungus and aggressive races of yellow rust. The concern for yellow rust is well recognized to obtain more resistance to new races that are more tolerant to higher temperatures.
- vi. Breeding for resistance to wheat blast due to its emergence in Bangladesh in 2016.
- vii. Spot blotch resistance for Eastern Gangetic Plains.
- viii. Genomic selection research for breeding climate resilient wheat.
- ix. Enhancing linkages and partnerships through training and visiting scientist programs at Mexico and Kenya.

Maize: As part of IMIC - Asia (IIInd phase), AICRP on maize takes part by i) receiving germplasm from CIMMYT, ii) collaborative evaluation of trials, iii) allocation of hybrid products for registration and commercialization, and iv) training in breeding, phenotyping and data management.

With support from ICAR, Quality Protein Maize (QPM) germplasm is being developed. Fodder quality evaluation of QPM lines and hybrids is in progress. In a USAID funded project, CIMMYT is leading a public-private alliance: 'Heat Tolerant Maize for Asia (HTMA)'. In the last four years: i) future and current heat stress hot-spots in South Asia were identified, ii) monthly

heat stress distribution maps generated, iii) genome-wide association studies (GWAS) revealed multiple haplotypes that were significantly associated with grain yield and anthesis -silking interval under heat stress. As part of the MAIZE CRP, germplasm with resistance to multiple maize diseases are being developed and shared through AICMIP, iv) A total of 17 heat tolerant hybrids were licensed to Indian maize program partners, including public and private, for large-scale testing and release or registration.

Germplasm research: CIMMYT is engaged in developing a genetic resources utilization platform, including: documenting the biodiversity of CIMMYT's maize and wheat seed bank; developing informatics tools; breeding "bridging germplasm," which incorporates new diversity in elite wheat and maize; and building professional capacity to use biodiversity to address current and future challenges to maize and wheat production.

Sustainable intensification (SI): The sustainable intensification program (SIP) works with public and private sector to implement the SI activities under CRPs on WHEAT, MAIZE and CCAFS as well as bilateral projects for example CSISA, SRFISI, BMZ-Wheat and ICAR-CA. Significant outputs and outcomes are:

- Long- term strategic research on CA based sustainable intensification
- Large scale impact of laser land leveling technology
- Accelerated uptake of CA based management (zero tillage, direct seeded rice)
- Conceptualizing and implementing precision water and nutrient management
- "Nutrient Expert (NE) Decision Support Tool" for maize and wheat and Android
- phone based app for hand held GreenSeeker sensor for scaling precision nutrient management in smallholder wheat and maize systems
- Genotype x Environment x Management interactions in maize and wheat systems
- Basic research on nitrogen use efficiency in wheat and precision nutrient and water management
- Strategic research on Food-Water-Energy nexus
- Understanding the complexity of farming systems for rationalization of resources
- Developing remote sensing technology for impact assessment of CA management practices
- Promoting new machines such as high clearance planter for sustainable intensification of cotton-wheat system and Turbo Happy seeder for eliminating residue burning
- Utilizing the KVK network at the district level to translate science in to actionable guidance

Climate Change Agriculture and Food Security (CCAFS): CCAFS, a CRP of all CGIAR centers, works with ICAR, SAUs, IMD, government departments, NGOs, and industry to develop and demonstrate strategies for climate adaptation in different regions. It has been working on following aspects:

1. Climate-smart villages to scale-out adaptation (practices, technologies, institutions and policies)
2. Quantification of environmental foot prints of agriculture and generate evidence on mitigation co-benefit of adapted technologies and practices
3. Designing improved agriculture insurance schemes
4. Crop growth monitoring and forecasting

Socio Economic Program (SEP): SEP aims to help prioritize, target, understand and enhance wheat and maize interventions to make the greatest impact. It helps optimize the use of research resources, accelerates the uptake of innovations and enhances impacts and their social inclusiveness for poor producers and consumers of wheat and maize.

In the prospective (ex-ante) phase of research-to-development, the program helps with positioning, prioritizing and foresight. In the implementation phase, it helps to keep or adjust the trajectory of activities by providing current perspectives on progress, process and operational issues. In the retrospective (ex -post) phase, it helps to document impact and draw out lessons. Cross-cutting research ensures social and gender inclusiveness. The program provides guidance on whether interventions are making changes that are transforming agriculture and rural landscapes.

4. Yearly action plan and collaborators from NARES

- i. Wheat breeding for early heat tolerance with IIWBR and major wheat centres through a project on “scaling breeding and agronomic management for increasing wheat productivity and adaptation to climate change causing rising temperatures and water scarcity in South Asia.”
- ii. Development of rust resistant, agronomically superior climate resilient wheat varieties and sharing with all wheat breeding centres of India.
- iii. Continuation of Genomic Selection research for breeding climate resilient wheat in collaboration with IIWBR and other wheat centres.
- iv. Continuation of HarvestPlus project for developing biofortified (Zinc and Iron rich) wheat varieties in collaboration with IIWBR and other wheat centres.
- v. With support from SFSA (Syngenta Foundation for Sustainable Agriculture) a new project, Improved Maize for Tropical

Asia (IMTA) was initiated.

- vi. IMIC-Asia II having ICAR-AICRP members including IIMR and SAUs are partners.
- vii. Next phase of abiotic stress tolerant maize for Asia (ATMA by GIZ, Germany) through a project on Climate-resilient maize for Asia (CRMA) with IIMR and other partners.
- viii. USAID and BMGF approved phase III of CSISA, running from December 2015 to November 2020. Building on the momentum and achievements of phases I and II, phase III CSISA will work to scale up innovations, strengthen local capacity and expand markets to support the widespread adoption of climate-resilient agricultural technologies in partnership with the national and developmental partners and key private sector actors.
- ix. Sustainable and Resilient Farming Systems Intensification in eastern IGP (ACIAR supported and in collaboration with ICAR, SAUs, Department of Agriculture in Bihar and West Bengal, NGOs, and Australian Advanced Institutions).
- x. Sustainable intensification opportunities for rainfed systems of Karnataka (in collaboration with ICRISAT, SAUs and Government of Karnataka).
- xi. Long-term research on sustainable intensification and nitrogen use efficiency.
- xii. Farming systems analysis and optimizing resource allocations using FarmDesign Modeling (in collaboration with ICAR-IIFSR, CSSRI, ICAR-RCER, Wageningen University).
- xiii. Understanding Genotype x Environment x Management interactions for breaking yield barriers in maize and wheat systems.
- xiv. Modelling for quantification of N₂O emission from agriculture and developing new emission factors (contributing to IPCC factors).
- xv. Generating hard evidence on CSAPs and adaptation-mitigation co-benefit potential of agriculture technologies and practices in maize and wheat based farming systems.
- xvi. Additional support to ICAR scientists will be provided in the form of capacity development 'short courses' for ICAR on all CIMMYT activities.
- xvii. Crop insurance program (with ICAR, MCNCFC, and insurance industry; funded by CCAFS).
- xviii. Climate-smart village program (with ICAR, SAU and others; funded by CCAFS, USAID and ITC).
- xix. Modelling for food security monitoring (ICAR, MCNCFC, IMD, CCAFS).
- xx. Integrating genetic diversity, modern breeding and sustainable intensification agronomy for enhanced productivity and climate smart wheat systems in Punjab.
- xxi. Addressing the sustainability issues in North Western states of India.
- xxii. Enhancing system productivity and profitability of agriculture in eastern and central India.

5. Way forward

- CRPs Phase II (WHEAT, MAIZE & CCAFS) fully integrated with NARES on issues of major importance for India in all collaborative researches through CGIAR site integration.
- Breeding for agronomically superior heat tolerant wheat will be a major priority.
- The number of materials phenotyped for the three rusts, in particular yellow rust and with resistance to terminal heat will be increased. For that effort, continuous support to the phenotyping in Mexico at Cd Obregon is extremely important as it directly increases the number of lines that are relevant for testing in South Asia.
- In view of wheat blast reported from Bangladesh, special attention will be given to this disease. Shuttling germplasm to Latin America for finding suitable resistance has already been initiated.
- Harnessing genotype x environment x management (G x E x M) interactions for breaking yield barriers.
- Sustainable intensification of wheat and maize based systems (irrigated and rainfed) with focus on improving water and nutrient use efficiency while minimizing environmental foot prints.
- Scale appropriate smart farm mechanization for smallholder conservation agriculture, precision farming and climate smart agriculture.
- ICAR institutes and SAUs will be invited to become partners IMTA. AICRP will continue to be partner with CIMMYT in IMIC-Asia II.
- Apart from continued development and sharing of trait donors, strategic research towards understanding the basis of resistance to major diseases of maize in the region will be taken up in close collaboration with SAUs.
- System intensification will be speeded up in Indo -Gangetic plains with focus on increasing nutrient and water use efficiency.
- Developing improved technologies, practices, institutions and policy to enhance resilience to climate variability and climate change.
- Capacity development of young researchers, extension workers and entrepreneurs in all disciplines of CIMMYT.

International Potato Centre

International Potato Centre (CIP) is non-profit international agricultural research organization with a global mandate to conduct research on genetic resources of potatoes, sweet potatoes, and other Andean roots and tubers, crop genetic enhancement and improvement, integrated crop management and sustainable management of natural resources. CIP's vision is to contribute from its areas of expertise to the fulfilment of the Millennium Development Goals (MDGs) in particular those goals that relate to poverty, hunger, child and maternal mortality, and sustainable development. CIP has its headquarters in Lima, Peru with staff and activities in locations across Africa, Asia and Latin America. CIP is a member of the Alliance of the CGIAR Centers, a network of 15 research centers mostly located in the developing world and supported by more than 60 donor members. The CIP office for SWA was opened first in CPRI, Shimla but shifted later to Delhi and a MOU was signed with Government of India in 1975.

2.i. Overall contribution to Indian agriculture

Potato: The CIP has supplied over 1000 accessions (advanced clones, parents and trues seed families for clonal selection) of diversified potato groups to India to develop new varieties through breeding or release locally adapted varieties. Eight potato varieties have been developed and released by CPRI by using CIP as one of the parents. Two of the processing varieties developed by using CIP as male parents are occupying over 100,000 ha area in country and has opened gates for processing industries. The farmers are benefitted by planting these varieties for contract farming or supplying directly to processing industries or market. In wholesale market these varieties fetches 20-25% higher price over HYVs. The Center has facilitated to train large number of scientists in CIP-Lima or other locations on different innovative technologies such as aeroponic for seed production, marker assisted selection,

study and exchange visit on GIS and crop modeling, TPS production technology and capacity building on developing bio-fortified varieties.

Sweet potato: Sweet potato has contributed to increased incomes and nutrition in Indian Agriculture in the past 3 decades. In collaboration with CTCRI, CIP has exchanged the elite germplasm that were procured from CIP-Lima, Peru which are rich in dry matter, beta-carotene and contributing to high yields. Several varieties have been released having CIP parental lines into the farming systems through AICRP on tuber crops in India. The estimated percentage increase in yields or productivity ranges between 10-20% with the improved varieties developed in the past two decades.

2.ii. Contribution during last one year

Potato

- CPRI/CIP jointly developed eight potato varieties from CIP germplasm. More than 1000 potato germplasm resistance to late blight, virus and cyst nematode, immune to wart, high dry matter, heat tolerant and bio-fortified supplied to CPRI.
- More than 33000 true potato seeds were produced from 14 successful crosses at CPRI Kufri by involving CIP parents in combination with exotic and Indian genotypes.
- 33 new clones including bio-fortified acquired from CIP and multiplied through in-vitro plants under net house at Modipuram to produce minitubers for further testing.
- 18 advanced CIP clones along with four control varieties were evaluated at 75 and 90 days for adaptability, and processing quality.
- Potato germplasm developed by CIP/CPRI parents with improved tolerance to abiotic stress and viruses evaluated at CPRI-C, Modipuram.
- Hybrid MCIP/11-118-white skin and MCIP/11-163-red skin were selected in confirmatory yield trial (F1C5 clones).
- Hybrid MCIP/10-15 was selected based on tuber yield, dry matter and desirable tuber attributes in final yield trial (F1C6 clones).
- CIP clone 397006.18) was introduced in AICRP for multilocation testing based on higher yield than K. Bahar (Modipuram) and K. Surya/K. Pukhraj (Jodhpur) at 90 days. It possessed high drought tolerance index under mild water deficit than K. Bahar/K. Pukhraj (Modipuram) and K. Surya/K. Pukhraj (Jodhpur).
- CIP clone 397186.70 introduced in AICRP based on 43 t/ha, higher than K. Bahar (35 t/ha), K. Pukhraj (40 t/ha), K. Sadabahar (37 t/ha) at Modipuram. It showed moderate resistant to late blight at Kufri.

- CP 4054 (CIP 397065.28) is being evaluated in on-farm trials and it is proposed to be released as commercial variety for early planting (early high temperature conditions) for arid and semi-arid agro-ecologies. The farmers will get better price by marketing it before main season harvest.
- CIP in collaboration with CPRI (for past 3-4 years) introduced potato cultivation successfully in the Thar deserts of Rajasthan in year 2016-17 to realize a dream to alleviate poverty by cultivating potatoes at large scale on farmers' field. The farmers got quite involved in the project, broke the norms of old traditional subsistence farming by adopting Potato as an important income generating crop.
- Seed potato production under low cost insect proof net house: The low cost insect proof temporary insect proof net house technology with drip-irrigation successfully tested in KVK Narayangaon, Pune to multiply the basic seed to check the virus vectors for sustainable seed production in plateau region. Suitable locations below thresh-hold level of aphid population were for quality seed production during Kharif and Rabi seasons in Karnataka and Maharashtra.



Women farmers were strong participant in the potato grown successfully in the arid region of Jodhpur, Rajasthan



Seed multiplication using temporary net houses to prevent virus infection at KVK Narayangaon, Maharashtra. Farmers field days were used to demonstrate the technology and quality of harvested tubers.

- A study on strengthening impact assessment in CGIAR (SIAC) was conducted to know the outcome of crop germplasm improvement. The major outcomes of six workshops conducted in Punjab, UP, Gujarat, Bihar, Karnataka and WB were: i) Kufri Pukhraj, the high yielding, early maturing/bulking variety has emerged as the top variety in India, ii) Kufri Jyoti was the top variety in the states of Karnataka and West Bengal, while it seconded in the state of Punjab, iii) among processing varieties, Kufri Chipsona 1 was found to occupy good acreage in UP (9.81%); K. Chipsona-3 in UP (2.99%) and West Bengal (1.43%), iv) the number of varieties (>15) being grown in a states of UP & West Bengal was found directly proportional to irrigation facilities as well as the suitable climate, v) shrinking potato growing window due to rising temperatures in northern India, where crop is mostly grown was estimated to be number one problem.

Sweet potato

More than 21600 true seeds of orange fleshed sweet potato clones were having high dry matter and beta-carotene content sent from CIP-Lima, Peru to India (CTCRI) to be used for breeding program in India. The clones received in the form of seeds will be established, multiplied, evaluated/screened and then selected. The selected clones will be further subjected for screening in different seasons and before being used for breeding program in India. The complete exercise will be done by CTCRI in association with CIP in India. The clones are primarily orange fleshed.

CIP is implementing a project on sweet potato called GAINS (Generating Advances in Incomes and Nutrition through Sweet potato) in Odisha supported under RKVY scheme through Directorate of Horticulture, Government of Odisha in 4 districts of the state. The area covered with improved varieties is 1350 ha over period of 3.5 years. The no. of farmers/ beneficiaries are around 4000 under the demonstration trials. The project sought to increase incomes and nutrition of farmers and bring awareness on the utilization of sweet potato.

2.iii Socio-economic impact/outcome

Potato

- Eight varieties have been released by using CIP material as one of the parents to develop locally adapted table and processing varieties resistant to abiotic and biotic stresses. More than 120,000 ha area is planted under these varieties. The farmers' income was increased by using the processing varieties as alternate to table purpose. These varieties fetch higher than table purpose varieties. Late blight resistant variety has reduced cost of cultivation by reduced use of fungicide and higher productivity

CIP germplasm in varietal development in India

Variety	Type of variety	Year of release	CIP Parent
K. Chipsona 1	Processing (Chips)	1998	MEX.750826 (CIP 720124)
K. Chipsona 2	Processing (Chips)	1998	F-6 (CIP 377427.1)
K. Surya	Heat tolerant	2006	LT-1(CIP377257 .1)
K. Chipsona 3	Processing (Chips)	2006	F.6 9CIP 377427.1)
K. Himalini	Late Blight Resistant	2006	Tollocan (CIP 720054)
K. Frysona	Processing (French Fries)	2009	Muziranzara (CIP-378711.5) and AL-575
K. Chipsona 4	Processing (Chips)	2010	CIP 378711.5 and CIP 720125
K. Lalit	Table	2013	CIP 380013.12

- CIP in partnership with CPRI has introduced first time potato cultivation in dryland system of Rajasthan to alleviate the poverty and enhance the nutrition and food security through potato introduction in zero potato growing district will be a real break-through for the most backward and resource poor population.
- Potato has been introduced in non-potato growing in rice fallow system in North Bengal through double transplanting technology of boro rice and planting early maturing rice and potato varieties. A significant number of farmers have adopted this system in North Bengal to increase their income by cultivation potato as additional crop.

Sweet potato

- *Capacity strengthening*: At least 3,000 farmers, women, and youth trained on various aspects of sweet potato production and utilization. Depending on the average land-holding pattern of the local farmers, the area of cultivation/expansion could be assessed.
- *Access to improved varieties*: Planting materials of improved varieties are available, in desired quantity and quality, to at least 80% of sweet potato farmers.
- *Crop production*: Sweetpotato production area and volume in tribal communities increased 150% in five years.
- *Crop performance*: On-farm yield average of sweetpotato and other crops increased 25%.

- *Household income:* Contribution of sweetpotato livelihoods (production-utilization) to overall household income increased by 50%.
- *Food consumption:* Year-round sweetpotato availability and consumption rate per capita increased 100%.
- *Nutritional well-being:* At least 1,500 women and children met RDA for micronutrients, through consumption of sweetpotato and other nutritious food crops.

Expected impact on livelihoods and poverty alleviation

- Farmers start generating more income from their land through sweetpotato production.
- A sound, self-sustaining seed production system is in operation.
- Farmers start consuming and marketing locally produced sweet potato.

3. Projects/activities in progress in India

Potato

- i) Development and evaluation of potato germplasm and varieties with improved tolerance to abiotic stress and viruses.
- ii) Development and evaluation of potato varieties with improved tolerance to heat, drought stress and viruses in different agro-ecologies: i) Hybridization, ii) Evaluation at Modipuram, iii) evaluation in different generations, iv) Multilocation testing trials in AICRP.
- iii) Innovative Technologies for cultivating potato in cereal based system in desert area of Jaisalmer, Jodhpur and Bikaner, Rajasthan.
- iv) Developing farmer's based sustainable potato seed systems in non-traditional seed areas in plateau region (Karnataka/Maharashtra).
- v) Introducing short duration potato through double transplanting technology of boro rice in fallow land after Khariff rice. (CIP/IRRI collaborative program).

Sweet Potato

- i). Quality planting material of OFSP (Orange Fleshed Sweet Potato) to be used in different sweet potato-growing areas of Odisha that is made available through research institutions of ICAR and extension departments under Government of Odisha, Directorate of Horticulture.
- II). Participatory approaches were used to facilitate the development of varieties and implementation of advanced sweet potato technologies among farmers. These activities are well covered under the AICRP on tuber crops implementation plan using improved varieties.
- III). Improved technical knowledge on improved practices for increased production and awareness of usefulness of OFSP and other sweet potato varieties. These activities are facilitated in collaboration of CIP with ICAR institutes, public and private partner institutions.
- IV). Improved marketing facilities, value chain strategies and access to farming communities for easy sale and achieving better price through proper decision making on the market price at the local level.

4. Yearly action plan and collaborators from NARES

Potato

- I. Varietal Improvement of potato for biotic and abiotic resistance varieties, processing varieties. Collaborators: ICAR/ CPRI, AICRP-Shimla, Agricultural Horticultural Universities, State Department of Horticulture Haryana, Potato Research Station, Deesa, Gujarat, AICRP Centers: Pune, Hassan, Kalyani, Bhuvneshwar, Chhindwara, Raipur, Kota, Faizabad, PepsiCo.
- II. Developing sustainable seed system in Plateau Region of Maharashtra and Karnataka. Collaborators: ICAR/ CPRI, Agricultural and Horticultural Universities, Shimoga State Department of Horticulture and Agriculture: Karnataka, Maharashtra, KVK-Naryanagaon, Maharashtra, AICRP, Pune and AICRP Hassan.
- III. Innovative Technologies for cultivating potato in cereal based system in desert area of Jaisalmer, Bikaner and Jodhpur, Rajasthan. Collaborators: ICAR/ CPRI, Agricultural University-Udaipur, AICRP Kota, Department of Horticulture, Rajasthan, PepsiCo.
- IV) improving income of poor farmers by intensification of potato in fallow rice lands after khariff rice in West Bengal- jointly by CIP/IRRI. Collaborators: ICAR/ CPRI, Department of Agriculture, West Bengal, ACIRP Kalyani, IRRI.

Sweet potato

CIP and CTCRI will possibly strengthen the sweetpotato breeding program in India as new clones of OFSP were received recently that are projected to give better yields, having high dry matter and beta-carotene. A new collaboration in the area of value chain improvement for sweetpotato is being explored between the two institutions, and to work on a project mode with specific objectives targeting locations that will help meet farmers requirements across India. New technologies under IPM umbrella can be explored in areas where there is critical need.

5. Way forward

Potato

The locally quality seed production in Odisha, Karnataka and Maharashtra will reduce seed cost imported from about 2000 Km from the north. The farmers will be benefitted by reduced cost of seed and increased production of quality potato. The introduction of potato in non-traditional potato growing areas in cereal based system in hot-humid agro-ecology of North West Bengal and in Arid ecology of Rajasthan will generate more income to farmers and improve food security by increased productivity of systems. The process of developing heat and drought tolerant varieties will continue to meet the challenges for climate change scenario for sustaining productivity and quality potato production.

Sweet potato

The projects will highlight introduction of nutritionally rich sweet potato varieties and expansion of sweet potato cultivation to increase and sustain its production in Odisha and in Indian states in general. The seed system has to be strengthened for sustainable production. The projects should be farmer led, supported with good technological interventions. The researchers and extension will play an important role in guiding and providing available technical options to farmers and helping them to make their appropriate choices. Scientists will also provide technical backstopping needed for further on-station and on-farm research.

CIP research integration sites in India



International Rice Research Institute

The International Rice Research Institute (IRRI) is a nonprofit autonomous international research and training organization with a mission to reduce poverty and hunger, improve the health of rice farmers and consumers, and ensure environmental sustainability through collaborative research, partnerships, and the strengthening of national agricultural research and extension systems (NARES). IRRI is a member of the CGIAR Consortium and works in partnership with public- and private-sector partners in the NARES in major rice-growing countries to do research, training, and knowledge transfer. IRRI is the lead center of the Global Rice Science Partnerships and RiceAgri-Food System Research Program RICE - CGIAR Research Programs (CRP).

Over more than five and half decades of operation, IRRI has amassed a unique portfolio of research products and intellectual assets on all aspects of rice systems, which remain as public goods.

IRRI and India have been successfully collaborating for almost five decades. Formal collaboration between India and IRRI dates back to 1967, when the ICAR and IRRI agreed on research cooperation. On 15 March 1974, Dr. M.S. Swaminathan and N.C. Brady, the then director generals of ICAR and IRRI, respectively, signed the ICAR-IRRI Memorandum of Agreement (MoA) for cooperation in research and training. Under this umbrella the two institutions sign work plans every 4-5 years, reviewing the progress of research and identifying future opportunities and areas of research collaboration. IRRI has been working in India under the broad framework in collaboration with a wide range of NARES institutions involved in agricultural research and development. ICAR is the nodal point for IRRI in India, and IRRI keeps ICAR informed for all its collaborative activities in India.

2.i. Overall contributions to Indian agriculture

India has been actively involved in IRRI's priority setting, strategic planning, scientific advising, and implementation of research in the region. Senior Indian scientists and government officials have served almost continuously on IRRI's Board of Trustees since its creation. Indian scientists at IRRI have contributed significantly to IRRI's success in using cutting-edge science to help bring food security, economic growth, and environmental protection to the world through their dedicated research and administrative efforts. Dr M.S. Swaminathan, the first World Food Prize Laureate in 1987, served as IRRI's fourth director general during 1982-88. Dr G.S. Khush, a rice breeder and 1996 World Food Prize Laureate worked for 34 years at IRRI and made most outstanding countless contributions to keep the Green Revolution in rice production on right path. Over the years, more than 50 Indians have distinguishingly served – or are serving – IRRI as globally recruited scientists and 17 have been decision makers as members of the Board of Trustees. Since 1964, several Indian scholars have studied at IRRI to earn advance degrees or participate in other educational programs. Numerous senior and emerging Indian rice scientists and agricultural policy specialists are IRRI alumni and there is an enormous reservoir of goodwill in India towards IRRI.

The synergy of partnership resulted in development of high yielding rice varieties, rice varieties tolerant to biotic stresses suited to various rice environments, hybrid rice varieties bred through government and private sector programs, improved crop and nutrient management practices including conservation agriculture in rice-wheat systems, and improved postharvest technologies for improved sustainability and productivity. The free exchange of genetic material at both the national and international levels through IRRI's International Network of Genetic Evaluation of Rice or INGER allowed testing and breeding under different rice ecologies and agro-climatic regions.

Key achievements emanated out of India-IRRI collaboration include,

- **Conservation and exchange of rice germplasm:** Out of 1,27,000 rice germplasm at IRRI's gene bank more than 17,000 are from India. Many of these have contributed immensely as door to rice breeding programs, such as Pokkali for salinity tolerance, N22 for drought and heat tolerance, FR13A for submergence tolerance, and *Oryza nivara* for resistance to grassy stunt virus.
- **Delivery of new varieties, practices, and technologies:** The success of the partnership between India and IRRI began with the introduction of the high-yielding rice variety IR8, dubbed miracle rice, which helped save India from a massive famine in the 1970s. This was only the beginning of a partnership that has led to more than 400 improved rice varieties that have resistance to pests and diseases, streamlined rice production practices, and extensive information exchange with Indian scientists and capacity building.

- **Breeding of stress-proof rice:** India was the first country to obtain the submergence- tolerant trait bred into local mega-varieties, through collaborative programs with IRRI. Many single- and multiple stress-tolerant lines (flash flood, stagnant flood, drought, salinity, etc.) introduced by IRRI in India are now being cultivated widely by the farmers. These varieties are helping enhance and stabilize rice productivity under the ever- changing climate in the region.
- **Improved roll-out of hybrid rice:** Hybrid rice research made a significant advance, thanks to partnership between India and IRRI. With IRRI's support, India now ranks second only to China in commercial production of hybrid rice.
- **Built capacity:** Between 1962 and 2016, 1,589 Indian researchers participated in education and training programs at IRRI. Indian scholars who have undergone training and done research at IRRI include 123 PhDs, 24 MScs, 13 interns, 10 research fellows, and 138 on-the-job trainees. More than 1,000 Indian scientists also attended short-term courses run by IRRI.

The results of this collaboration have been outstanding, setting an example in international research collaboration. India now has an extensive partnership with IRRI in which around 250 institutions/organizations all over India are collaborating with IRRI.

2.ii. Contribution during last one year

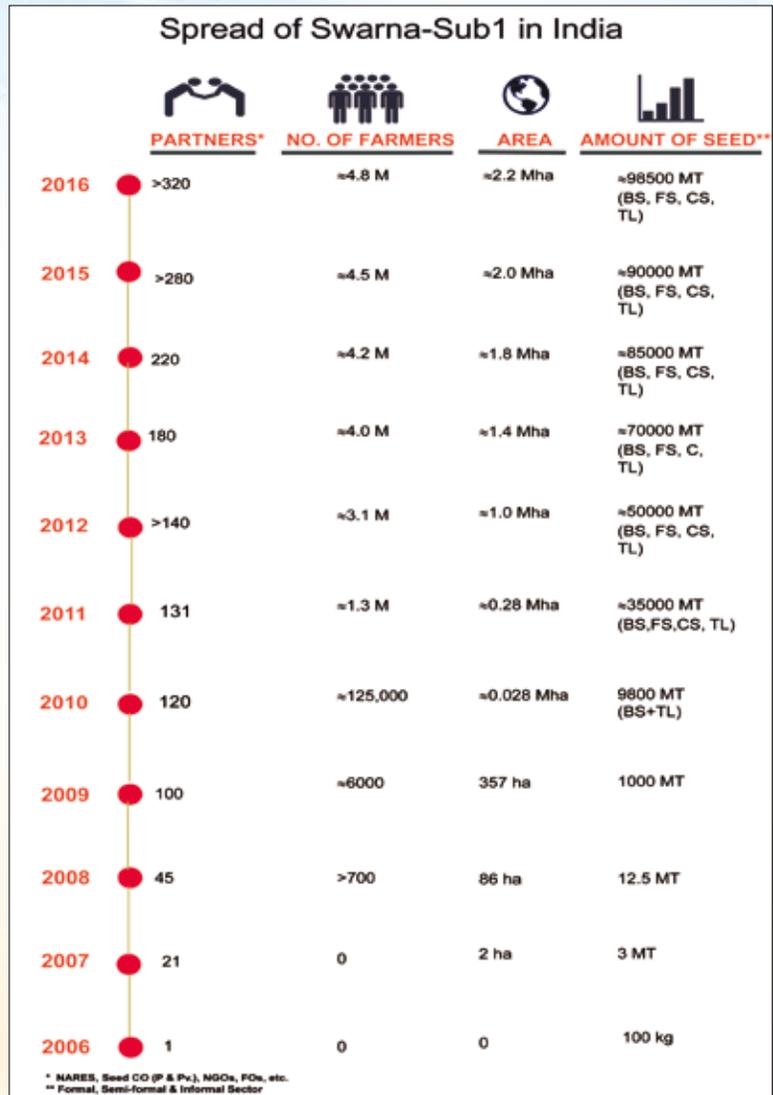
- Yield evaluation of 1321 MAGIC-Indica lines at IRRI led to selection of 395 elite lines for yield evaluation at 3 sites evaluation done during 2016 dry season (*Rabi*) at Maruteru (AP Agril. Univ) while on going during 2016 wet-season (*Kharif*). Genotype data along with grain quality for the 395 lines shared with partners.
- Phenotyping for bacterial blight, blast and BPH at IRR (DRR).
- Salinity and sodicity evaluation (seedling stage) at CSSRI completed.



- New breeding lines identified from 9 locations in SE Asia, shared with Indian partners for further testing in South Asia during *kharif* 2016.
- Development and analysis of C4 rice prototype.
- Photosynthetic gene discovery from 3K Rice Genome, CRISPR-Cas9/Cpf1 mediated genome editing for precision breeding, High throughput Phenomics.
- Improvement of elite Indian cultivars for biotic stress resistance and high yield potential using genomics strategy.
- An array of new breeding lines with early stage seedling vigor, better plant type with strong culm, partial stay green leaves, varied maturity groups and grain type with better adaptability and high yielding ability under DSR were developed.
- In Sambamahsuri, Swarna, MTU1010 and NDR 359 grain type segment more than 400 new breeding lines with early to medium maturity, strong culm and high grain yield were developed and shared with NARES partners.
- More than 3000 entries with desirable traits for machine sown DSR condition are in different segregating generations.
- 450 breeding lines were screened for Iron deficiency tolerance under dry DSR condition and 45 promising lines were identified.
- Six entries are in AICRIP trials and eight lines are in State level trials.
- Crop and nutrient management software/application released for different crops (Rice, wheat, maize), cropping systems (rice-rice, rice-wheat, rice-maize), and regions (Bihar, Odisha, eastern UP, Tamil Nadu) that can be used on ICT based devices (mobile, tablets, laptops) by extension services or other stakeholders.
- The Apps developed to provide site specific nutrient and crop management recommendations in both irrigated and rainfed environments in vernacular languages.
- In November 2016, IRRI celebrated the 50th anniversary of the official release of the semi-dwarf rice variety IR8 to Asia and the world. IR8 was developed by rice scientists working at IRRI in the early 1960s and is believed to have saved many regions of Asia from famine after it was released in November 1966. It became popular with farmers because it had short growth duration and a high-yield capacity related to its response to nitrogen fertilizer.
- In 2016, there are a total of 42 Indian scientists and students who came to IRRI. Of these, 15 are pursuing their PhD, 1 doing their MS, 2 came to undergo on-the job training, 6 came as interns, and 18 attended various short term training courses.

2.iii. Socio-economic impact/outcome

- Over the years, several rice varieties were released from joint collaboration in India more recent being the first flood-tolerant rice variety, Swarna-Sub1 which was released in India in August 2009.
- Swarna-Sub1 is a shining example of India-IRRI collaboration, but, it is primarily an Indian story. SUB1 gene was identified and fine mapped from one of the Indian land races, FR13A, and was transferred to an Indian mega variety, Swarna (MTU 7029), at IRRI using marker assisted backcross breeding. Indian scientists were involved in its development and evaluation of the final project. Elaborate experiments were conducted at NRRI, Cuttack to find the worth of the line prior to its identification and release.
- Due to outstanding field performance and strong support from national system, Swarna-Sub1 reached millions of farmers in India covering over 2.0 million ha rice area. A number of multiple stress tolerant rice varieties are in the pipeline.
- One-quarter of overall Indian rice varietal development program can be attributed to IRRI germplasm.



3. Projects/activities in progress in India

Name of the Project Theme	Specific Activity	NARES Collaborators
Global Rice Array	Partnership to strengthen global phenomics network	ICAR: CSSRI, CIARI, NRRI, IIRR, IARI, ICARRC-Goa SAU: GBPUAT, APRRS-Maruteru, TNAU, RARS-AAU, IGKV
New Rice Varieties	Identification of traits, genes, physiological mechanisms to develop climate smart varieties for unfavourable environment	ICAR: IARI, ICAR-RCER, NRCPB, CSSRI, NRRI, IIRR, NBPGR, ICAR-NEH (Tripura) SAU: AAU (Titabar), PAU, PJTSAU, OUAT, IGKV, BHU, RAU, PAJANCOA, DBSKKV, TNAU, ANGRAU, UAS Departments of Agriculture of GOI and States: State Agricultural Departments of Chhattisgarh, West Bengal, Bihar
	Advance breeding technologies to speed up genetic gain, create durable resistance to biotic stresses and increase Indian farmers' and consumers' food and nutritional security	ICAR: IARI, NRCPB, IASRI, IIRR, NRRI, ICAR-RCER SAU: OUAT, TNAU, BAU, BHU, Visva Bharati Departments of Agriculture of GOI and States: Odisha, Bihar, EUP
	Genomics-assisted breeding for increasing yield potential and durable resistance to major biotic stresses (BPH, Blast, BB, Sheath blight) of Indian elite varieties	ICAR: IIRR, NRRI, IARI SAU: PJTSAU, OUAT, ANGRAU Departments of Agriculture of GOI and States
	Development of High Zinc rice varieties	ICAR: IIRR, NRRI, IARI SAU: BAU, AAU, PJTSAU, IGKV, TNAU, UAS-B, UAS-D
	Increasing the Health potential in rice by lowering glycaemic index response in high yielding lines	ICAR: IIRRI, IARI, NRRI SAU: As may be interested Departments of Agriculture of GOI and States Others: National Institute of Nutrition, Hyderabad, India
	New high yielding rice varieties for Irrigated and Mechanized Dry Direct Seeding systems (DSR) of India	ICAR: IIRR, NRRI, CSSRI SAUs: PAU, BAU, ANGRAU, NRRI, UAS-Raichur, GBPUA&T, OUAT, PJTSAU Others : Osmania University, Hyderabad

Name of the Project Theme	Specific Activity	NARES Collaborators
	Hybrid rice	ICAR: IIRR, NRRI, IARI SAU: TNAU, PJTSAU, ANGRAU, JNKVV Departments of Agriculture of GOI and States Others: Indian seed companies
	Green super rice for the resource poor of Asia and Africa – Phase III	ICAR: IIRR, NRRI, IARI SAU: TNAU, PJTSAU
	Trait, pre-breeding and varietal development for rainfed ecology	ICAR: NRRI, IARI, IIRR, NRCPB, ICAR-NEH, ICAR-RCER, NIASM SAU: PAU, PJTSAU, TNAU, OUAT, BHU, IGKVV, BAU (Sabour), RAU
	C4 rice, C3 photosynthesis and Genome Editing	ICAR: IARI, NRCPB, NRRI, IIRR SAU: TNAU, GKVK Others: ICGEB, NIPGR, JNU
	Epigenetics: Potential roles in controlling agronomically important traits	ICAR: NIASM SAU: TNAU Departments of Agriculture of GOI and States Others: Delhi University South Campus
	INGER & Multi Environment Testing of New germplasm	ICAR: IIRR, NRRI, IARI, NBPGR SAU: All interested Departments of Agriculture of GOI and States
Accelerating Impact & Equity	Accelerating impact and adoption of STRVs through innovative research and approaches	ICAR: NRRI, IIRR, SAU: OUAT, RAU, NDUAT, BAU, AAU Departments of Agriculture & Farmers Welfare of GOI and State Governments of Assam, Bihar, Chhattisgarh, Jharkhand, Odisha, UP, AP, Telangana and TN: RRS, Chinsurah, State Seed Corporations, Pvt. Seed Associations Others: NGOs, Farmers' clubs, SHGs and Progressive farmers

Name of the Project Theme	Specific Activity	NARES Collaborators
	Gender and Youth sensitive rural entrepreneurship development for value added agricultural services	ICAR: IARI, NIAP, NRRI, IIRR, CIWA, IIWM SAU: AAU, OUAT, BAU, KAU Departments of Agriculture of GOI and States: State agricultural and allied departments of Odisha, Bihar, UP, Assam Others: Madhyam Foundation, EIT, Reliance Foundation, ITC
	Rural household dynamics in eastern and southern India and developing future rice strategy for India	ICAR: IARI, NIAP, NRRI, IIRR, CIWA, IIWM SAU: AAU, OUAT, BAU, KAU Departments of Agriculture of GOI and States: Odisha, West Bengal, UP, Bihar, Assam, Telengana and AP Others: Madhyam Foundation, EIT
	Recommendation domains of improved cropping systems, stress tolerant cultivars and direct seeded rice in eastern India	ICAR: NRRI, IIPR, IIRR, IARI SAU: OUAT Departments of Agriculture of GOI and States: State agricultural and allied departments of Odisha, Bihar, UP, Assam ORSAC Others: NGOs and Private sector partners
	Supporting the rice sector with digital extension strategies	ICAR: IIRR, NRRI, CIWA SAU: AAU, OUAT, APRRI, BAU Departments of Agriculture of GOI and States: Assam, West Bengal, Odisha, AP, Telangana, Jharkhand and Chhattisgarh and Bihar Others: NGOs – Digital Green, MSSRF, Access agriculture, Reliance foundation, Pradan and others
	IRRI – India collaborative capacity development program	ICAR: DDG (Education), IIRR, NRRI, CIWA SAU: Odisha, Assam, Bihar, Jharkhand, Chhattisgarh, West Bengal, Andhra Pradesh, Tamil Nadu Departments of Agriculture of GOI and States: Odisha, Assam, bihar, Jharkhand, Chhattisgarh, West Bengal, Andhra Pradesh, Tamil Nadu

Name of the Project Theme	Specific Activity	NARES Collaborators
Upgrading Rice Value	Improved mechanization in post-harvest to reduce losses and improve quality	ICAR: IARI, IIRR, NRRI SAU: OUAT, AAU, RAU, BAU Departments of Agriculture of GOI and States: Odisha, Bihar, Assam Others: NGOs
Sustainable Farming Systems	Development of climate-smart practices for climate-resilient varieties	ICAR: NRRI, CSSRI-Canning Town SAU: Vishwa Bharti
	Evaluation of climate-smart agricultural practices (CSAPs) and long-term monitoring	ICAR: NRRI, IIRR, IARI, NBPGR SAUs: BAU, OUAT, ANGRAU, UAS-B
	Biology, epidemiology and management of rice false smut caused by <i>Ustilaginoidea virens</i> (Cke.) Tak	ICAR: IARI SAU: PAU
	Precision management of rice-based cropping systems through use of new advances in information and communications technology (ICT) and spatial analysis	ICAR: NRRI, IIRR, IARI, ICAR- RCER, , ICAR-RCNEH, IIPR, IIFSR SAU: OUAT, BAU, RAU, AAU, IGAU, BHU, NDUAT, BCKV, UBKV, BAU-Ranchi Departments of Agriculture of GOI and States: Odisha, Bihar, UP, Assam, West Bengal, Jharkhand
	Crop and resource management practices for irrigated cereal systems	ICAR: IIRR, NRRI, RCER, IIWBR SAU: OUAT, BAU, BHU, Visva Bharati Departments of Agriculture of GOI and States: Odisha, Bihar, EUP
	Crop and resource management practices for rainfed low land systems in eastern India	ICAR: NRRI, CSSRI (Lucknow and Canning Town), IIRR, ICAR-RECR SAU: NDUAT, SVPUAT, BHU, RAU, BAU, OUAT Departments of Agriculture of GOI and States: RRS, Chinsurah, W.B.

4. Yearly action plan and collaborators from NARES

While IRRI-India collaboration has matured, so have the needs, expectations, and environment of doing business in relation to what is happening not only in India but also regionally and globally. India has a strong national rice research program, and increasing participation by the private sector (seed industry) and civil society organizations. The need to work together is stronger than ever and it is crucial to meet the agricultural, nutrition, health, and environmental challenges facing India. The new CRP on Rice- Rice Agri-Food System Research Program RICE, on the basis of which the current work plan is developed and intended to address all these concerns.

Accordingly, the current work plan has been signed this year between the ICAR and IRRI, outlining an “exciting and forward-looking” research and development partnership that will enhance India’s rice sector for the coming 6 years period.

The collaborative work plan for 2017-2022 includes new projects that seek solutions for better managing environmental resources, climate change, and sustainability of rice production to meet future demand. These will involve upstream research on crop genetic improvement and intensive rice-based systems. There is also a new focus on nutrition, gender equality, and creating attractive opportunities in the rice sector for the youth.

The work plan includes 26 ongoing as well as new initiatives grouped into 5 major thematic areas (Flagship programs) of RICE CRP that include areas of work on sustainable farming, improving extension systems, mechanization, and the development of a future rice strategy for India. Following are the on-going mega projects that have been built in the work plan as well.

- Cereal Systems Initiative for South Asia (CSISA)
- Stress-Tolerant Rice for Africa and South Asia (STRASA)
- IRRI South Asia Rice Breeding Hub – Hyderabad
- Regional cooperation on release of rice varieties
- Projects in a mission mode with various states in India such as Odisha, AP, Assam, UP and other similar rice growing states to promote and accelerate expansion and dissemination of improved varieties, research technologies and package of practices to enhance the livelihood of the poor farmers.

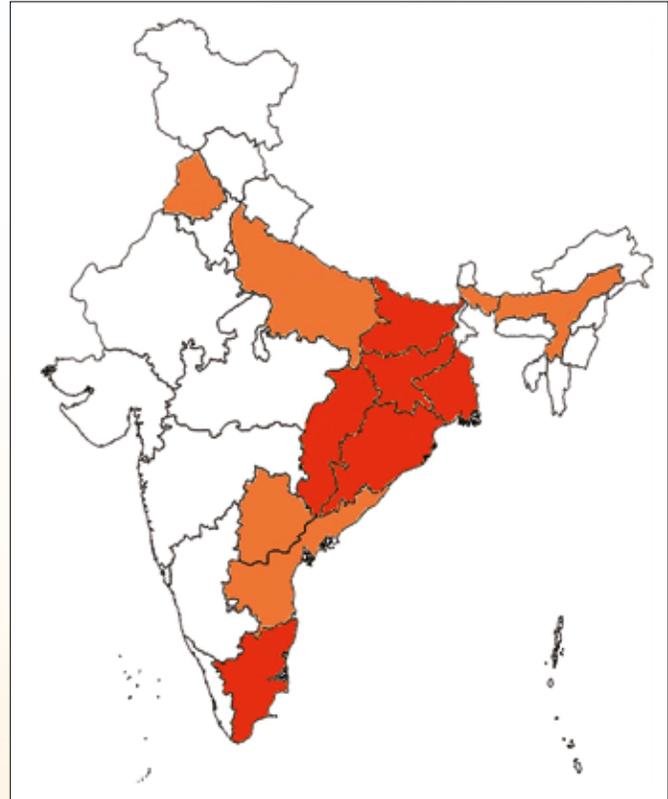
IRRI now has an extensive partnership with India in which around 250 NARES institutions/ organizations all over the country are collaborating in carrying out the projects included in the above signed work plan. The NARES network includes:

- ICAR institutes
- State Agricultural universities
- Department of Agriculture and Cooperation, GOI
- State Departments of Agriculture

- Department of Biotechnology
- NGO and Private Sector
- Public & private sector seed corporations/ companies

5. Way forward

With the establishment of a new regional rice hub at ICRISAT, Hyderabad and in close collaboration with ICAR and other public- and private-sector institutions and intend to build similar facilities in other parts of the country such as UP so that the IRRI-India partnership can assist rice-growing countries in South Asia and Africa in strengthening their rice program. This facility would allow the implementation of upstream research agenda agreed under the India-IRRI collaborative research program including targeted breeding research and training program with a spill over benefit to other SAARC countries and Africa. In upstream areas such as genomics and bioinformatics where Indian institutions have strong program, India could play a key role in supplementing IRRI's global agenda. India with its large diversity of soil and climate, provide unique opportunities to develop situation specific rice varieties which will be relevant to not only India but also to other neighboring countries and Africa. While our on-going work on trait/variety development with multiple abiotic (drought, submergence, salinity) and biotic (sheath blight, blast, bacterial blight, RTV, gall midge, stem borer) stresses will continue to be focus, there is a need to initiate research to deal with emerging problems such as false smut, nematodes and low light intensity. Shorter duration rice which can fit in diverse cropping systems and appropriate grain quality should continue to be the priorities. With increasing the purchasing power of a significant sector of rice consumers, grain quality will have increasing demand. Emerging labor shortages and rising labor wages will require focusing in conservation tillage and direct-seeding



Map showing major collaborative work sites of IRRI in India (shaded)
<http://irri.org/about-us/our-history>

of rice. System agronomic research and development of best management practices for key rice systems will have to be developed. This is primarily to broaden the scope of work to maximize the yield potential of new varieties. There is strong need of technology targeting and development of extrapolation domains for an efficient uptake of new technologies. Our social science agenda would also include socio-economic and gender analyses for technology evaluation, and strategic foresight, priority setting, and impact assessment for rice research.

In addition, IRRI is being approached by various rice growing states in India such as Odisha, Assam, UP and other similar rice growing states recently to promote and accelerate expansion and dissemination of improved varieties, research technologies and package of practices to enhance the livelihood of the poor farmers in a mission mode by including much wider scope of collaborative activities. Accordingly, MOUs are being entered into by IRRI with these states as well.

Activities of IRRI in India are supported by ICAR (through window 3), external donor funding (BMGF, USAID, ADB, and IFAD), Ministry of Agriculture and Cooperation and DBT. As we move, sustainability of funding becomes crucial. IRRI continues to explore additional and new project funding including philanthropic donation/grants from Indian donors and tapping Corporate Social Responsibility source.

International Water Management Institute

The International Water Management Institute (IWMI) is a non-profit research for development organization, focusing on the sustainable use of water and land resources in developing countries. IWMI was established in 1985, with headquarters in Colombo, Sri Lanka and with offices throughout Asia and Africa. IWMI's team of over 310 researchers and support staff provides technical expertise and science leadership in productive water use; water availability and access; water quality and health; and water for the environment and society. The international quality and relevance of IWMI research was acknowledged by the awards of the 2011 Crystal Drop Award and 2012 Stockholm Water Prize.

IWMI works in partnership with governments, civil society and the private sector to develop locally adaptable, scalable agricultural water management solutions that have a real impact on poverty reduction, food security and ecosystem health. IWMI has established programs and considerable depth of knowledge on agriculture and water management options in South and Southeast Asia with innovative, locally adaptive approaches to managing the water-food-energy nexus in developing countries. IWMI has been involved in implementation and evaluation of participatory irrigation management in diverse contexts.

With offices in New Delhi and Anand, IWMI has been working in India on issues related to water and agriculture for over two decades. The researchers work in close collaboration



ICAR-IWMI Steering Committee Meeting and Field Visit, Colombo

with national and state governments and contribute to water resources policies and planning. IWMI also partner's with numerous national and state level bodies, such as the Indian Council of Agricultural Research (ICAR), the National Mission for Clean Ganga (NMCG) and various civil society organizations and foundations. In India, IWMI's annual expenditure is approximately USD 18 million. Funding partners include governments, foundations, multilateral organizations and the private sector.

2.i. Over all contribution to Indian agriculture

IWMI is leading the Water and Land Ecosystem (WLE) as a part of CGIAR Research Program (CRP) in the country. IWMI research in the past has contributed towards achieving the millennium development goals in India and presently working to support the sustainable developmental goals. IWMI's research in India has had a significant impact on water policy. Innovative science and evidence-based solutions were provided for emerging national priorities. These includes river basin management, sustainable groundwater management, climate change and adaptations, improvement of water use efficiency, business models for waste and wastewater management, urban and peri-urban farming.

IWMI has contributed to different river basin management aspects addressing water security and agriculture. To this, the national river linking project of India has contributed to the enhanced knowledge on the environmental flows of river, water productivity of irrigated and rain-fed lands. The IWMI-TATA Water policy program (ITP) undertook extensive research on the groundwater-energy nexus and identified practical ways to unlock the issues through Jyotigram Yojana scheme in Gujarat. This has become a flagship program and implemented in several states of India (Madhya Pradesh, Punjab, Haryana, Andhra Pradesh and Karnataka).

IWMI has also extensively worked on the micro-irrigation adaptation through awareness programs on maintenance of the system and scheduling of irrigation. This led to the reduction in water abstractions and increased yield up to 40 percent in southern states of India. Policy guidelines was also developed for promotion and improvement of micro-irrigation in Tamil Nadu state.

Developed database for different river basins (Krishna, Ganga, and Brahmaputra) in India and map of the irrigated areas. The maps are available in IWMI website for research reference and policy advocacy.

2.ii. Contribution during last one year

IWMI has contributed to various programs and policies related to climate change adaptation and mitigation, water resources and productivity, water-energy-food nexus, resource recovery reuse and wetland ecosystem services.

Minor Irrigation Census Report: IWMI-India Collaborated with MoWR, RD & GR for the republishing of the 4th minor irrigation census report.

NGMIP: GoI-World Bank: IWMI-India to help the overall strategy and state-level plans for participating states under NGMIP

PMSKY- Policy & Programs: Organized Policy Dialogues in Delhi, Jharkhand and Chattisgarh on PMKSY, IWMI studies helped MoWR prepare EFC Memo for a new sub-program PMSKY- Har Khet Ko Paani – Groundwater. Inclusion of “Under Ground Taming of Flood for Irrigation (UTFI)” in the District Irrigation Plan (DIP) of Rampur under PMSKY is clear evidence of uptake of IWMI’s technology.

Concurrent Evaluation of AIBP: IWMI developed a model AIBP evaluation report based on the work in Omkareshwar Project, Madhya Pradesh.

CWC & CGWB Restructuring: IWMI was part of the Mihir Shah Committee, which recommended major restructuring of the Central Water Commission and the Central Groundwater Board.

Agricultural Insurance: IWMI contributed to the expert committee on agricultural insurance and flood index guidelines in Bihar for risk management.

Climate Change and Adaptations: In addition to the flood index tools and South Asia Drought Monitoring System (SADMS), IWMI has implemented and promoted various water saving initiatives viz., direct seeding of rice, alternate wetting and drying of rice and mechanized transplantation of rice in Andhra Pradesh and Telangana states in coordination with State Agricultural Universities. The area under adaptation of these technologies has raised from 200 ha to 1.5 lakh hectares during the last five years. The Government of Andhra Pradesh has taken the interventions under AP Primary mission program targeting to five lakh ha in the state.

IWMI-led innovative models called **SPaRC (Solar Power as Remunerative Crop) and Solar Pump Irrigators’ Cooperative Enterprise (SPICE)**, which help farmers sell excess electricity from their solar pumps to the grid, have been taken up by the Gujarat State government for scaling up.

In a first of its kind initiative in the country, a pilot to showcase fecal sludge management is being undertaken in partnership with Delhi Jal Board, Cure, Gates Foundation and Water Aid in 2017.

2.iii. Socio-economic impact/outcome

IWMI research is mapped around the critical issues of poverty reduction, equitable growth and sustainable resource use. IWMI aims to aid the decision maker by providing evidence based and science based tools and solutions.

Solar Power as Remunerative Crop (SPaRC): Solar pumps are not new in India; their number has already grown from less than 7,500 in 2010 to 66,250 in 2014-15. The SPaRC has formed the World’s first Solar Pump Cooperative Enterprise (SPICE) in Gujarat, India. The members use solar energy to run irrigation pumps and pool the surplus solar energy and sell it to the grid at Rs.4.63 /kWh. In addition, IWMI and CCAFS have offered a green energy bonus of Rs.1.25 /kwh and water

conservation bonus of another Rs.1.25 /kWh. Six solar pumps, with a total capacity of 56.4 kWp, installed in the pilot sites to generate an income of three lakh rupees per year from solar power sales. SPaRC can play a big role in fulfilling the Prime Ministers dream of doubling the farm incomes in the country.

Underground Taming of Flood for Irrigation (UTFI): The household data of UTFI project reveal that water availability for domestic use has increased because improved groundwater levels. The community participation in terms of site renovation and maintenance was formalized through inclusion of Mahatma Gandhi Rural Employment Scheme (MGNREGA). Additionally UTFI has been included in the District Irrigation Plan (DIP) for Rampur.

Index Based Flood Insurance (IBFI): IBFI is the insurance vehicle proposed to scale-up the agricultural flood insurance to 1 million farmers by 2025. The project has developed the flood insurance products using remote sensing data and flood hazard modelling tools that can accurately depict yield loss in smallholder farming due to weather and/or other perils.

Climate change and adaptations: Farmers adapting the water saving interventions were able to reduce the cost of cultivation, improve yield and income along with the water use efficiency. The adoption of DSR, AWD and MSRI in Guntur district of Andhra Pradesh was able to gain a net impact of 10,000 to 26,000 Rs/ha and 166.3 crores in the district due to uptake of the interventions. The government of Andhra Pradesh has targeted to increase the area under adaptation through 'Rythukosam Program', a mission mode approach for the double digit growth of agriculture.



Underground taming of flood water for irrigation, Rampur District
(<http://utfi.iwmi.org>)

3. Projects/activities in progress in India

The **Under Ground Taming of flood for Irrigation (UTFI):** is in progress under the Ganges River basin. The project is addressing the two major water challenges of seasonal flooding and groundwater depletion through the interventions. The project has demonstrated that the community-owned assets can be converted in to recharge structures that are effective in achieving both flood mitigation and enhance groundwater availability. The community has actively participated under MGNREGA program in the pilot site.

The recharge rate in recharge wells were measured by measuring drop in water depth over a period of time. The groundwater quality on heavy metals, arsenic, cadmium, cobalt, chromium, copper and fluoride are found to be below detection limit or within the acceptable limit.

Index based flood insurance and drought monitoring system: IWMI has developed the flood and drought monitoring tools that allow governments to better plan their investments in development. These are helping the policy makers and local communities to address the impacts of climate change and enhance resilience of agriculture.

The flood hazard model for Bagmati and Burhi Gandak river and flood mapping tool using satellite data for Bihar to assess flood severity and impact on agricultural losses was completed. The insurance product is planned to be rolled out in 2017 flood season in Bihar along with insurance companies.

South Asia Drought Monitoring System (SADMS): The drought hotspots are determined for risk assessment and planning preparedness measures. Two case studies were developed in Maharashtra and Bundelkhand to evaluate the integrated drought severity index (IDSI) and its applicability. The project has developed a near-real time monitoring and forecasting system based on probabilistic medium-range forecasts and seasonal forecasts

Water Policy Program - ITP: The use of solar pumps for irrigation is taking off in India. The solar power as a remunerative crop (SPaRC) is promoting sustainable groundwater management. SPaRC is allowing farmers to pump the irrigation water and sell the excess electricity generated to the grid, creating a solar cash crop.

Clean Ganga and fecal pollution prevention: The study on the prevention of pollution from fecal sludge has completed integrated baseline assessments of the 3 selected cities (Mughal Sarai, Gangaghat and Unnao) to identify challenges and opportunities. The study report that almost 40% of the household in Ganga states are connected to septic tanks but in the absence of FSM, with frequent desludging, septic tanks have nil treatment capacity. The FSM has received little attention but shows good potential for small and medium cities alone or in combination with other sanitation solutions (cheaper and quick win).

The healthy Ganga – Cleaner water and more productive ecosystems project from WLE presented practical solutions based on the research for cleaning the river, and making productive use of the liquid and solid waste to a wide range of stakeholders including MoWR officials, research organizations and other international organizations working on the Ganga.

Adaptation to innovations: An integrated science stakeholder approach to develop adaptation framework to climate change was implemented in the southern states of India (Andhra Pradesh, Telangana and Tamil Nadu). The project has implemented promising adaptation practices such as, direct seeded rice, Modified SRI (Mechanized transplantation of rice), alternate wetting and drying in rice, weather index insurance and Green Manure, Azolla and BGA. The project has created awareness on climate change impacts and improved the adaptive capacity by reducing inputs. International conference on climate change, water, agriculture and food security (ICCCWAFS) was organized from 2-3rd November 2016 in Hyderabad with 16 international institutes and 21 national institute's participation.

Risk and responses to Urban futures: Understanding peri-urban dynamics for enhanced ecosystem services. The study from Delhi, Hyderabad, Bangalore, Varanasi, Dhaka and Nepal show that in a 50 Km radius from cities agriculture

land is lost at a rapid rate. The area under agriculture was diminishing but production hotspots contributed to increased production. Migration to peri-urban areas were high and these were not accounted in census data. Indicators for multiple dimensions of poverty were higher in high production *mandals* e.g. Hyderabad.

Promoting the wise-use of wetlands in urban and peri-urban areas: The study was carried out in Maharashtra and west Bengal. The spatio-temporal studies identified over 3300 wet lands in 30 km radius with class size 0.38 ha and above. Between 2000 and 2013, 50% of these wet lands were lost. Hence, framework for wise use of wetlands was discussed at high level meeting in Kolkata with stakeholders including ICAR institutions. The workshop recommended developing a large proposal to capture the ecosystem services in wetlands in a catchment. Also proposed to develop new smaller wetlands to develop ideas and use the funds from PMSKY, RKVY, AMRUTH, etc.

Collective models for farm system intensification: Collective models have achieved unprecedented success. Labour management, ability to operate a contiguous plot and making irrigation more feasible has increased the cropping intensity to 300% in Bihar site. Solar pumps were installed for monitoring the institutional and technical performance.

Solar power as remunerative crop (SPaRC): IWMI is piloting solar power as the source of energy for pumping groundwater and selling the surplus power to the grid. The model is helping the farmers to incentivize and become water and energy efficient. The SPaRC is offering farmers a stable and climate proof income. The model will help in improving the financial viability of the DISCOMS. This also reduces the greenhouse gas emissions. The government of Gujarat has come forward and adopted the approach in their solar policy. Solar pump irrigators cooperative enterprise (SPICE) was also formed.



Access to irrigation during dry season for small holder using solar pump



Solar irrigation in Dhundi village, Kheda district, Gujarat

Fecal sludge management: IWMI is designing the technical, institutional and financial model for implementation of FSM as demonstration site for Delhi. Improvement in sanitation facilities is estimated resulting in improved quality of life and hygiene. Generation of employment opportunities is also expected at the location, establishing a sustainable model.

4. Yearly action plan and collaborators from NARES

In 2017, IWMI-India proposes to work with the ongoing and new proposals in collaboration with NARES, non-NARES and NGO partners. The details of the projects are as below:

Underground Taming of Flood for Irrigation: The UTFI project will continue to monitor and analyze the physical impact and quality of water for evidence based results. The project also proposes to communicate with potential strategic partners and liaise with administration/ministers to include UTFI in ongoing schemes/programs. The scaling-up activities will also be taken to cover the wider geographical areas under Ganges. The project will evaluate technical, social, economic and environmental performance of UTFI as a basis for recommendations and replication at regional scale. The project partners include CSSRI Research Centre, Lucknow, and National Institute of Hydrology (NIH), Roorkee is also proposed to be involved in the proposed scaling up project of UTFI.

IBFI and post-disaster management to promote agriculture resilience: About 73% of the Bihar's area and 76% of the population in North Bihar is at risk of recurrent flooding. There is a large scope for upscaling IBFI from pilot to large-scale implementation to provide coping mechanism for smallholder farmers in the state. Hence, research project has been developed under the ICAR-IWMI collaboration aiming at decreasing the climatic risk in agriculture including post flood management. The key NARES partners in the project include ICAR-IIWM, Bhubaneswar, ICAR-RCER, Patna and RAU, Pusa. The proposed collaborative research effort focuses on combining multiple approaches in deriving flood parameters and crop loss modules to create hybrid methodology for designing the insurance index for the proposed pilot villages in Bihar.

Drought Monitoring, Planning and Management: IWMI and ICAR agreed to collaborate and strengthen research activities on drought monitoring technologies / systems, field/in-situ validation, enhancing knowledge platforms and executing research programs of mutual interest in drought monitoring, planning and management beneficial for the India's food security. IWMI in collaboration with other international partners developed an operational state-of-the-art drought monitoring system for South Asia (SADMS) to plan and reduce drought risk faced by millions of smallholder farmers by providing long term, spatially rich datasets on historical and ongoing drought for stakeholders involved in planning. Through this collaboration, IWMI & ICAR will strengthen research, development and improvement of currently operational SADMS. The NARES partners include ICAR-CRIDA and selected centres of AICRP Dryland Agriculture. The collaboration will ensure rigorous evaluation of the SADMS and long term sustainability of the product. Pooling the strengths of ICAR-CRIDA

in crop science, crop models, agricultural water management and strong regional presence of allied institutes with IWMI's core competencies in remote sensing assessment, drought monitoring and agro-economics will lend multi-disciplinary expertise to drought monitoring and management including preparedness and contingency planning.

Building climate resilience of Indian smallholders to strengthen nutrition and food security: The main goal of the project is to improve agricultural productivity, adaptive capacity and livelihoods of the farmers in the north-eastern states of India. The project partners include, NIBIO (Norway), NRRI- Cuttack, OUAT, AAU, MSSRF, IWMI (will collaborate with ICAR-IIWM). IWMI and IIWM will contribute to the socioeconomic vulnerability assessment, identification of most relevant CSA technologies, integrated water resource management and improving WUE, flood and drought advisory services. The NARES partners and SAUs will implement the CSA and provide capacity building and knowledge dissemination from farmer to farmer.

IWMI-TATA water policy research: IWMI will continue implementation of SPaRC in Gujarat and Bihar. The projects will help in groundwater-abundant, energy-scarce eastern India. The study will help in catalyzing equitable solar irrigation service with access to high quality and affordable irrigation, especially for small and marginal farmers. In addition, the program will also pay attention on the rethinking of PMKSY, revitalizing canal irrigation in India, small farmer prosperous farmer (SFPF) initiative, cities as smart irrigation systems, tank aquifer agro-ecosystems and rural drinking water enterprises. The NARES, ICAR-IISWC is proposed to collaborate in the program on managing groundwater as Common Property Resource (CPR).

Enhancing economic water productivity in irrigation canal commands: The proposed project under ICAR-IWMI collaboration will investigate the interactions of water availability, water use in a canal command area in the State of Maharashtra, and identify appropriate interventions (physical and institutional) for increasing the economic water productivity (EWP). The Indian Council of Agricultural Research (ICAR), especially the IIWM, Bhubaneswar and AICRP IWM, Rahuri Centre, are the primary partners for the research component and pilot testing. The project will establish contacts with other national research institutions (NIH, Roorkee), and with the state and central government departments, including the State Groundwater Boards, Agricultural Department, Irrigation Department, WALMI and State Remote Sensing Institutes etc.

Portfolio of Climate Smart Land and Water Interventions for Climate Smart Villages: The NRM interventions for the CSV in six states (MP, Maharashtra, Rajasthan, Bihar, West Bengal and Uttar Pradesh) under CCAFS will be undertaken. Portfolio of interventions and training modules will developed in coordination with the ICAR and CCAFS for the CSV interventions. Scientist under professional Attachment Training is also involved in the project.

Wise use of wetlands: Based on the recommendations from workshop held in Kolkata, a proposal would be worked upon to capture the Ecosystem Services in wetlands in a catchment and explore all the incentives and schemes for livelihood opportunities that farming communities could tap into in collaboration with CIFRI Barrackpore, ICAR-RCER Patna.

Stakeholder workshops/policy dialogues: IWMI will organize/co-organize workshops and also participate in the workshops/dialogues in collaboration with NARES. Proposed key areas include water productivity, water related climatic risks and building resilience, ecosystem services, etc.

5. Way forward

IWMI proposes to work on three strategic programs from 2017, building resilience (SP1); enabling sustainable growth (SP2); and managing rural-urban linkages (SP3). SP1 delivers innovative science into policy, investment and practice that enable communities to build resilience and thrive in the face of climate, social, economic, and environmental stresses and shocks. It is focused on directly addressing the needs of rural communities and improving their livelihoods.

SP2 will pursue promoting sustainable growth through inclusive and innovative water management in transforming economics. The program provides policy and practice solutions for equitable, environmentally-sound and sustainable growth in the face of growing and often competing demands for water associated with rapidly changing economies. It aims to inform decisions and choices for fostering economic opportunities, using water in agriculture, agro-processing and other value chains as a medium for rural transformation and sustainable economic growth.

SP3 manages the water, food and waste innovations in urbanizing landscapes. The program delivers green business innovations, investment and policy advice on the value of waste from agro-industrial and municipal waste and provides integrated urban water and rural-urban food management solutions, to address hungry and thirsty cities, and human health.

IWMI will continue to work more closely with the NARES in planning and implementing joint proposals and projects.

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