1. PREAMBLE

The eastern region comprising of eastern UP, Bihar, Jharkhand, West Bengal, Assam, Orissa, and Chhattisgarh occupies about 22.5 per cent of the country's geographical area and is inhabited by about 35 per cent of the country's population (Fig. 1). The region can be divided into 3 distinct physiographical units, namely (i) Plains of eastern UP, Bihar, West Bengal, and Assam; (ii) Hilly and plateau regions in eastern UP, Bihar, Jharkhand, West Bengal, Orissa, Chattisgarh, and Assam; and (iii) Coastal plains of West Bengal and Orissa.

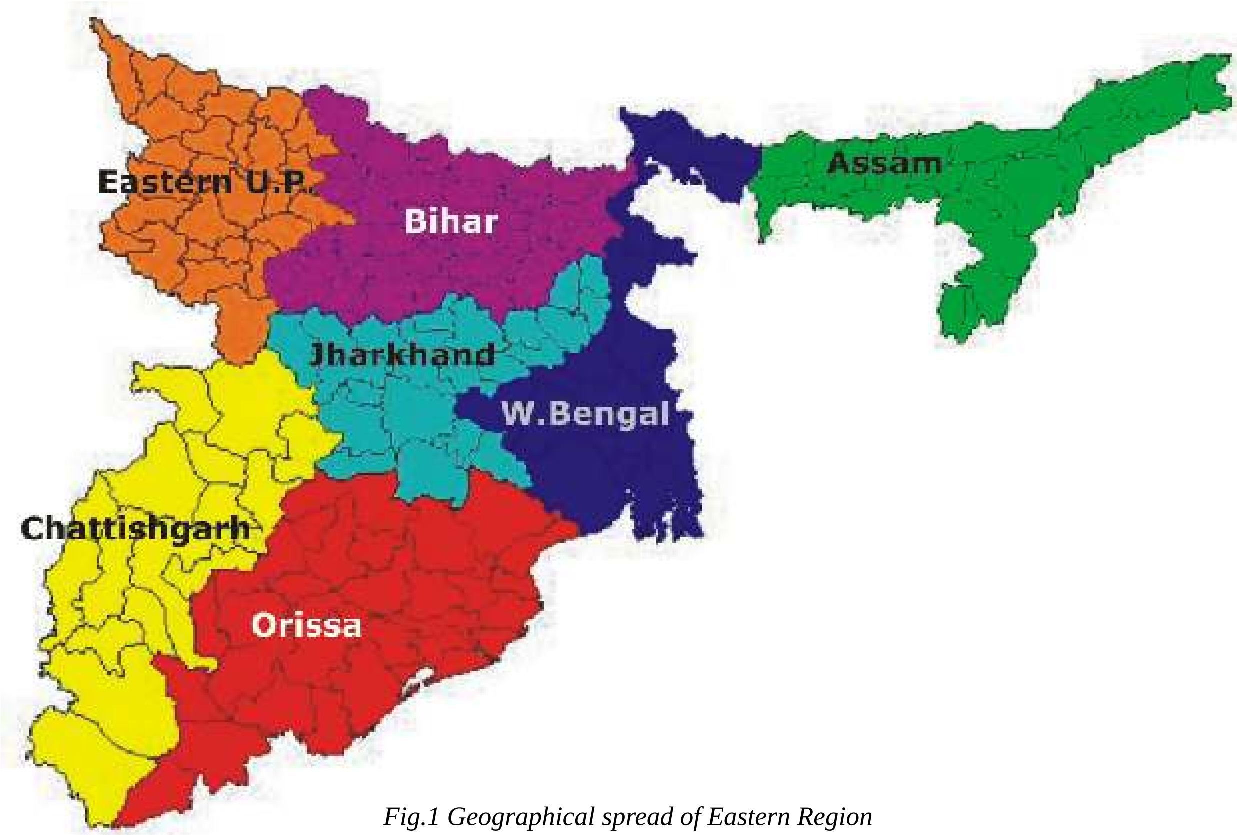


Fig.1 Geographical spread of Eastern Region

The eastern region is a 'Low Productivity-High Potential', resource rich region inhabited by resource poor people with small land - human ratio. The climate of the region is tropical, hot and humid except in hilly areas with high rainfall. The average annual rainfall varies from 1025-2820 mm. Even though the region has rich rain, surface and ground water resources, they are grossly underutilized, with the result that a large proportion of the cultivated area does not receive any irrigation water. The farmers depend on the vagaries of the monsoon for crop production. Owing to poor utilization of water resources, the cropping intensity in the region is low. Perennial and seasonal water bodies abound in this region but their potential has not been exploited. These provide a great scope for development of aquatic crops like makhana and fisheries. The eastern region has specific advantages as well as handicaps. Though, eastern region is endowed with natural resources but, so far its potential could not be harnessed in terms of improving agricultural productivity, poverty alleviation and livelihood improvement. There is a large gap between potential and productivity of major crops, horticulture, fisheries etc.

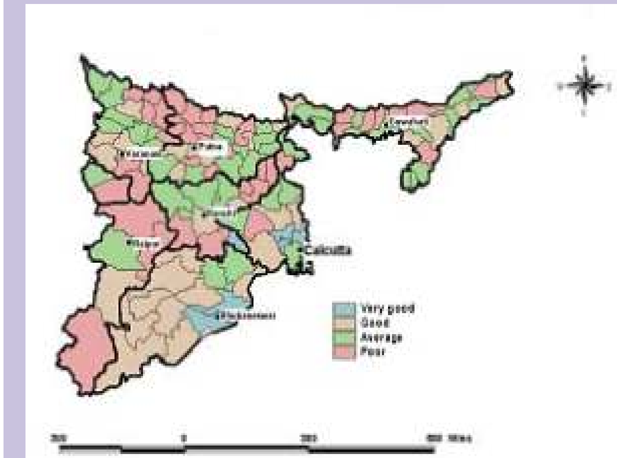


Fig. 2 Socio-economic characterisation of Eastern Region
(Source: Socio-economic Atlas, NATMO, GOI, 2001)

According to socio-economic characterization (Fig.2), the districts in the eastern region have been classified into four different categories: very good, good, average and poor on the basis of eight parameters : a) road length, b) credit by scheduled banks, c) percentage of urban population. d) percentage of children below six years e) percentage of literates, f) percentage of workers, g) percentage of double cropped area, and h) decennial growth rate. Maximum number of districts fall under poor and average category. Employment in agricultural sector is limited and a large proportion of the population still remains below the poverty line and suffers from malnutrition. On the basis of socio-economic conditions, Planning Commission has identified 150 disadvantaged districts in the country for livelihood improvement. Majority of these districts fall in eastern region in the states of Bihar, Orissa and Chattisgarh underling the need for research and developmental efforts to generate opportunities for self-employment in rural areas through agri-based and allied activities.

The ICAR Research Complex for Eastern Region came into existence on Feb 22, 2001 after merger of Directorate of Water Management Research, Patna with the Complex. On 1st April, 2001, Central Horticultural Experiment Station, Ranchi and Central Tobacco Research Station, Pusa were merged in the Complex. After the merger the ICAR Research Complex for Eastern Region is a broad based institutional framework to address diverse issues relating to land and water resources management, crop husbandry, horticulture, fishery, livestock and poultry, agro-processing, and socio-economics in a holistic manner for enhancing research capability and providing backstopping for improvement in agricultural productivity and sustainability in the eastern region. After amalgamation of the aforesaid three Units and creation of new Programmes, the ICAR Research Complex for Eastern Region comprised of five research Programmes, viz., Land Water Environment and Engineering Research Programme (LWEERP), Patna; Crop Research Programme (CRP), Pusa; Horticulture and Agro forestry Research Programme (HARP), Ranchi; Livestock and Fishery Improvement and Management Programme (LFIMP), Patna; Socio-Economic and Extension Research Programme (SEERP), Patna. The National Research Center on Makhana was brought under the administrative and financial control of the ICAR Research Complex for Eastern Region as its Research Centre for Makhana in the approved X Plan EFC Memo of ICAR-RCER vide letter No.18-3/2003-IA.II dated 12 December, 2003.

The ICAR-RCER has a broad-based mandate in view of emerging opportunities of research in frontier areas, initiatives for regional cooperation, globalization, and cost competitiveness. National Agriculture Policy-2000 envisaging 4 per cent growth of agriculture sector and the new government policies necessitated research reorientation and preparation of a new Vision-2025 document. The document therefore has been prepared keeping in view above issues and challenges for betterment of agricultural growth and livelihood improvement in the eastern region. The major research focus would be on multi-dimensional, multi-commodity, multi-disciplinary research in a program matrix involving land and water management, crop improvement, horticulture, agro-forestry, livestock and poultry, fishery and agriculture, makhana and other aquatic crops, agro-processing, socio-economics, gender and policy issues in a holistic manner by developing need based Integrated Farming Systems to take advantage of complementarities among them for improving overall resource productivity, resource or input use efficiency and livelihoods in the eastern region. A network and consortium approach is envisaged to achieve mission of the complex through partnership and collaboration with SAUs, ICAR Institutes and NGOs in eastern region. The present document is prepared after several rounds of discussion with the scientists of the Complex, incorporating the opinion and recommendations of the RACs, SRCs and IMCs, and analysis of projected scenarios by 2025. The research activities and proposed Programs are based on the assumption that manpower and facilities as proposed in the document would be available.

2. MANDATE

"To undertake strategic and adaptive research for efficient and integrated management of natural resources to enhance productivity of agricultural production systems comprising of field and horticultural crops, aquatic crops like makhana, agro-forestry, livestock, avian and fisheries in different agro-ecological zones of the eastern region".

The modalities to achieve the mandate are :

- ❖ To facilitate and promote coordination and dissemination of appropriate agricultural technologies through network/consortia approach involving ICAR institutes, state agricultural universities, and other agencies for generating location-specific agricultural production technologies through sustainable use of natural resources.
- ❖ To provide scientific leadership and act as a center for vocational as well as advanced training to promote agricultural production technologies.
- ❖ To act as repository of available information and its dissemination on all aspects of agricultural production systems in the eastern region.
- ❖ To collaborate with relevant national and international agencies in liaison with state and central government departments for technology dissemination.
- ❖ To provide need based consultancy and advisory support in promoting agriculture, horticulture, and livestock in the eastern region.

MISSION

- Transform 'Low Productivity-High Potential' eastern region into High Productivity region for food, nutritional and livelihoods security in a manner that is environmentally sustainable and socially acceptable.
- Tap unutilized potential of vast seasonally waterlogged and perennial water bodies for multiple uses of water and aquatic crops for social upliftment.
- Poverty alleviation, livelihood improvement and women empowerment through income and employment generation through on-farm and off-farm job opportunities.
- Promote network and consortia research in the eastern region.

❖ Socio-economic evaluation and impact assessment of agricultural technologies.

The ICAR-RCER, as nodal agency in the eastern region, will endeavor to achieve the mandate with active involvement of its own manpower, networking and collaboration with SAUs, ICAR institutes, other R & D organizations and NGOs and Private Institutions. The Complex will have its activities tuned towards technology development for product improvement in view of emerging trends in globalization and WTO.

3. GROWTH

3.1 Infrastructure

3.1.1 Headquarters

The Complex headquarters are located in an area of 65 acre near Patna airport.

Laboratory - cum - administrative building of ICAR - RCER

Laboratories

The Complex has developed four well-equipped laboratories on soil, water and plant analysis, micro-irrigation and livestock and fisheries.

Soil and water analysis laboratory : The laboratory is equipped with state-of the-art equipment for micro and macro nutrient analysis like atomic absorption spectrometer, particle size analyzer, automatic nitrogen analyzer, flow injection analyzer, time domain reflectometer, neutron moisture probe, pressure plate apparatus and soil penetrometer besides basic laboratory facilities.

Plant science laboratory : The laboratory has sophisticated equipment like portable photosynthesis measuring system, chlorophyll fluorometer, porometer, pressure chamber apparatus, thermocouple psychromotor, sap flow meter, automatic leaf area meter, crop canopy analyzer, line quantum sensors, tube solarimeters, UV-VIS double beam spectrophotometer, theta probes and portable chlorophyll meters.

Pressurized irrigation laboratory : The laboratory was developed under Team of Excellence Project funded by NATP on "Pressurized Irrigation" and is equipped to undertake the indoor and outdoor testing of various pressurized irrigation system components. It also has a plastic injection moulding machine for in-house fabrication of various components of pressurized irrigation system for research and development work.

Livestock and fisheries laboratory : The laboratory is equipped with modern equipments like Automatic Milk Analyzer, Kjeltech, Trinocular Research Microscope with digital photographic system, Trinocular Stereo Zoom Microscope, Water Analyzing Kit beside basic laboratory facilities for conducting research in animal and fishery sciences. A small eco-hatchery has been installed as a facility for breeding of fishes.

Other facilities : The Complex has installed automatic weather stations at Patna for recording meteorological observation. It has developed an excellent workshop with basic facilities for fabricating farm implements and items required for day to day research activities. All the scientists and technical personnel are provided with computers connected through a Local Area Network. Internet access is provided to all the scientists through Ernet. The Complex has developed GIS facilities by procuring latest versions of software packages like Geomatica, TNTmips, ENVI, ArcView, ArcGIS etc.

Library : The Complex library is stocked with a total of 10,256 books covering different areas of agriculture and allied subjects. The library subscribes to 44 Indian and 23 foreign journals and periodicals and has procured electronic scientific reference databases like CAB abstracts, Agricola etc. for easy information retrieval.

Research farm : The Complex has two research farms one of 4.0 ha at WALMI Complex and another of 17.0 ha at Sabajpura (about 2 km from WALMI Complex) besides main farm at the Complex site. The research farms have basic facilities for supporting field experimentation and demonstrations. A cattle shed, poultry shed, and four fish ponds are developed for supporting livestock and fisheries research. The facilities are being strengthened.

Guest house : The Complex has two VIP suits (air-conditioned) in Kisan Bhawan and 16 rooms (2 AC) in Chhatravas (Hostel) in WALMI Complex, Patna.

Residential quarters : At present the staff of ICAR-RCER at Patna is accommodated in 37 residential quarters available in the WALMI Campus. Thirteen residential quarters have been constructed at main campus of the Complex and are fully occupied.

3.1.2 Research centres

Horticulture and Agroforestry Research Programme (HARP), Ranchi : The HARP, Ranchi is located at Plandu, 17 km away from Ranchi on Ranchi-Tata Road (NH-33). The center is housed in a spacious building. The laboratories are well equipped with Atomic absorption spectrophotometer, UV-VIS Double Beam spectrophotometer, Plant canopy analyzer, Soil moisture meter, Neutron probe, Flame photometer, PCR machine, electrophoresis apparatus, phase-contrast stereo zoom microscope, wood microtome apparatus etc. to support soil and plant analysis, plant pathology, mushroom research and micro propagation, and seed testing. The center has 16 greenhouses for large-scale multiplication of different horticultural crops. The other infrastructural facilities available include cool chamber for research on storage of horticultural crops, seed storage facility, automatic weather station etc. The research farms of HARP are located at four places namely Plandu (70.4 ha), Churu (99.2 ha), Garake (7.5 ha) and Lalkhatanga (41.7 ha) and have excellent facilities for field experiments on horticultural crops. The facilities are being strengthened.

Horticulture and Agro-forestry Research Programme Building, Plandu, Ranchi

Crop Research Centre (CRP), Pusa : The CRP Pusa is located at Pusa (Distt. Samastipur, Bihar) in the RAU, Pusa campus. The CRP, Pusa has a research farm of 16 ha in RAU campus. The centre has facilities for field experimentation and seed production. Basic laboratory facilities exist and are being strengthened. The Centre is being merged with IARI Regional Station, Pusa

Crop Research Programme Building, Pusa, Samastipur

Research Centre for Makhana, Darbhanga : Research Center for Makhana, is housed in top floor of the leased building of European guest house belonging to Mithila University. Basic facilities including small laboratory, furniture and equipments are created. The Centre has 25 acres farm at Basudevpur which is being developed.

3.2 Budget

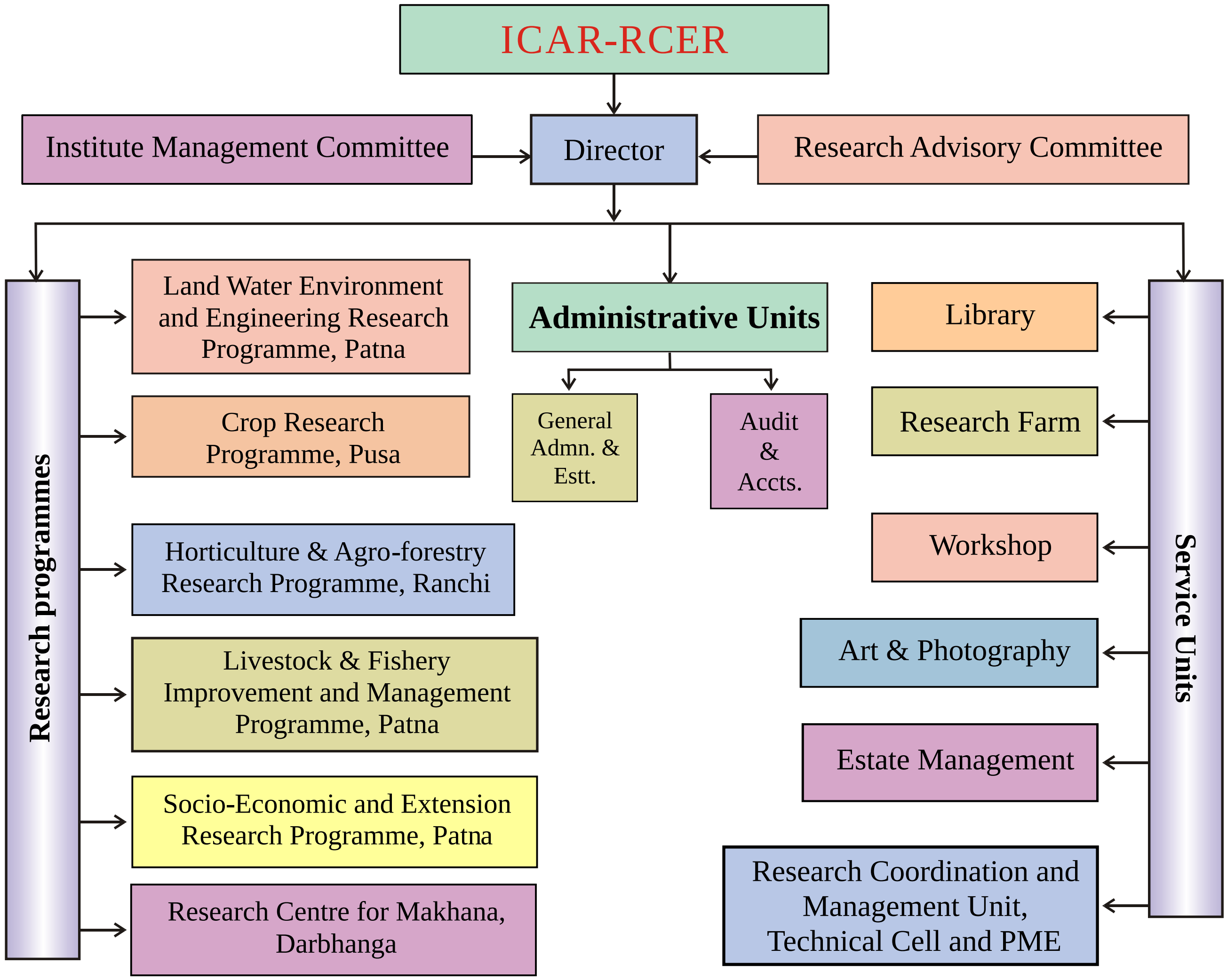
The Complex has an approved overall outlay of Rs.1981.57 (1695.33 lacs for ICAR-RCER and Rs.286.24 lacs for Centre for Makhana) lacs as per revised EFC for the X Plan period (2002-07).

3.3 Manpower

The sanctioned manpower for the Complex including Research Centre for Makhana is as follows:

Sl. No	Category	ICAR-RCER, Patna	Research Centre for Makhana, Darbhanga	Total
		Sanctioned		
1.	Scientific	79	14	93
2.	Technical	63	14	102
3.	Administrative	42	7	49
4.	Supporting	77	10	97
	Total	**261**	**45**	**341**

3.3 The Complex Organogram



Organogram of ICAR Research Complex for Eastern Region, Patna

4. RESEARCH ACHIEVEMENTS

The ICAR Research Complex for Eastern Region is a newly established institute. Ever since its establishment, despite constraints on facilities and manpower, it has made significant achievements in natural resource management, crop improvement, horticultural and agro-forestry and socio-economic and extension research. A modest beginning has been made in research on livestock and fisheries improvement and makhana. Some of the salient research achievements are presented in this section.

Development of database on natural resources

- A database containing surface water, ground water; crop area and crop production; meteorological information containing rainfall, temperature, humidity, sunshine, wind speed; soil information containing soil type, texture, chemical and physical properties;

socio-economic information containing population, literacy rate, land holdings etc, was created using MS-Access. The database tables are created to store different data basin-wise, district-wise and block- wise.

- Under Integrated National Agricultural Research Information System (INARIS), E-R diagrams for six databases namely ground water database, surface water database, water pricing database, water quality database, project database and technology database are prepared.
- Resource appraisal at regional level was carried out using secondary data of socio-economic and biophysical resources in a Geographical Information System (GIS) environment. Thematic maps of socio-economic and biophysical resources in respect of eastern region have been developed.
- Under the climate change project increasing trend in rainfall was observed during monsoon in majority of the stations with significant (at 5 per cent level of significance) increase only at Gomlai in Brahmani basin in Orissa. Increasing trend in mean monthly temperature was observed throughout the Brahmani basin.

Management of rain, surface and ground waters

- Under the study on development of operational plans/ strategies for efficient water allocation and distribution from Patna canal in Bihar, it was observed that there was a large gap between water release and irrigation requirement. In order to minimize the gap between water supply and irrigation requirement, OPTALL model based on quadratic programming technique was employed. It was found that the optimal water allocation schedule is much better than actual release and supply : demand ratio is never more than 1.0, whereas in case of actual release, in many distributaries, it is much higher than 1.0 indicating inequitable water distribution.
- In order to promote multiple uses of water to improve the productivity of canal/ground water by routing it through a fish pond-cum-secondary reservoir and weekly exchange of water, the studies indicate that fish harvest upto 10 t/ha as additional income can be obtained.
- Out of the three interventions on multiple uses of seasonally waterlogged areas in the canal commands, canal seepage fed secondary reservoir supplemented by tube well yielded Rs. 1,32,000/ha income from horticulture on bunds (banana, guava, lemon and vegetables), fishery, and duckery besides irrigation for cereal production. Fish trenches-cum-raised bed intervention yielded a benefit of around Rs. 85,000/ha from horticulture and fish production. Under the rice-fish system, rice production improved due to stocking of fish. By stocking poly-cultured fish @ 30,000 yearlings/ha , rice yield increased by 4-13 per cent and income increased by 32 per cent as compared to sole rice cultivation.
- The Complex has developed and demonstrated a participatory approach for water and land management with wider stakeholders participation under DFID project. Participatory process was developed and demonstrated for efficient management of land and water

resources through constant dialogues, communication products and wider constituency of stakeholders.

- A simple water balance spreadsheet model was developed and linked with GIS. The tool helps in analyzing water availability and demand and suggests various water management options. The tool was demonstrated and discussed with water users, canal managers and other stakeholders to get their feedback for further implementation.
- A tool for analyzing the tubewell and canal irrigation was developed in Visual Basic in Hindi and English and was demonstrated in the study area. This tool explores option for economic use of canal and groundwater conjunctively in a distributary command. It facilitated community members in understanding the concept of conjunctive use and its implications in enhancing crop water productivity.
- Farmers of RPC-V adopted low cost interventions like maximum utilization of rainwater by raising bund height, canal management by installing low cost wooden gates, adoption of improved irrigation practices in rice and wheat, conjunctive use of water, multiple use of water logged areas by including rice-fish and fish production.
- Studies on water productivity assessment in the outlet commands of RP Channel-V distributary of Patna Main Canal and two tubewell commands in Vaishali district indicate that crop water productivity (Rs/m^3) considering applied water varied from 4.79 to 8.39 and considering water used it ranged between 2.57 to 3.33 in the outlet commands. In tubewell commands, crop water productivity ranged between 14.03 to 29.61. Similarly total water productivity (Rs/m^3) including crops, livestock, fish and trees, considering applied water varied in the range of 5.28 to 10.66, while for total water used it ranged between 2.83 to 4.23 in the outlet commands. In tubewell commands, total water productivity ranged from 18.09 to 38.73 for applied water and 3.09 to 3.68 for total water used.

Design and evaluation of gravity and pressurized irrigation systems

- A Low Energy Water Application (LEWA) device operating at 0.4 kg/cm^2 pressure and fittable on existing sprinklers has been developed for irrigating rice, wheat and other close growing crops. The system resulted in reducing overall energy requirements and enhancing high water and nutrient-use efficiency as compared to other pressurized irrigation systems.
- In order to cut down on cost and energy requirement by using low pressure rating pipes and other system sub components, a low cost LEWA (Low Energy Water Application) irrigation system has been developed and compared with the sprinkler. The system is estimated to cost 2.5 times less than the cost of sprinklers (impact) system for the same area.
- Application of micro irrigation to vegetables revealed that drip irrigation scheduled at 80 per cent ET once in three days gave maximum marketable yield (85.7 t/ha) of tomato. For cabbage, drip irrigation scheduling at 60 per cent ET once in two days gave maximum yield of 61.7 t/ha.

Development of suitable agro-techniques for agricultural crops

- Boro rice seed sown in November in open field with use of FYM @ 15t/ha avoided injury due to severe cold and saved 15 per cent additional seedlings for transplanting. By use of polyhouse, raising of boro rice seedling was possible even in January when seed did not germinate in open field due to cold.
- Studies to evaluate the impact of late sown wheat indicated that grain yield was significantly higher for 6th December sowing (5.31 t/ha) followed by 16th December sowing. Among the dates of first irrigation, grain under 20 and 26 Days After Sowing (DAS) was significantly superior over 38 DAS.
- Studies on soil moisture dynamics and nutrient uptake in rice based cropping system under optimum and suboptimum supply of water and nutrient indicate that cereal dominated rice based cropping sequence was more remunerative than pulse dominated with respect to production potential of crops. Whereas pulse dominated rice based cropping system was beneficial for improving soil health, fertility status and physical properties, pulse-dominated rice based cropping system was found to be more profitable.
- Among the cropping systems evaluated, maximum yield equivalent was recorded in rice-wheat-green gram (12.02 t/ha) followed by rice-lentil-green gram (11.21 t/ha) based on three-crop cycles. Among levels of irrigation and nitrogen, maximum rice yield equivalent was recorded at optimum (recommended nitrogen level) level (12.11 t/ha & 12.35 t/ha) followed by sub optimum (half the recomonded nitrogen level only) level (11.12 q/ha & 10.88 t/ha). Highest net returns were obtained in rice-lentil-green gram followed by rice-wheat-green gram at optimum and sub-optimum level of irrigation. Pulse based cropping system used water more efficiently (78.90 & 75.62 kg/ha/cm) than the cereal based cropping system (74.51 & 71.42 kg/ha/cm) at both the level of irrigation. Uptake of NPK in cereal dominated cropping system was more than the pulse dominated cropping system. Uptake of nutrients at optimum level of irrigation and nitrogen was higher than sub-optimum level.
- A comparative study of different tillage technologies revealed that adoption of zero tillage could save a total of Rs. 1850/ha (Rs.1400 under land preparation for sowing and Rs.450 in irrigation). Under raised bed system, an additional amount of Rs. 600/ha was incurred for land preparation and sowing but there was a saving of Rs. 2622/ha from irrigation water application.
- Research work conducted to evaluate different drought tolerant and water use efficient traits in wheat indicated that Drought Stress Index (DSI), Dry Matter Stress Index (DMSI) and Yield Stability Ratio (YSR) calculated from the post harvest data could be used to identify drought tolerant and susceptible wheat genotypes. Whereas genotypes RW 899, RW 890 are identified as most susceptible to drought, C-303, K-8047 and RW 927 are identified as drought tolerant.

- Studies to demonstrate the beneficial effects of Deep Summer Ploughing (DSP) revealed that DSP had significant effect on grain yield and yield attributes over non-DSP. DSP effectively reduced the weed population. Effect of normal supply of water was pronounced in DSP over non-DSP. Similar trend was recorded on nematode population.
- Studies on tillage management under rice-wheat system in South Bihar indicate that Deep Summer Ploughed (DSP) field retained more moisture and offered less penetration resistance providing conducive environment for root development in wheat. Zero tillage also showed better root growth under DSP plots. DSP on alternate years resulted in significantly higher grain yield of wheat (4.14 t/ha) over non-DSP (3.93 t/ha) fields. Similarly in rice, though the initial root proliferation was observed in DSP every year, highest root growth was observed in DSP in alternate years with maximum grain yield of 4.69 t/ha.
- Long term manurial trials on chewing tobacco under irrigated conditions indicate that two irrigations at 30^{th} and 60^{th} day after transplanting of chewing tobacco significantly increased leaf yields and quality parameters. With increase in the levels of nitrogen from 0 to 112 kg N/ha, significantly superior yield, puckering, spangling and maturity scores were recorded.
- Studies on nutrient management in chewing tobacco intercropping system indicate that intercrop rajmah followed by garlic planted in two rows in alternate tobacco rows, recorded significantly higher total cured leaf yield over potato as intercrop. Fertility levels significantly influenced the yield and physical quality parameters of tobacco leaf.
- Among diversified cropping systems developed at Sabajpura Farm, Patna, maximum yield equivalence was recorded in rice-tomato-bottle guard (50.30 t/ha) followed by rice-potato-onion (26.72 t/ha), rice-mustard-tomato (26.58 t/ha) and rice-coriander-ladies finger (26.42 t/ha), respectively. Farmers' crop diversification patterns revealed that majority of farmers were high crop diversifiers. The survey of farmers for crop diversification reinforced the view that smaller the farm size; higher is the level of crop diversification.
- Crop diversification by introduction of QPM + potato on raised beds and maize + vegetables on level land gave 3.2 t/ha and 23.9 t/ha QPM and potato yields, respectively. The summer green gram (HYV Vishal) yielded 0.85 t/ha in comparison to farmers' practice (0.4 t/ha).
- The benefit : cost ratio was found to be highest (3.36) under winter maize intercropped with aromatic and medicinal plants (maize + ashwagandha and maize + lemongrass) in winter maize based cropping system at Pusa, Samastipur.
- Evaluation of geo-textile material for mulching in pointed gourd indicated improved root growth with increase in thickness of the geotextile mulch. The highest growth was observed in 300-gsm mulch treated plots followed by 250 gsm plots. Root growth in straw mulched plots was found to be at par with 250 gsm geo-textile mulched plots.

- Fertigation studies in vegetable crops indicated that under 100 per cent recommended dose, liquid fertilizer (LF) showed highest root growth over the solid soluble fertilizer (SSF) and commercial fertilizer (CF). Root surface area of tomato was highest in liquid fertilizer application and root length was 251 and 126 per cent higher over commercial and solid soluble fertilizers, respectively. In cauliflower, under 100 percent dose, root surface area was highest in liquid fertilizer applications which were 129 and 59 per cent higher and root length was 125 and 31 per cent more over commercial and solid soluble fertilizer, respectively.

Genetic resource management of horticultural crops

- A total of 2958 germplasm lines including fruits (771), vegetables (1836) and ornamental plants (351) have been collected and are being characterized, evaluated and used in breeding programme to develop high yielding varieties resistant to biotic and abiotic stresses.
- Thirty one different varieties of horticultural crops including viz., Swarna Roopa in litchi; Swarna Manohar and Swarna Poorti in Jackfruit; Swarna Alaukik and Swarna Rekha in pointed gourd; Swarna Shree, Swarna Mani, Swarna Shyamli, Swarna Pratibha, Swarna Shobha, Swarna Ajay(F_1 hybrid) and Swarna Shakti (F_1 hybrid) in brinjal; Swarna Lalima, Swarna Naveen, Swarna Baibhav (F_1 hybrid), Swarna Sampada (F_1 hybrid) and Swarna Samridhi (F_1 hybrid) in tomato; Swarna Poorna, Swarna Swetha, Swarna Sheetal and Swarna Agethi in cucumber, Swarna Manjari and Swarna Uphar in ridge gourd, Swarna Lata and Swarna Priya in French bean; Swarna Amar and Swarna Mukti in garden peas; Swarna Sweta, Swarna Suphala and Swarna Harita in cowpea, Swarna Utkrist in Dolichos bean have been developed. These varieties are gaining popularity for their special attributes including high yield, better quality, disease and pest resistance etc.
- Stable, high yielding and promising varieties for different maturity periods, flavor, quality and usages for different purposes have been identified for mango, litchi, guava, banana, pineapple, citrus, aonla, passion fruit, jackfruit, custard apple, papaya, sapota, strawberry and bael. The station has also evolved 18 elite lines of vegetable crops which are at an advanced stages of evaluation under the All India Coordinated Vegetable Improvement Project.
- For round the year cultivation under eastern plateau and hill conditions, brinjal cultivars Swarna Shyamli and Swarna Pratibha and tomato hybrids Swrana Sampada and HATH-5 have been found suitable. In pea, the powdery mildew resistant line CHPMR-2 was found promising for prolonging the availability period in the market till May by growing it at higher altitude in Jharkhand (Netarhat hill).

Development of production technology of horticultural crops

- Among fruit crops, mango (Cv. Amrapali) planting at a spacing of 2.5x2.5m accommodating 1600 plants per ha as compared to 100 plants per ha in case of traditional method of planting resulted in nearly 2.5 times higher fruit yield than the traditional method of planting up to 12 years age. In litchi (cultivars Shahi and China), double hedge row planting at a spacing of 4.5 x 4.5x 9 m, accommodating 329 plants/ha as compared to 123 plants in traditional method resulted in nearly three times higher yield than that in case of traditional method of planting. In guava (cultivar Allahabad Safeda), double hedge row planting at a spacing of 2.5x2.5x5.0 m accommodating 1060 plants per ha as compared to 400 plants per ha in case of traditional method of planting resulted in nearly two times higher yield than that in case of traditional method of planting. High density planting of banana (cv. Dwarf Cavendish) at a spacing of 1.4 x 1.4 m accommodating 5,100 plants/ha has resulted in higher economic yields.

- Fruit crop based cropping system model consisting of aonla, litchi and mango as main crop; guava/Kagzi lime/Assam Lemon as filler crop and cowpea or French bean as intercrop has been found to provide sustainable higher returns per unit area from the uplands and medium uplands. Intercropping of French bean, cow pea and groundnut have been found to be the most profitable combinations under mango, litchi and aonla based multitier cropping systems with guava as filler crop under Chotanagpur plateau conditions up to initial 10 years of orchard establishment. Under grown up mango orchards, intercropping of shade tolerant crops like turmeric was found to be most profitable.
- Application of 100 g N, 600 g P_2O_5 and 800 g K_2O in guava (cv. Allahabad Safeda) resulted in highest fruit yield per plant whereas soil application of Phosphobacterin was found to be most effective in improving the fruit quality of guava (cv. Lucknow-49). Application of 500 g N, 500 g P_2O_5 and 300 g K_2O in litchi (cv. China) was recommended for junior adult bearing orchards.
- Exposing litchi roots in a trench of 150 cm diameter around the trunk to a depth of 30 cm after harvesting for 7 days and filling up the trench with recommended dose of manures and fertilizers after the onset of monsoon resulted in increase in yield of litchi (cv. Shahi).
- Full-moon terracing and mulching with paddy straw was found to improve fruit size, reduce fruit cracking and increase yield of litchi (cv. Shahi).
- In guava (cultivars Allahabad Safeda and Lucknow-49), manual removal of 50 per cent of rainy season crop was found most effective for increasing the yield of winter crop and total profitability both under rainfed as well as irrigated conditions of eastern plateau and hill conditions.
- Rejuvenation pruning during December and application of fertilizer at a rate of 800:300:1000 g NPK + 50 kg FYM per plant was found effective for improving the productivity of old, senile and unproductive mango orchards in three years.
- In vegetable crops, intercropping of cowpea with okra gave 31 to 53 per cent increased okra equivalent yield. Similarly, planting of 4 rows of onion 15 cm apart between 2 rows of tomato (30 x 100 cm) gave 36 per cent higher tomato-equivalent yield and higher return without

affecting the quality of tomato. In cabbage, intercropping with coriander or fenugreek enhanced the yield (16 per cent) and also restored the soil fertility. The maximum net returns were recorded from cabbage-fenugreek followed by cabbage-coriander intercropping.

- In cabbage (cv. Pride of India) application of N P K : 180:60:50 with a plant spacing 45 x 30 cm recorded 28 per cent higher yield. Under soil amelioration studies for vegetable crops, application of lime at the rate of 3.4 t/ha and molybdenum 1.5 kg/ha or ammonium molybdate as foliar spray 0.2% four times at 12 days interval increased curd weight and curd diameter of cauliflower (cv. Pusa Snowball-1). Application of lime increased the yield by 12 per cent, and improved the soil pH, available molybdenum in soil and also increased molybdenum, calcium and magnesium in leaf tissue. Soil application of 1.5 kg B/ha during rainy season was found sufficient for three successive crops of cauliflower in overcoming brown rot and to boost yield. However, when Boron was applied to the winter crop, its residual effect was extended to next rainy season only.
- Regeneration of pointed gourd explants in media containing BA 1.0 ppm + IAA 0.2 ppm and sub-culturing them in media containing IAA 0.2 ppm +IBA 1.5 ppm were found optimum for *in vitro* multiplication of pointed gourd.

Integrated pest management of horticultural crops

- In fruit crops, shoot gall psylla, a serious pest of mango could be effectively managed with three sprays of quinalphos (0.05%) starting from 1st week of August followed by 3 applications of 2, 4-D (80 ppm) at 10 days interval beginning gall appearance stage. Guava wilt was verified to be caused by *Fusarium oxysporum* f. sp. p*sidii* and association of spiral nematode *Heliotylencus* dihystera aggravated the disease. Use of biopesticides gave encouraging results. Application of *A.niger* (Kalisena) was found to reduce the incidence of guava wilt and improve the plant vigour
- In vegetable crops, powdery mildew in pea caused by *Erysiphe pisi* could be managed by preponement of sowing date in September and October. The disease could be controlled by spraying calexin (0.05%). Powdery mildew of cucumber caused by *Erysiphe chichoracearum* could be controlled by spraying karathane 0.1%. Powdery mildew of bottle gourd caused by *Sphaerotheca fuligena* could be controlled by spraying Topsin M-70 (0.1%). Bacterial wilt of tomato caused by *Ralstonia solanacearum* could be managed by soil application of Karanj (*Pongamia*) cake @ 0.10 and 0.15 kg/m^2 or bleaching powder @ 30 kg/ha or lime @ 2500 kg/ha applied 15 days before transplanting. Seed treatment of tomato with *Azotobacter chroococcum* + soil application was most effective against incidence of damping off. Treatment of tomato seeds with *Trichoderma viride* + Captan showed minimum root and shoot length indicating the incompatibility with them.

Basic studies in agricultural and horticultural crop production

- To simulate soil-water flow in SWAP model, Richards' equation was solved using an implicit backward finite difference scheme with explicit linearization. It was observed that with increase in bund height runoff decreases. By shifting rice crop growth period by one month, rainfall utilization decreases to the tune of 36 per cent. By reducing the irrigation depth from 7.5 cm to 5 cm in rice, deep percolation reduces, transpiration increases and total irrigation requirement reduces.
- van Genuchten parameters were determined using particle size data from 81 soil series of West Bengal through a pedotransfer model. Saturated hydraulic conductivity, field capacity, wilting point and available water capacity (AWC) were estimated for all the soil series of eastern Himalayas, Indo-Gangetic alluvial plains, Bengal basin , coastal plain and eastern plateau of West Bengal.
- Under evaluation of drought tolerant and water-use efficient trials in field crops, 13 wheat varieties were tested under irrigation and non-irrigated control. Grain yield and yield attributes were significantly reduced by water stress in the genotypes. The per cent reduction in mean total dry matter (TDM) for all genotypes was 40.6 percent, whereas grain yield was reduced by 36.1 per cent over control.
- The Particle Size Distribution (PSD) models predicted the unsaturated hydraulic conductivity of clay, clay loam and loamy textured soils within the studied range of water contents quite reasonably. The predictability of the model can be improved by identifying some physical variables and their interactions that influence the unsaturated flow process considerably.
- In litchi (cv. Shahi) the time of emergence and girth of second flush, content of carbohydrate and tryptophane in the second flush during October was found as promising criteria for prediction of intensity of panicle emergence under Chotanagpur plateau conditions.

Makhana crop improvement, production, post harvest management & processing

- Initial exploration of makhana germplasm was undertaken during the crop season in Madhubani and Darbhanga districts with active support from National Bureau of Plant Genetics Resources, New Delhi. Forty-six accessions have been collected and deposited in the gene bank.
- A Scientist - Entrepreneur interface has been developed in association with Bihar Industries Association, which resulted in establishment of first fully automatic Makhana Processing Plant at Patna with capacity of 50,000 packets per day of 20 gm each.
- Makhana centre has initiated steps for expansion of makhana area through energizing of ideal ponds, yield maximization, saving output loss, reform in pond lease markets, empowerment of makhana growers, institutional and promotional support, infrastructural development, trade reforms and development, value addition, rapid connectivity, export enhancement, risk hedging and contract farming.

- For value addition and processing of makhana, two automatic industrial units one in public sector (COMFED, Bihar Patna**)** and one in private sector (Shakti Sudha industry, Patna) has been set up with technical support from the centre and the production has already started. A variety of ready- to-eat products of makhana are available for the first time at the shelves in important markets, resulting in increased demand of the raw product.
- Constraints of makhana cultivation and thrust areas for extensive promotion of makhana towards livelihood improvement of farmers through integrated farming system have been studied and field experimentation initiated at farmers' field.
- The study on understanding makhana production system was initiated and stakeholders were identified. Survey schedule were prepared and pre tested to study the socio economic and marketing aspect of makhana production system in four districts of North Bihar namely, Darbhanga, Madhubani, Purnia and Katihar.

Livestock and fisheries improvement and management

- Survey on animal husbandry practices in Bihar revealed that buffalo is preferred over crossbred cattle by farmers due to higher content of fat in milk. Buffalo comprises of 30 per cent of the total livestock population while crossbred cows accounted for 18 per cent.
- Animal husbandry is a remunerative practice in rural areas of Bihar generating 15-35 per cent of the farmers' total income. Goat, pig and backyard poultry are mostly owned by socio-economically poor farmers.
- No definite breeding policy is followed. However, artificial insemination is normally practiced with Holstein Frisian and Jersey semen.
- Progressive farmers use concentrate feed for crossbred cattle and buffalo. Out of the total land only 8.25 per cent is spared for fodder production. Fodders like *Sorghum* and *Berseem* are cultivated for feeding of animals. There is scarcity of fodder for about 122 days during May-June and October to December. Feeding of Berseem increased 30.25 ± 3.4, 22.0 ± 2.68 and 24.58 ± 2.16 per cent while feeding of Sudan increased 13.27 ± 1.90, 11.66 ± 0.68 and 13.06 ± 1.65 per cent of milk yield in crossbred cow, indigenous cow and buffalo, respectively.
- Incidence of infectious diseases like Foot-and-Mouth Disease, Haemorrhagic Septicaemia and Black Quarter are common in the area, but due to timely vaccination, incidence of these diseases were reduced. Tail gangrene and surra are also prevalent in the region. Anoestrus and repeat breeding are some of the problems associated with reproduction.
- The fresh water resources in the villages are meagre and untapped. Most of the farmers are unaware of scientific techniques of aquaculture. They stock fish fries at the high rate of 14-30, 000 per hectare while productivity is observed to range between 0.9 and 1.2 t/ ha. Even the fish yield from developed ponds is at low level of about 2.175 t / ha / yr. The fishery of the river is dominated by catfishes namely *Channas sp, Mystus aor, M. seenghala and Heteropneustes fossilis* etc.

- Fishponds in the villages were found infested with aquatic weeds like *Hydrila sp, Eichhornia sp, Azolla sp* and *Potamogeton sp.* Banana leaves and berseem are used for feeding of grass carp while Indian major carps are being fed with mustard oil cake, rice bran and wheat bran @ 1-2 per cent of body weight.
- Majority of the farmers reported medium knowledge level on aquaculture. As high as 70 per cent farmers adopted liming of ponds and 60 per cent adopted supplementary feeding (rice bran and mustard cake). Non-availability of quality seed and credit to farmers were major constraints for fish production.

Technology transfer, assessment and refinement

- Advancing the date of rice transplanting by 15 days, has increased the plant population by 25 to 40 per cent. This has enhanced utilization of rainwater from 40-50 percent to 80-100 percent and doubled the production. Partial adoption of the improved rice production technology package has spread over 10,294 ha in 102 villages. The farmers are now harvesting 4.5 t/ha rice and 4.0 t/ha wheat instead of 1.30 t/ha rice and 1.99 t/ha wheat, respectively in these villages.
- Two “Farmers' Information and Service Centres” in Vikram block with one sub-center at village Sangrampur and another at Bedauli village in RP Channel -5 distributary were established to supply quality inputs and to create scientific awareness among farmers.
- Large scale FLDs on released varieties of tomato, brinjal, cucumber, pointed gourd, ridge gourd, peas and beans etc. were conducted to demonstrate the advantages of new varieties. Similarly FLDs on 3-tier system production involving mango/litchi/aonla as main crop, guava/custard apple/lemon etc. as filler crop and vegetable / cereals / pulses / oilseeds / tuber crops as intercrop were demonstrated at 60 farmers' fields.
- Minikit trials of pre released vareiteis in different vegetable crops have been conducted at farmers' fields to help growers know the performance of pre released varieties.
- *Kisan diwas* / field days have been organized from time to time to educate the farmers. Every year field days on litchi, aonla, vegetables etc. are organized.
- Training programmes on different horticultural crops have been organized for increasing production and productivity. Altogether 60 training programme of 1 to 10 days and two programme of 72 days duration have been conducted in which more than 3500 farmers/officers have been trained.
- Seeds and planting materials have been supplied to Zonal Research Stations of BAU at Dumka, Chianki and Darisahi; KVKs at Hazaribagh, Ranchi, Sahebganj, Chianki in Jharkhand and Jamuai and Madhubani in Bihar. Seeds have been supplied to Deptt. of Agriculture, Govt. of Jharkhand and to various NGOs and farmers for distribution/cultivation in almost all the districts of Jharkhand.

- An average increase of 16 per cent, 51 per cent and 43 per cent in yield of rice, potato and maize respectively in rice-potato-maize cropping system was achieved where balance dose of fertilizer was applied under IVLP at Patna.
- Rearing of Divyan breed of poultry was observed to be more economical than indigenous breed in respect of age at first egg laying and total egg production in a study at Patna.
- For the improvement of livelihood through additional income generation, Khaki Campbell breed of ducks were distributed among 41 landless farmers and unemployed youth from 8 villages. On an average, a farmer earned Rs. 480 from single bird by the sale of eggs. Moreover, 5 farmers raised ducklings from the eggs with the help of indigenous poultry and generated an additional income of Rs. 700 per family per year.
- Low productivity of dairy animals, delayed maturity, anoestrous, unexplained infertility, high cost of animal feeds and scarcity of green fodder especially during October to December were some of the constraints faced by the farmers. Lack of scientific knowledge about aquaculture, unavailability of quality fish seed and infestation of ponds by weeds were some of the major constraints in traditional fish production, based on survey conducted in selected villages of Patna.
- Under resource conservation, the Zero Tillage technology has been popularized in 22 districts of Bihar, covering more than 6000 ha area. This reduced the cost of cultivation by about Rs. 2000 per ha**.** Majority of farmers (80 per cent) reported that there was increase in wheat yield under ZT in comparison to conventional sown wheat. Twenty two per cent farmers reported 2 to 4 q/ha increase in yield through ZT.
- The improved varieties of different vegetable crops developed at HARP have been demonstrated in fields of 1000 farmers. Under economic assessment of horticultural technologies at farmers fields, the varieties developed at HARP, Ranchi demonstrated under the Front Line Demonstration proved their consistency by promising net returns with benefit : cost ratio ranging from 2.11 to 4.79 irrespective of category of farmers.
- Rice-fish system was popularized in low land area. By adopting this technology farmers harvested 2 to 3 tonnes fishes and 3 tonnes of rice in one-hectare area.
- Field exposure of farmers to technologies on enhancement of water productivity through multiple use of water indicated that, one-third farmers were encouraged to adopt fish related technologies. Thirty seven per cent farmers preferred fish-cum-horticulture in waterlogged area. Nineteen per cent respondents equally liked fish pond- cum- secondary reservoir and rice- cum- fish cultivation. Only 15 per cent farmers were reluctant to adopt any fish production technology.
- Twelve technologies viz. multiple use of water, multitier horti based cropping systems, fish production in low land area programme, polyhouse for raising early vegetable nursery in winter season and early summer crop, mushroom production by landless families, zero tillage in wheat, rice-fish system, backyard poultry for livelihood improvement of resource

poor farmers, small scale duck farming for livelihood improvement of landless families and unemployed rural youth, animal health care support to farmers, bund height and LEWA (Low Energy Water Application) device in farmers' fields were accelerated. It was reported by the farmers that the Low Energy Water Application (LEWA) device reduced the total irrigation time and the expenditure incurred on energy cost. Overall, a saving of 30-50 per cent of water and energy was obtained.

- Raising bund height from 5-7 cm to 20-30 cm in 50 plots of 9 ha, prolonged soil moisture availability causing reduction of two irrigation with less disease incidence and weed.
- The technology of raising early vegetable seedlings for winter and summer vegetables was adopted by large number of farmers and farm women. This increased their income by 2-3 times.
- More than 100 women in Self Help Groups (SHGs) have started mushroom production in south Bihar and are earning a minimum of Rs. 50/Kg Mushrooms by spending only Rs. 8 /kg.

5. IMPACT

ICAR Research Complex for Eastern Region, Patna is a newly established institute by merger of erstwhile DWMR, Patna; CHES, Ranchi; CTRI Regional Station, Pusa and NRC for Makhana, Darbhanga. The on-going programs for these centers were carried forward and are being reoriented to meet the mandate of the Complex. The institute, over a period of short time has made some visible impact through generation and dissemination of various technologies.

Rice-Wheat production technology

The Complex with the support of Center for Environment and Agricultural Development (CEAD), New Delhi has demonstrated integrated agricultural technology in participatory mode in 178 villages in the commands of 8 distributaties of Sone Canal System in Patna district to enhance crop productivity. A system approach consisting of techniques such as advancing the date of transplanting of rice, improved package of practices for rice and wheat production, balanced use of fertilizers, improved water management practices and plant protection made significant impact which is evident from the increased yield of rice and wheat in these areas to an average of 4.5 t/ha for rice and 4.0 t/ha for wheat as against 1.9 t/ha for rice and 2.0 t/ha for wheat respectively. There has been an encouraging trend of adoption of this system technology and its effect could also be seen in other adjoining districts of south Bihar. With the advancement of date of seedling raising in the nursery and advancing transplanting by 15-20 days, there has been increased utilization of rainwater (from prior level of 40-50 to over 80-90 per cent). This has also encouraged the conjunctive use of rain, canal and ground water, which has been amply demonstrated in RP channel-V area of Sone Command under DFID project with least incentivisation. Based on the benefits of this approach, the farmers and scientists of the Complex were able to convince Irrigation Department, Government of Bihar for timely release of water to coincide with early paddy nursery raising and transplanting. This system approach also resulted in timely sowing of wheat in the study area (starting from 2nd week of November) against earlier practice of sowing wheat in the first week of December to the first week of January. Study on participatory impact assessment of agricultural technologies revealed that 92 per cent farmers have adopted the technology of Optimization of Rice Transplanting (ORT) which resulted in reduction of seed requirement of nursery by more than 50 per cent.

Participatory land and water management for improving livelihood

The Complex has been striving to make its presence felt in the area through various land and water management interventions. Through the DFID-NRSP project, the institute has been able to make a convincing impact on land and water management through involvement of wider constituency of stakeholders (WUAs, SHGs, Outlet Management Group) with least or no incentivisation by implementation of need based and people driven low cost interventions. The Complex has, in the process, developed a participatory approach to achieve this success. Technological interventions and adoption of these interventions viz. conjunctive use of ground water, canal water and rain water management, increased bund height, installation of low cost wooden gates on the outlets, multiple use of water bodies for fish including rice fish culture, micro level GIS mapping and development of decision support tool in a participatory mode have helped in improving the livelihood of the local community farmers, landless farmers, sharecroppers and the poor.

Conservation agriculture

The institute over the past five years has undertaken extensive work on accelerating Resource Conservation Technologies (RCTs) under NATP, USAID and IFAD projects. The technologies fostered were (i) zero till direct seeded rice (ZTDSR), (ii) Co-culture of Sesbania with rice for brown manuring, (iii) use of LCC for real time N use in rice, (iv) zero till wheat through different methods, (v) balanced use of nutrient in surface seeded wheat, (vi) rice based crop diversification, (vii) introduction of extra early pigeon pea for crop intensification, (viii) promotion of alternate livelihood production system of socially/ economically weaker section through SHGs like commercialization of vegetable nursery raising in polyhouse, mushroom production, duckery/backyard poultry and honey production.

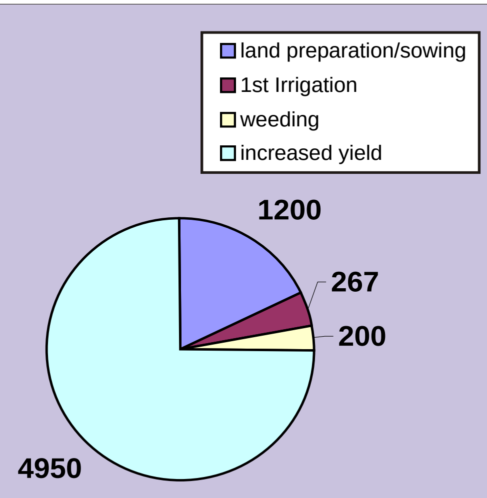


Fig. 3 Monetary benefit of ZT wheat over conventional tillage

Under NATP, ZT wheat had been accelerated in 22 districts of Bihar covering an area of over 6000 ha and more than 7200 farmers. A total saving of the order of Rs. 6,600/- per ha in zero tillage over conventional sowing of wheat in various items is reported (Fig.3). Under USAID/ IFAD projects, pertinent research findings on technology validation and alternate livelihood support system are being evaluated in Patna, Vaishali and Buxar districts of Bihar. There was monetary saving of Rs. 7,500/ha along with 50 per cent water saving and 1.3 t/ha additional yield due to ZTDSR over conventional transplanted rice, which also resulted in better yield of rabi crop due to no puddling. Co-culture of *Sesbania* could save 20-25 kg N/ha in rice and improved soil health by addition of organic matter. Use of LCC by farmers could save 30-50 kg N/ha over traditional fertilizer use in rice. ZT wheat performed better over conventional in many ways like resource saving in tillage (Rs. 2500/ha), seed (60 kg/ha), first irrigation and weed management besides timely seeding and yield gain of about 5-8 q/ha. There was 5 per cent higher yield in paired ZT over normal ZT. Wheat sowing in rice residue was successfully possible through double disc and rotary till disc drill. ZT wheat sown in control traffic with rice residue was found best for yield and restoring soil health. Use of 60 and 40 kg/ha P_2O_5 and K_2O, respectively in surface seeded wheat resulted in additional yield of 11.7q/ha with net profit of Rs. 4,800/ha. After rice, cultivation of QPM maize + potato under raised bed system has resulted in 12 t/ha additional yield of potato and 30 q/ha maize. Extra early pigeon pea (ICPL 88039) could yield about 11.2 q/ha with timely harvesting for sowing of wheat in December, which resulted in 100 per cent increase in crop intensity. Economically weaker section could be organized in Self Help Group mode and were able to earn income through raising of vegetable nursery in polyhouse, mushroom cultivation and backyard poultry/duckery. These activities improved their livelihood. Large-scale sensitization of different stakeholders like fellow farm families, scientists, government officials, extension personals, policy makers and media person was done by their visits to demonstration sites.

Farming system and multiple water use

Under the Technology Assessment and Refinement program through Institute Village Link Program (IVLP), various aspects such as a Farming System integrating crops with livestock, fisheries and horticulture were assessed, refined, and demonstrated in irrigated ecosystem in the four selected villages of the Patna district in Naubatpur and Phulwari Blocks. Introduction of fisheries component, through the secondary reservoirs and on common property resources, i.e., common water bodies paid rich dividends to the farmers. Based on the convincing results, the farmers of the area have undertaken the activity of multiple water use by utilizing otherwise under-utilized waterlogged areas for raising fish and horticultural crops through different Self Help Groups and

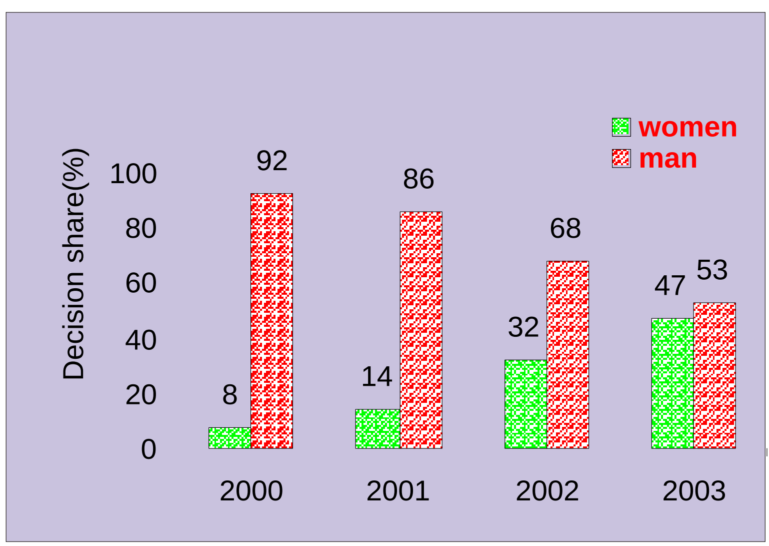


Fig.4 Share of women in decision-making

Social Fisheries Associations. The average profit per family increased by 25 per cent through crops and 30 per cent through fish based activities. The annual income per family increased from Rs. 50,420/- to Rs.75,300/- in 2003. As a result of the interventions in mushroom cultivation, bee keeping etc., through women Self Help Groups, the role of women in decision making has facilitated women empowerment (Fig.4). Drip irrigation system for cultivating banana has shown encouraging impact on water saving and increase in yield (uniformity of quality and size of the fruits), early flowering and subsequent early maturity of fruits to capture early market. As a result of these interventions there is a visible impact on social cohesion and harmonious relations among the people in the IVLP area.

Technology acceleration programme

Well-tested 12 technologies were accelerated in canal-irrigated area of Patna district. In 50 rice fields, bund height was raised up to 30 cm by 12 farmers of 5 villages. Due to raising of bund height, there soil moisture was available for longer time during critical period, resulting in saving of 2 irrigations, less incidence of diseases, reduction of input cost and possibility of extra crop like pigeon pea and Okra. LEWA demonstrated in one village had shown that there was overall saving of 30-50 per cent water and energy saving besides higher yield. The mango and Aonla based cropping systems were demonstrated in five villages. Multiple use of water and fish production in lowland was demonstrated in three villages. One village formed Social Fisheries Association. Raising early season vegetable nursery under polyhouse was adopted by number of farmers/ women and their farm income was increased up to Rs. 6,000 per family. Through mushroom production, the landless families especially women SHGs could earn Rs. 40 per day per head during growing season. From rice + fish system, extra yield of fish by 2 to 3 t/ha was harvested. Due to introduction of improved poultry bird Divyan, there was an average income of Rs. 600 per bird per year. Khaki Campbell breed of ducks reared by 41 landless farmers and unemployed youth of 8 villages generated an additional income of Rs 700 per family per year.

Crops research

The Complex has released a chewing tobacco variety “Lichchavi” in 2001 with a yield potential of 2700 kg/ha with a mean 1730 kg/ha productivity of the crop in north Bihar. The tobacco + garlic/coriander intercropping system developed by the Complex has spread over 40-50 per cent of tobacco cultivated area.

Horticulture and agro-forestry

The growth of horticulture sector in the eastern region during the last four decades has already resulted in a perceptible influence on the overall socio-economic condition of the people. There has been a rapid increase in the area under different fruits and vegetable crops resulting in improvement in the nutritional as well as economic security of the farmers. The presence of the Complex in the region has contributed significantly towards growth of horticulture sector in the region. With the identification of improved varieties of different horticultural crops with different maturity period, the availability period of different horticultural produce has been prolonged which has helped in reducing the market glut to a considerable extent.

Rapid increase in the area under different horticultural crops has also resulted in upsurge in pesticide consumption. The demand for aesthetic values in the horticultural produce for fetching premium market price has also added to the problem of overuse of pesticides. The institute has already developed integrated pest management packages for different horticultural crops. The farmers of the region have already started using these technologies for management of pest and diseases of different horticultural crops resulting in reduction in pesticide consumption in the region.

Improved varieties of vegetable crops

With the development of improved varieties of different vegetable crops by HARP, there has been significant increase in the area under different vegetable crops in the plateau region. Efforts for popularization of the technologies during the last five years have resulted in wide spread adoption of the improved varieties in an area of about 4450 ha area. The community vegetable nursery programme initiated for production of healthy seedling of wilt resistant tomato and brinjal has resulted in promotion of rainy season cultivation of tomato and brinjal in the state of Jharkhand. With an investment of Rs. 5000 in the community vegetable nursery, an income of Rs. 20000 could be generated by sale of about one lakh healthy seedlings of tomato and brinjal. Again, from rainy season cultivation of tomato and brinjal, the farmers' could obtain an income of about Rs. 700/- per decimal area as against Rs. 40/- per decimal area in case of traditional varieties. The increased income obtained due to cultivation of these improved varieties has contributed significantly towards ensuring nutritional and economic security in the tribal region. Cultivation of improved varieties of vegetable crops also increased the employment opportunity by about four fold than that in case of traditional varieties. This has been adopted as an entry point activity by the NGOs of the plateau region.

Fruit based multitier cropping system for uplands

The fruit based multitier cropping system for uplands, a technology developed at HARP has been included in the State Plan of Govt. of Jharkhand under the Chief Mininster's Bagwani Vikas Yojna for its plantation in 2500 ha area in Jharkhand, after its evaluation and declaration as bankable by NABARD. Under the National Horticulture Mission, the system has already been planted in 250 ha area in the state of Jharkhand. With the adoption of the technology, there has been a marked improvement in the input use by the farmers, particularly an increase in the use of seeds of improved varieties, organic manure and farm labour. A two-fold increase in the use of pesticide by the farmer warrants integration of integrated pest management practices in the fruit based multitier cropping system. With the adoption of the technology there has been a shift in the waste utilization pattern from the farming system. The leaf litter, which was used earlier for fuel purposes, is now being used for composting purpose. A significant proportion of paddy straw produced is being used for mulching of fruit plants. The increased availability of fruits and vegetables in the multitier system has resulted in increase in the consumption of fruits and vegetables in the household. The multitier system has been effective in generating more job opportunities for the women particularly in the operations like marketing of produce, weeding and fertilizer application.

Human resource development and capacity building through systematic training protocols helped in spread of technologies through different developmental agencies. Critical gaps in the past research and emerging issues are being tackled by integrating with modern tools and procedures of great reliability. The technologies developed under the aegis of the Complex have made significant impact by way of increased horticultural production in the eastern region.

Impact in policy change

The efforts of the Complex of statewide demonstration and sensitization resulted in influencing Govt. of Bihar to declare 25 per cent (up to Rs 5000) subsidy on purchase of zero till drill and bed planter. Water Resource Department, Govt. of Bihar rescheduled releasing of canal water as per recommendations of water management research in canal command areas. Multi-tier cropping system technology (mango, aonla and litchi based) was made bankable by NABARD and have also been included as a policy instrument to implement this model through Mukhya Mantri Uddyan Yojna in Jharkhand.Various finance institutions are supporting the financial help to SHGs for agricultural purposes in the model developed by Complex under DFID project. Institute developed technology of multiple use of water was recognized by the Bihar state for productive utilization of waterlogged areas and accordingly existing leasing policy for leasing of water bodies was modified for long term.

5.1 Growth

The participatory on-farm water management technology has been demonstrated at the farmers' field in the command of RPC-V in Sone Command in Bihar. This has created awareness among farmers on avoiding wasteful use of irrigation water. The technology of advancing the date of rice nursery and its transplanting and insitu conservation of rain water by raising the bund height of paddy fields have ensured maximum utilization of rain water and reducing the irrigation water requirement of rice. Cultivation of boro rice in low lying waterlogged areas and excess moisture condition holds promise for paddy yields up to 3.06 t/ha. Resource Conservation Technology under DFID, IVLP and CEAD and NATP projects especially zero till in wheat and rice have economized on cultivation cost, reduction of irrigation water requirement and advancing of wheat sowing by 10-15 days. Studies on water efficient irrigation practices, planting patterns, irrigation-nutrient interactions have resulted in economy of water and fertilizer use for various crops of eastern region. The development of a Low Energy Water Application (LEWA) device operating on 0.4 kg/cm^2 pressure and fittable on existing sprinklers holds scope for economizing energy and water requirement. Water-use efficient irrigation schedules under drip irrigation have been developed for vegetable crops. Multiple use of water and farming system approach have shown encouraging response in the region.

Tobacco based cropping system like tobacco + garlic, tobacco + rajmash, tobacco + potato, tobacco + coriander/ fenugreek/black cumin and crop sequence viz. sesame-tobacco-sunflower/onion; jowar+moth (fodder)-tobacco-black grain/cowpea; maize-tobacco-sesame have been identified as productive intercropping systems. Whereas research work on tobacco is continued, studies have been initiated on evaluation of promising strains and varieties of oilseed crops viz. India mustard and pulses like pigeonpea and lentil.

Under Horticulture and Agro-Forestry Research Programme, concerted efforts have resulted in collection and conservation of a total of 2958 valuable germplasm lines including fruits (771), vegetables (1836) and ornamental plants (351) at the institute gene bank. Researches on varietal screening and production technology have resulted in increased production of off-season vegetables in the region. Development of bacterial wilt resistant varieties has helped in significant increase in the production of rainy season tomato. Similarly, development of integrated management strategies of bacterial wilt of tomato and fungal wilt of guava has helped in ameliorating the problem in the region. Research efforts in soil management have helped farmers for better understanding of soil fertility in upland acid soils and use of micronutrients in different horticultural crops. Technologies developed in horticultural crops have resulted in rapid spread of area under different fruits and vegetable crops in Jharkhand during the last decade (Fig. 5). Later the emphasis was laid on horticulture based cropping system in which multitier cropping system was well adopted by the farmers of uplands. Promotion of floriculture activities has resulted in increase in area under floriculture. Development of sustainable agro-forestry models is given priority lately. The Complex has played a significant role in promotion of mushroom cultivation involving rural women in the eastern region resulting in 8 folds increase in the production of mushroom in Jharkhand.

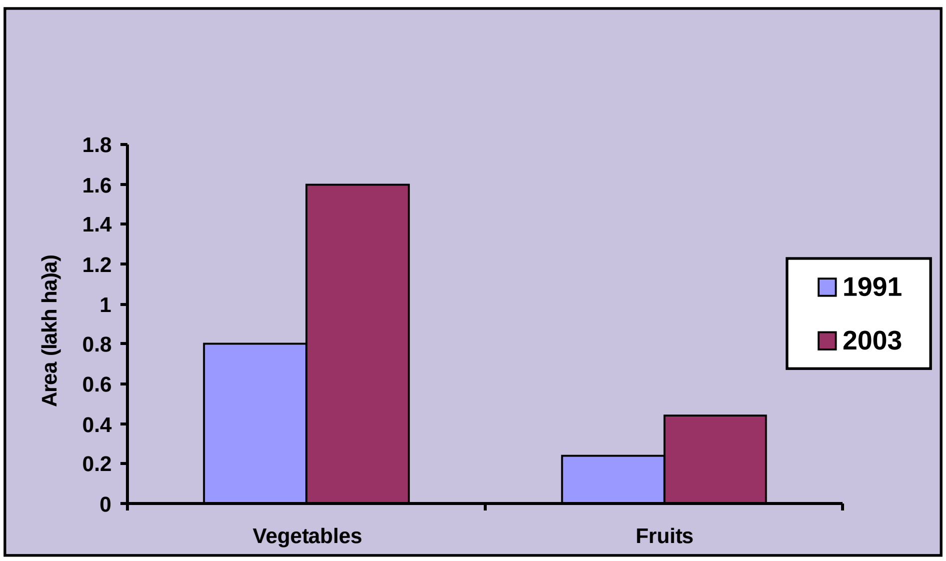


Fig.5 Increase in area under fruits and vegetable crops during 1991 to 2003 in Jharkhand

5.2 Input -Output

The Complex has generated several low input and higher output technologies in respect of natural resource management, field and horticultural crops. These technologies have been adopted by the farmers to a considerable extent resulting in higher crop yields, employment and income generation. It has contributed significantly towards livelihood improvement. Exploring multiple uses of water by routing water through a secondary reservoir could give additional fish yield upto 10 t/ha. Over a short period of time, the technology has spread to the farmers in Sone Command where the farmers are switching over to paddy+fish cultivation and undertaking fish production in common water bodies and have dug up individual ponds for fisheries production and integrating with horticulture, duckery etc. Fabrication of a low cost bamboo stick and iron bar polythene based polyhouse costing around Rs.3000/- has been developed to grow off-season seedlings of tomato, capsicum and papaya. It has potential to capture early market for employment generation for rural youth. Advancing the date of rice nursery sowing during May end and transplanting in the June end have increased paddy yields from 1.9 t/ha to 4.0 t/ha and adoption of improved water management technology of border strips has increased wheat yield from 2 t/ha to 4.0 t/ha. Adoption of zero till technology in wheat saved around Rs.1850/ha and surface seeding technology saved around Rs.6000/ha. These savings projected over entire zero till area in Bihar amount to around Rs. 4.2 million. Encouraged by the success, zero till technology is fast catching up in Bihar and other states in eastern Indo-Gangetic plains. A low cost LEWA device developed by the Complex can replace the existing costly sprinklers and can minimize the energy requirements in irrigation.

Financial and human resources input into horticultural research have been very inadequate in relation to enormity of the problem and the large population of eastern region dependant upon horticulture. Considering inputs of farming community, private sector and other allied activities, the percentage of investment in horticultural research works out to be less than 1 per cent. Despite this limitation, the Complex made significant contributions wherever the technologies have been transferred. Adoption of improved varieties and production technologies have resulted in an overall increase in the productivity of fruit crops by 1.5 to 2.5 times and of vegetable crops by 2.5 to 3.0 times during the last decade in the plateau region. This coupled with doubling the area under fruits and vegetable crops due to technology intervention, rapid plant multiplication and seed production programme has led to almost four times increase in production of fruits and six times that of vegetables during the last decade resulting in nutritional and economic security of the people in the plateau region.

6. SCENARIO

Land, water and biomass are the most precious natural resources. Water, a vital part of socio-ecological system, provides life support system for humans, vegetation/plants, animals, fisheries and aquatics. The declining per capita land and water availability coupled with degrading land and water resources, pose serious challenge to humanity and underscore the need for their protection and efficient management. Demographic changes, increasing pressure on natural resources, changing food habits and life styles, livelihoods and socio-economic scenario need serious consideration for developing future perspective for the eastern region where natural resources abound and agriculture and allied activities govern the economy and livelihoods. Various component of changing scenario are described below.

Livelihood and income scenario in the eastern region

Over 85 per cent population of eastern region consisting of small, marginal and landless farmers depends directly or indirectly on agriculture and contributes 40 per cent towards GDP. The region is ranked lowest in terms of per capita income (< Rs.6000). The per capita income distribution in different states is presented in Fig. 6. Out of seven poorest states of India (Bihar, Chhattisgarh, Jharkand, Madhya Pradesh, Orissa, Rajasthan and U.P) whose per capita income is less than Rs.10,000/-, five occur in eastern region. Out of 150 disadvantaged districts identified by Planning Commission based on their socio-economic condition, 83 occur in eastern region.

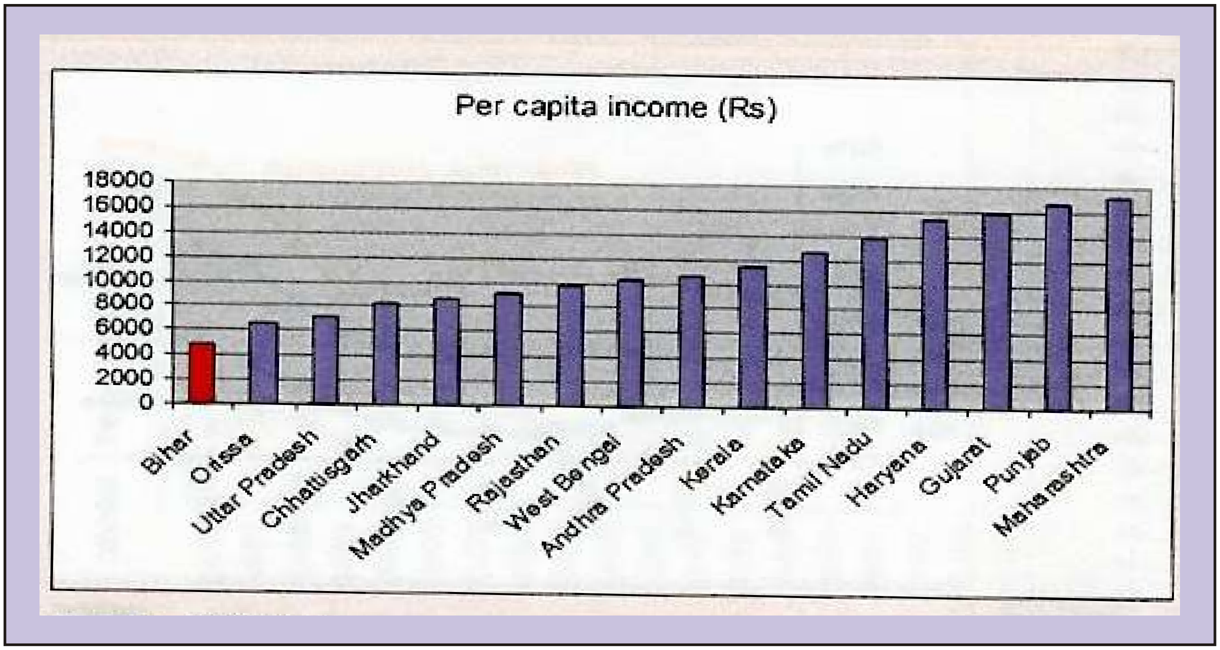


Fig. 6 Per capita income of different states of India.

Household malnutrition is a major concern for the small, marginal and landless farmers of hilly, tribal and backward areas of eastern India. According to National Sample Survey, 2 per cent of population of eastern region suffers from acute and chronic hunger and 10 per cent of the people suffer from seasonal food insecurity. As per the World Food Programme food insecurity mapping, the states like Jharkhand and Bihar having high poverty and dependence on labour income are most insecure. Low agricultural productivity in general and lack of agri-based activities in the region forces the community to work as labourers to earn their livelihood and out migrate in search of job. Overall, there is a high incidence of poverty notwithstanding the abundance of natural resources and high potential for agricultural growth in the region.

Tribal livelihoods

Nearly 46 per cent area of eastern region constituting plateau and hill region is homeland to 43 major and minor tribes. Tribals constitute about 22 per cent of total population of eastern region and are highly concentrated in the states of Chhatisgarh (36%), Jharkhand (29%), Orissa (22%) and Bihar (7.7%). The incidence of poverty among the tribals is very high with 46% and 35% living below poverty line in rural and urban areas, respectively. This is primarily due to a large number of tribals being landless with no productive assets and no access to sustainable employment. Tribals do not have a satisfactory dietary pattern and their diets are deficient in calcium, Vitamin-A, Vitamin-C, Riboflavin and protein. Malnutrition is fairly common especially in women and children. More than 87% of tribals primarily depend upon agriculture for their subsistence and majority of them are small holders. Vegetable cultivation and livestock rearing occupy the central position in their livelihood. The growing tribal population and the declining agricultural and livestock productivity have become a serious threat to the subsistence base of the tribal communities, endangering their self supporting food security system which leads to seasonal migration to other economic activity zones deserting the cultivation of land. The over exploitation of forest produce without their replenishment for supporting their livelihood has led to degradation of natural resources and erosion of plant and animal gene pool. A vast area of cultivable land and large number of seasonal waterbodies remain unexploited in eastern plateau. Lack of inclination of tribal youth towards agriculture has enhanced unemployment.

Shrinking land resources

Per capita availability of net cultivated land in the eastern region is among the lowest in the country. Per capita availability of land in India decreased from 0.5 ha in 1950-51 to 0.15 ha in 1999-2000 and based on past trends it is likely to reduce further to 0.08 ha in 2025 in eastern region. Approximately 80 per cent of the total farm holdings fall in the category of small and marginal with an average holding of less than 1 ha. Most of the holdings are not only small but also fragmented. Throughout India marginal land holdings have been increasing at a steady rate for the last thirty years or so. The rise in the number of marginal holdings as a percentage of the total number of holdings has increased from 51% in 1970-71 to 59% in 1990-91 and to 62% in 2000-01. The marginal landholders have been reduced to agricultural labours in almost all parts of the country leading to fabulous growth of agricultural labour during the period 1991 to 2001. Marginal holdings account for over 75% in West Bengal, 69% in Orissa and over 82% in Bihar-Jharkhand. Because of these high percentages of marginal holdings in the states of Eastern Region, the growth of labour force in agriculture is higher in Eastern India than in the country as a whole.

In view of the highest percentage of net sown area to geographical area, there is hardly any scope of expanding the area under cultivation in this region. The present land scenario has serious implications for small and marginal farmers and pose challenges for Scientists to develop technologies suited to small holdings and/or to evolve suitable social interventions including land consolidation, contract farming etc. for wider adoption of existing technologies.

Soil erosion and land degradation scenario

Soil erosion and land degradation are a serious concern not only affecting soil productivity but also robbing storage capacity of water harvesting structures and reservoirs due to siltation. It is estimated that 146 Mha of the total geographical area of the country is subjected to various forms of land degradation (NBSSLUP, 2005). Out of this 93.68 Mha suffers from water erosion. Based on the potential soil loss estimates made by CSWCRTI and NBSS & LUP, about 54 per cent area of the eastern region has potential soil loss > 10 t/ha/year. It is maximum in Jharkhand followed by Assam, Chattisgarh, U.P. and Bihar in eastern plateau and alluvial plains. Depleting organic carbon stock is responsible for stagnant productivity of major crops in recent years. If corrective steps are not taken, these problems are likely to accentuate further by 2025. Results of studies on efficacy of soil conservation measures indicate that 25 to 30 per cent additional yields can be obtained by following conservation practices besides checking soil loss. A large area in the eastern region particularly in plateau and hills region is suffering from excess leaching of bases due to high rainfall rendering the soil acidic and unfit for crop production without the use of costly amendments.

Water scenario

- ***India's population, per capita water availability and projected food requirements***

The population of India which is around 1000 million at present is expected to rise to 1389 million by 2025, 37 per cent of which will live in urban areas. The different states in India will have different population trends. Whereas, population of some states, such as Andhra Pradesh, Kerala, Karnataka, Punjab and Tamil Nadu will have fast declining trends, population of the states of Haryana, Gujarat, Orissa, Maharashtra and West Bengal will decline moderately (IWMI, 2006). However, states such as Bihar, Jharkhand, Madhya Pradesh Chattisgarh, Rajasthan and Uttar Pradesh will continue with positive growth. For meeting this burgeoning requirements of the population, the country will require to produce 320 Mt of food grains by 2025, from a current level of 212 Mt. Agriculture will continue to be a major user of water besides water required for domestic, industrial, municipal and environmental needs. The average annual surface water resources in India are 1869 km^3, as per the estimates of Central Water Commission (CWC). However, due to various topographical, climatic and geological constraints, the utilizable surface water is assessed to be 690 km^3 (Anon., 1998). The annual replenishable (dynamic) ground water resource is about 432 km^3, as per estimates of the Central Ground Water Board (Anon., 1998; Bhatia, 1999; Chadha, 1999). Thus, the total annual surface and ground water utilizable resources have been estimated at 1122 km^3.

The per capita water availability in India came down from 5300 m^3 in 1955 to 2200 m^3 in the early nineties, and at 1703 m^3 in 2005. It is projected to be 1465 m^3 and 1235 m^3 by the year 2025 and 2050, respectively (Navalawala, 2000). Below a threshold of 1700 m^3, water availability is considered a severe constraint on socio-economic development and environmental quality. Within the country, per capita water availability is region specific. The per capita water availability in some of the east flowing rivers of Tamil Nadu is as low as 380 m^3, while it is as high as 18,400 m^3 in the Brahmaputra Basin. However, this per capita water availability is also likely to be affected by the anticipated climate change in terms of volume, seasonality and spatial distribution.

Whereas average annual water availability on long term basis is more or less fixed (except for the years with extreme climatic events), the demand is growing exponentially and is expected to grow even faster. Development of future water scenarios requires a knowledge of water and food demand drivers to identify the supply-demand mismatch to build future perspective. Three scenarios: (a) National Commission for Integrated Water Resources Development (NCIWRD's) Projections with high and low population growth rate, (b) IWMI's Projections with water and food drivers based on their present changes, and (c) the assessment of Standing Sub-Committee of CWC (MoWR) taken as Business-As-Usual (BAU) scenario are considered here to build water resources scenario.

- ***Water and food demand drivers***

Many of the food and water demand drivers have under gone significant changes in recent times. Based on the assessment of their changes and directions, the water demand drivers as recently estimated by IWMI are shown in Table 1.

Table 1. Growth in food and water demand drivers

Water demand drivers	2000	2025
Demography		
· Population (million)	1007	1389
· % urban population	28%	37%
Economic growth		
GDP growth (US$ 1995 prices)	463	1765
Nutritional Intake		
Total calorie supply (kcal/pc/day)	2495	2770
· % of grain crops	65	56
· % from non-grain crops	28	33
· % from animal products	8	12
Grain consumption (kg/pc/year)		
· Grain consumption	172	166
Crop yields (Ton/ha)		
· Irrigated	2.63	3.40
· Rainfed	1.00	1.27
Crop area (M ha)		
· Net sown area	142	142
· Gross crop area	189	210
· Net irrigated area	55	84
· Groundwater irrigated area	47	70
Project irrigation efficiency (%)		
· Surface	30-40	45
· Ground water	55-65	75-80

(Source : Based on IWMI's work "India's Water Futures", 2006.)

The composition of nutritional intake in India is fast changing. There is a propensity to include more non-food grain products in the diet due to increasing income and expanding urbanization. Non-grain crops and animal products (dairy, poultry and fishery) are projected to provide a major part of the nutritional intake in the future. Due to increasing demand for animal products the feed grain demand will increase several folds. The grain consumption per person in both urban and rural areas is decreasing. As a result, the total food-grain demand is projected to increase only slightly. The demand for non-grain crops including fruits and vegetables will also increase many times. In terms of calorie (kcal) consumption per day per person, the requirement has increased by 11% from 2495 in 2000 to 2770 in 2025 (Table 1). The growth in kcal per capita per day in grain crops, non-grains and animal products is projected at -14%, 18% and 50% respectively by 2025. This suggests increased emphasis in land use and crop diversification to include fruits, vegetables, livestock, fisheries etc. in the farming systems and need for raising productivity of agriculture. Changing life styles and food habits, and so the consumer preferences will not only lead to changed emphasis on agricultural commodities but will also determine product profiles. Therefore, processing, storage and value addition of food and fruit products would assume greater importance in future.

- ***Water demand projections under different scenarios***

The National Commission on Integrated Water Resources Development (NCIWRD) projects that the total water demand will increase to 784-843 km^3 by 2025, depending on low or high population growth scenario (Table 2). The agricultural sector, by far the largest consumer for water use, will account for 72 per cent of the total water demand projection by 2025.

Table 2. The NCIWRD projections under high and low population growth scenarios

Variables	**Growth scenario**	**Base year**	**Projected year**
		1997/98	**2025**
Total water withdrawal (Km^3)	High	629	784
	Low		843
Irrigation water demand -% of total	Low-high	83	72
Domestic water demand -% of total	Low-high	5	7
Industrial withdrawals - % of total	Low-high	5	8-9
Environmental needs - % of total	Low-high	0	1
Other water demand - % of total	Low-high	7	11-12
Total grain demand (M Mt)	High	190	320
	Low	”	308
Total irrigated area (M ha)	High	73.6	98.2
	Low	”	90.8

(Source: GOI 1999 (Integrated Water Resources Development- An Action Plan, NCIWRD Report)

A comparison of demand projections in 2025 by various agencies (Table 3) suggests IWMI's projected total water demand to increase by 28.6 percent in 2025 as compared to that of 1997-98. IWMI's total water demand projections are 4.1% lower than the projections of the NCIWRD considering high anticipated population growth. This is attributed to assumption by NCIWRD of higher irrigation efficiency at 60% (as against the present level of 30-40%) for surface irrigation against 45% by IWMI by 2025, which appears to be more realistic looking at the past trends. CWC/MoWR's Standing Sub-Committee for Assessment of Availability and Requirement of Water for Diverse Uses under BAU scenario demand projections at 910 km^3 are highest and seem unrealistic. NCIWRD and IWMI scenarios appear to be more realistic for building future perspective. In both the scenarios, a major part of the additional water demand is projected for the industrial and domestic sectors with relatively lesser increase in irrigation water demand.

Table 3. A comparison of water demand (km^3) scenario under BAU, NCIWRD and IWMI by 2025

Water Demand (km^3)	1997-98 (Reference Year)	Projections - 2025			
		Standing Sub-Committee Assessment	NCIWRD		IWMI's Projection
		BAU scenario	High	Low	
Irrigation	524	910	611	561	675
Domestic	30	73	62	55	40
Industrial	30	23	67	67	94
Others (including power inland navigation, flood control, environment afforestation and ecology, and evaporation losses)	45	87	103	101	–
Total	**629**	**1093**	**843**	**784**	**809**

- ***Reduction in the share of water for agriculture***

India's economy is expanding at a rapid pace, and urban centres are booming. The water demands of the non-agriculture sectors are increasing at a rapid pace. The water used for agriculture, which is about 83 per cent of the developed water resource, is likely to be reduced further by about 72 per cent by 2025 to meet the growing demand for drinking water and economically more competitive demand for industrial uses. A major challenge for India in the future is, therefore to increase agricultural water productivity while meeting the increasing demand of non-agriculture sectors. Devising ways and means to enhance agricultural water productivity by 2025 and beyond is a major challenge for the Scientists.

- ***Anticipated climate change impact on water availability and demand***

Future climate change will have both positive and negative ramifications on agriculture. Growing scientific opinion predicts a continued global climate change with regional imbalances, which are likely to affect water balance, surface and groundwater availability, frequency and extent of floods and droughts and shift in timing or seasonality of runoff. Due to early rise in temperature, glaciers have already started melting earlier resulting in shifting of peak time and volume of runoff. The preliminary assessment has revealed that under the GHGs scenario, the severity of droughts and intensity of floods is projected to increase in various river basins of India. In general, reduction in the quantity of annual runoff is anticipated. Luni basin occupying about one-fourth of the area of Gujarat and 60 per cent of the area of Rajasthan is likely to experience acute water scarcity. Mahi, Pennar, Sabarmati and Tapi basins are likely to experience constant water scarcities. Cauvery, Ganga, Narmada and Krishna basins are likely to experience seasonal or regular water stress conditions (MoEF, 2004). Godavari, Brahmani and Mahanadi basins are projected to experience water shortage at few locations. While the total annual runoff is projected to decrease drastically (15 to 70%) in Krishna, Pennar, Luni and Sabarmati, it is projected to increase (by 10 to 25%) in Ganga, Brahmani and Mahanadi basins. Change in seasonality may also lead to excessive flooding, drainage and water logging problems in some parts of the basin(s).

- ***Flooding, waterlogging/drainage congestion & wetlands***

The Ganges basin in eastern region, having highly fertile soils, remain flooded for a significant part of the year. The menace of flooding is getting accentuated due to mismanagement of land in the catchments resulting in severe erosion, raising of river beds due to siltation and flooding in downstream areas. A vast stretch of area (3.5 Mha) is permanently or seasonally waterlogged and / or faces serious drainage congestion problem owing to flat topography. About 9.41 lakh ha of land is suffering from problems of waterlogging in Bihar alone. These areas are characterized by tal, diara, chaur and mauns (ox bow lakes). In West Bengal 2.2 million ha area is waterlogged. It is estimated that out of 3.3 lakh ha of cultivated area of Mahanadi delta, 1.75 lakh ha in Orissa is waterlogged. Canal irrigated areas are dotted with canal induced waterlogging. These areas offer great potential and challenge for their productive utilization through appropriate multiple use and farming system including fisheries, aquaculture, horticulture like banana, vegetables, makhana and other aquatic crops.

- ***Water quality scenario***

In eastern region, the industrial and sewage effluents containing heavy metals such as zinc, cadmium, lead and mercury are polluting the rivers. Poor ground water quality is also a matter of concern. Ground water quality for drinking and irrigation has deteriorated due to presence of high amount of nitrates, high fluoride, low iodine and high arsenic contents in some districts. Fluoride toxicity is prominent in states of Bihar, eastern U.P. and West Bengal. Average fluoride level varies from 0.37mg/l in West Bengal to 0.77 mg/l in Eastern U.P. Higher concentration of fluoride (> 1.50 mg/l) is recorded at Girdih, Jamui and Dhanbad districts. Fluoride in the range (0.5-1.0 mg/l) in groundwater is found to occur in Muzaffarpur, Vaishali, Madepura, Deoghar, Bhagalpur, Godda, Siwan and Saran districts. In Naispur area in Nalhati block of Birbhum district fluoride content of groundwater as high as 10-16 mg/l has been reported causing deformity of bones, fluorosis, dental carries, etc. Maximum incidence of arsenic occurs in 24-Parganas, Nadia and Murshidabad districts with 74, 72 and 58 per cent affected area respectively. Such high values of arsenic occurs in shallow aquifers (20-100m) of the region. If this deteriorating water quality trend continues, per capita availability of fresh water is likely to be reduced further by the year 2025. This would require focus on management of poor quality waters.

- ***Ground water exploitation***

In India, about 36 M ha-m of ground water is available for irrigation on annual recharge basis. In eastern region the total utilizable ground water resource for irrigation is estimated to be 16.0 M ha-m/year. Almost the whole eastern region can be categorized as “white” in respect of ground water exploitation as the average exploitation level is around 23% in the region against the national average of 42%. It varies in different states- 4.5% in Assam, 5.6% in Chattishgarh, 14.3% in Orissa, 32% in West Bengal, 36% in Bihar and 42.4% in eastern U.P. To feed huge population of eastern India by 2025 exploitation level of ground water for irrigation has to be raised upto the level of 60% following efficient water management practices. However, utmost caution is required in coastal belts to avoid seawater intrusion.

Expanding horticulture scenario

Horticultural scenario of the eastern region is undergoing a sea change in recent years. Fruits and vegetable crops cover more than 70% of the total area under horticulture in the eastern region. The last decade has witnessed about 31% increase in the total production of fruit crops which was mainly due to the increase in about 27% of area under fruit cultivation with no marked increase in the productivity of fruit crops because a large proportion of plateau region supporting fruits is having low soil fertility, low water holding capacity and remains dry for major part of the year. However, in case of vegetables, productivity increase of about 37% (present productivity 13.3 t/ha) coupled with 27% increase in area during the last decade has resulted in about 76% increase in the total production of vegetable crops in the region. This can be attributed to large-scale introduction of improved varieties of different vegetable crops alongwith adoption of high input based production technologies by the farmers of the region. At present the per capita availability of fruits in the eastern region is about 70g per day and considering a post harvest loss of about 30 per cent of the produce, the per capita availability of fruits in the region amounts to about 49 g/day. This is much below the dietary requirement of about 90g fruits per day according to ICMR recommendations. To expand area under horticulture, there is a need for intensive plant multiplication activities to produce huge quantity of seeds and saplings. Post harvest management of fruits and vegetables would be needed for maintaining the profit level. Changing market scenario with entry of MNCs such as Wallmart, Bharati Agro, Reliance Fresh etc. in food market would bring great impetus to fresh fruits and vegetable marketing.

Livestock production scenario

The Eastern Region is inhabited by 28 per cent of livestock population in India comprising of cattle, buffalo, sheep, goat, pig and poultry including duck. Mostly these are of non-descript type with low productivity resulting in low economic return. Moreover, prevalence of infectious diseases like FMD, HS, BQ, RD etc. and reproductive problems like anestrous and repeat breeding among livestock & poultry and lack of rapid disease diagnosis and monitoring system particularly in rural areas ultimately results in low production. The area under fodder cultivation in the region is also reduced for high demand of food crops. This together with high cost of concentrates reduces the feed availability of the animals for optimum production. There is also lack of proper storage & marketing facility of animal and fishery products and by-products. At industrial level, the livestock as well as fish products technology is yet to get due importance. Lack of general awareness in people in general and farmers in particular pose hurdles to overall livestock development in the region.

In spite of large number of livestock population, milk production is only 12 % of national production. The milk production on national basis has annually grown over 4% between 1990-91 and 2000-01. During last five years (between 2000-01 and 2004-05), annual growth in milk production has reduced further to 2.58 per cent annually. In the eastern region, the milk production has shown varying growth trend. Whereas, in Jharkhand and Orissa, it is over three times the milk production at national level, it is much lower in other states. In view of population increase projections of the requirement of milk in eastern region states as per recommendation by ICMR (220g/person/day) is shown in Table 4.

Table 4. Requirement of milk and growth rate in states of the region by 2025

States	Annual Milk Production (2004-2005) ('000 t)	Annual Growth of Milk Production during last 5 years (%) (2000-01 to 2004-05)	Projected Annual Growth Rate (%)	Projected Milk Requirement ('000 t) in 2025
Assam	739	1.64	12.40	2574
Bihar	2974	3.89	10.26	9080
Orissa	1293	9.29	8.18	3383
West Bengal	3790	1.83	5.59	8028
Chhattisgarh	831	1.39	8.69	2276
Jharkhand	1330	9.23	5.02	2665

(Source : Department of Animal Husbandry, dairying and fisheries, Govt. of India, www.dahd.nic.in)

Egg production during last 5 years has grown annually at 4.57% at National level and at 0.61, 1.99, 4.01, 5.38. 13.32 and 1.45 per cent respectively in Assam, Bihar Chattisgarh, Jharkhand, Orissa and West Bengal. The region has 86 per cent share of total duck egg production in India.

Fisheries scenario

The eastern region contributes 52.4 per cent of total inland fish production in India. The region has 1.1 million ha total water area constituting reservoirs, ponds, tanks and beels, oxbow lakes etc. besides 15046 km length of rivers and canals for fisheries production. The annual fisheries production of the eastern region has increased from 0.75 million tonnes of fish and shellfish in 1950 to about 6.1 million tonnes in the year 2002, indicating eight folds increase. Aquaculture contribution in the inland fisheries sector has been significant in recent years. The production from capture fisheries in the last two decades has grown by only 72 per cent, but the aquaculture sector has shown impressive growth of 468 per cent in the same period (i.e. 0.37 million tones in 1980 to 2.1 million tones in 2000). The primary challenge before the country is to increase per capita fish availability from the present level of only 8 kg to 11 kg (as recommended by World Health Organization). Considering the limited scope of the capture fisheries from coastal waters and natural inland waters like rivers and estuaries, greater emphasis on aquaculture and culture based fisheries from reservoirs and floodplain wetlands is essential to meet the targetted fish requirement of 8.3 million tones by 2020 and 9.3 million tones by 2025. Eastern region, with rich water endowments holds promise to raise production and productivity of vast water resources and rich cultivable species diversity.

Makhana and aquatic crop scenario

Amongst the aquatic food crops, makhana is highly productive, nutritious, fully organic non-cereal food and remunerative crop grown in stagnant water of wetlands. It is predominantly cultivated in the eastern part of the country, mainly north Bihar, some districts of West Bengal, lower Assam. Practically no such scientific investigations have yet been done in the field of appropriate farm technology, agro-techniques, plant protection measures, post harvest technology including value adding and marketability. Absence of technology innovation and new agronomic practices hamper the productivity which is at a present level of 3 t/ha. A complete package on these lines will help the growers to promote its production as well as its export mission for national consumption and export purpose.

Productivity gaps scenario

The eastern region has a rich production resource base for intensive and diversified agriculture. Average productivity of rice, varies from 1.46 t/ha in Bihar to 2.51 t/ha in West Bengal. The gap between present and potential yields ranges between 2.49 t/ha in West Bengal to 4.92 t/ha in eastern Assam. The productivity of fruits varies between 6.22 t/ha in Orissa to 12.7 t/ha in Chattisgarh. The area holds promise to raise the productivity of fruits upto 20 t/ha. Similarly the productivity of vegetables varies from 10.9 t/ha in Jharkhand to 20.1 t/ha in eastern U.P. with enormous scope of further raising potential of vegetable production. The average fish productivity in the region stands at 0.36 t/ha/year in eastern U.P. to 1.81 t/ha/year in W.B. The gap between the potential and the present fish yields varies from 0.46 t/ha in Bihar to 1.99 t/ha in eastern U.P. Eastern region is particularly known for producing fruits like litchi and makhana, besides mango, jack fruit, jamun etc., special vegetables and spices like pointed gourd (parwal), red capsicum, turmeric etc. Perennial and seasonal water bodies abound in this region and provide a great scope for development of fishery. The untapped potential ingrained in these specified advantages need to be harnessed.

Service delivery system

The service delivery in agriculture consisting of transfer of technology, input, market and other logistics and infrastructural support, at present, is mainly considered responsibility of government departments or govt. owned institutions. The extension and service delivery system of the government has now become weak. In future also it would be virtually impossible for the govt. alone to cater the extension needs of the 30 million farmers' household of the eastern region. Community based organizations like Panchayati Raj Institutions, NGOs and SHGs though exists, these play a limited role in service delivery. There is inadequate coordination and linkages among Govt. departments for fulfillment of farmers' needs. For successful agricultural development, an efficient system of service delivery wherein information, the skills, the logistics etc. will be available to the larger segments of farming community is imperative. At the local level, experimentation in innovative community approaches to service delivery has shown very promising results. In irrigation, for example, Participatory Irrigation Management and in natural resources Participatory Watershed Management has shown encouraging results in improving service delivery. As the agricultural extension is going cyber and global, the Information Communication Technology (ICT) can also be handled by the private agencies. Therefore, participation of different stakeholders in service delivery, other than the government departments, is sine qua none.

The scenario described above posses challenge for researchers in agriculture and natural resource management to evolve new, effective strategies for delivering rural services and for implementing local institutional arrangements to improve livelihoods of the rural poor through agriculture based activities. In order to increase income and employment generation, it is essential to develop other vocations like horticulture, animal husbandry, poultry, beekeeping, fisheries, mushroom, makhana cultivation etc.

SWOT analysis

A fresh SWOT analysis for the Complex and eastern region was undertaken and indicated in the following table :

Strengths	***Weaknesses***	***Opportunities***	***Threats***
Rich natural resource endowed region	Significant number of vacant scientific positions	High potential, low productivity region	Large area with lack of sub-centres
Well defined mandate and programmes	Inadequate technical manpower	A large yield gap of crops, fish and fruits	Inadequate capacity of handling surplus due to increase in production
Adequate provision of multi disciplinary manpower	Poor physical. Electric, electronic connectivity	Abundant untapped natural resources	Unfavourable ponds leasing policy for makhana cultivation
Adequate budget provision	Inadequate research linkages, inadequate infrastructure in the region	Large farm workforce	Alarming growth in population and widening land : human ratio
Good laboratories and infrastructure facilities	Absence of effective value chain management	Complimentarity due to existence of ICAR institute, SAUs and NGOs	Genetic erosion of native germplasm in horticulture crops due to crop substitution by commercial horticultural species
Recognised by external national / international funding agencies	Inadequate transfer of technology mechanism (ICTs), service delivery system	Possibility of multi-disciplinary research through public- private partnership	
Adequate outreach extension activities	Lack of residential accommodation	Potential for national and international bidding for competitive grants	