Vision 2050

भाकृअनुप
ICAR

Indian Institute of Water Management
Indian Council of Agricultural Research

भारतीय जल प्रबंधन संस्थान
ICAR-IIWM

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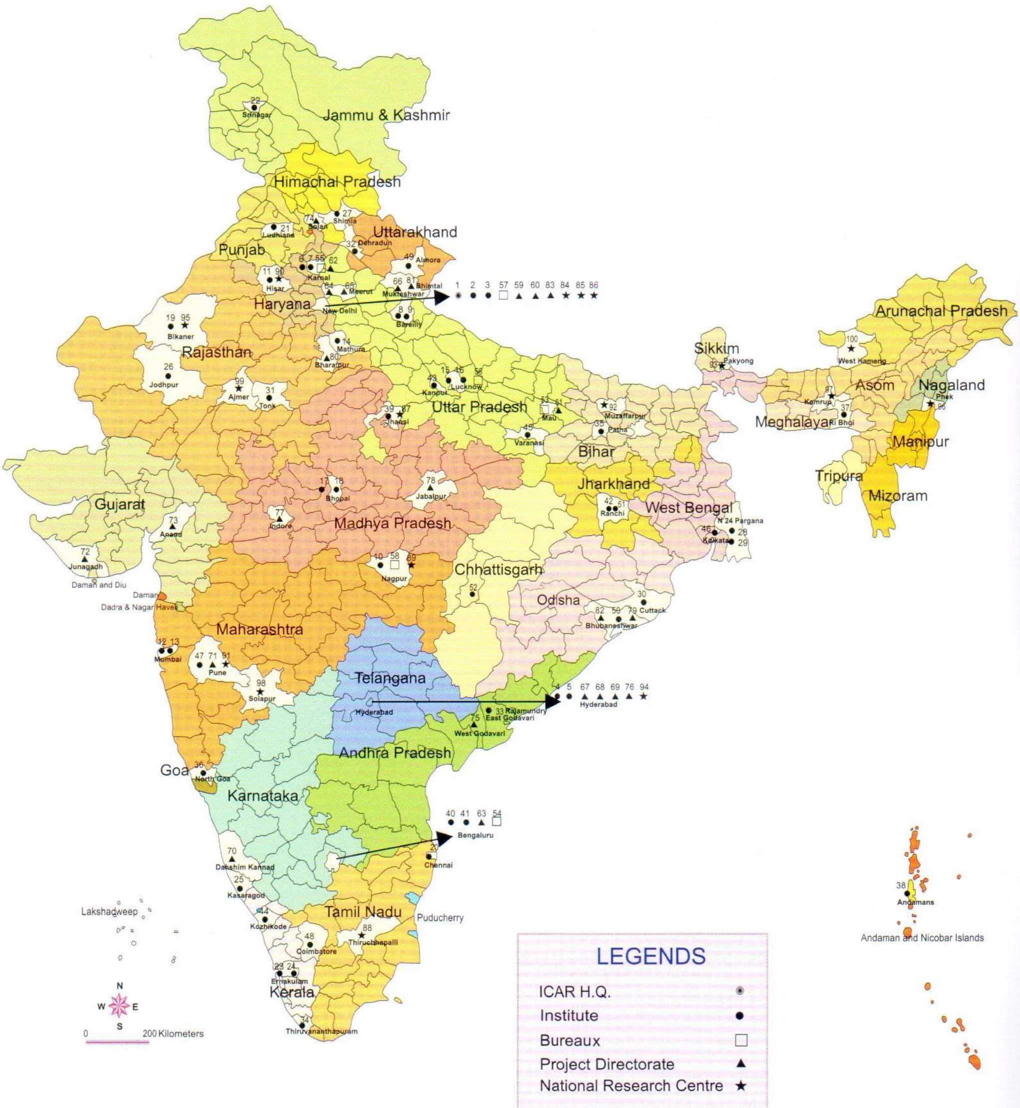

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Vision 2050

ICAR-IIWM

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संदेश

भारतीय सभ्यता कृषि विकास की एक आधार रही है और आज भी हमारे देश में एक सुदृढ़ कृषि व्यवस्था मौजूद है जिसका राष्ट्रीय सकल घरेलू उत्पाद और रोजगार में प्रमुख योगदान है। ग्रामीण युवाओं का बड़े पैमाने पर, विशेष रूप से शहरी क्षेत्रों में प्रवास होने के बावजूद, देश की लगभग दो-तिहाई आबादी के लिए आजीविका के साधन के रूप में, प्रत्यक्ष या अप्रत्यक्ष, कृषि की भूमिका में कोई बदलाव होने की उम्मीद नहीं की जाती है। अतः खाद्य, पोषण, पर्यावरण, आजीविका सुरक्षा के लिए तथा समावेशी विकास हासिल करने के लिए कृषि क्षेत्र में स्थायी विकास बहुत जरूरी है।

पिछले 50 वर्षों के दौरान हमारे कृषि अनुसंधान द्वारा सृजित की गई प्रौद्योगिकियों से भारतीय कृषि में बदलाव आया है। तथापि, भौतिक रूप से (मृदा, जल, जलवायु), बायोलोजिकल रूप से (जैव विविधता, हॉस्ट-परजीवी संबंध), अनुसंधान एवं शिक्षा में बदलाव के चलते तथा सूचना, ज्ञान और नीति एवं निवेश (जो कृषि उत्पादन को प्रभावित करने वाले कारक हैं) आज भी एक चुनौती बने हुए हैं। उत्पादन के परिवेश में बदलाव हमेशा ही होते आए हैं, परन्तु जिस गति से यह हो रहे हैं, वह एक चिंता का विषय है जो उपयुक्त प्रौद्योगिकी विकल्पों के आधार पर कृषि प्रणाली को और अधिक मजबूत करने की मांग करते हैं।

पिछली प्रवृत्तियों से सबक लेते हुए हम निश्चित रूप से भावी बेहतर कृषि परिदृश्य की कल्पना कर सकते हैं, जिसके लिए हमें विभिन्न तकनीकों और आकलनों के मॉडलों का उपयोग करना होगा तथा भविष्य के लिए एक ब्लूप्रिंट तैयार करना होगा। इसमें कोई संदेह नहीं है कि विज्ञान, प्रौद्योगिकी, सूचना, ज्ञान-जानकारी, सक्षम मानव संसाधन और निवेशों का बढ़ता प्रयोग भावी वृद्धि और विकास के प्रमुख निर्धारक होंगे।

इस संदर्भ में, भारतीय कृषि अनुसंधान परिषद के संस्थानों के लिए विजन-2050 की रूपरेखा तैयार की गई है। यह आशा की जाती है कि वर्तमान और उभरते परिदृश्य का बेहतर रूप से किया गया मूल्यांकन, मौजूदा नए अवसर और कृषि क्षेत्र की स्थायी वृद्धि और विकास के लिए आगामी दशकों हेतु प्रासंगिक अनुसंधान संबंधी मुद्दे तथा कार्यनीतिक फ्रेमवर्क काफी उपयोगी साबित होंगे।

(राधा मोहन सिंह)

केन्द्रीय कृषि मंत्री, भारत सरकार

Foreword

Indian Council of Agricultural Research, since inception in the year 1929, is spearheading national programmes on agricultural research, higher education and frontline extension through a network of Research Institutes, Agricultural Universities, All India Coordinated Research Projects and Krishi Vigyan Kendras to develop and demonstrate new technologies, as also to develop competent human resource for strengthening agriculture in all its dimensions, in the country. The science and technology-led development in agriculture has resulted in manifold enhancement in productivity and production of different crops and commodities to match the pace of growth in food demand.

Agricultural production environment, being a dynamic entity, has kept evolving continuously. The present phase of changes being encountered by the agricultural sector, such as reducing availability of quality water, nutrient deficiency in soils, climate change, farm energy availability, loss of biodiversity, emergence of new pest and diseases, fragmentation of farms, rural-urban migration, coupled with new IPRs and trade regulations, are some of the new challenges.

These changes impacting agriculture call for a paradigm shift in our research approach. We have to harness the potential of modern science, encourage innovations in technology generation, and provide for an enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy, and technology dissemination need to be given priority. Multi-disciplinary and multi-institutional research will be of paramount importance, given the fact that technology generation is increasingly getting knowledge and capital intensive. Our institutions of agricultural research and education must attain highest levels of excellence in development of technologies and competent human resource to effectively deal with the changing scenario.

Vision-2050 document of ICAR-Indian Institute of Water Management (IIWM), Bhubaneswar, Odisha has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario 35 years hence, towards science-led sustainable development of agriculture.

We are hopeful that in the years ahead, Vision-2050 would prove to be valuable in guiding our efforts in agricultural R&D and also for the young scientists who would shoulder the responsibility to generate farm technologies in future for food, nutrition, livelihood and environmental security of the billion plus population of the country, for all times to come.

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

Water has been and will remain a crucial resource which is being utilized and affected due to increasing population, industrialization, urbanization, deforestation and above all climate change. The ICAR-Indian Institute of Water Management (formerly Directorate of Water Management) is addressing the issues of on-farm water management through basic, applied and strategic research activities in the water domains of rainwater, canal water, groundwater and wastewater for agriculture. The Institute developed various technological options in different agro-ecological regions of the country with adequate institutional linkages, infrastructure support and capacity building to handle on-farm water management issues. Beside, future thrust will be given on water policies, governance and transfer of technology to the stakeholders. I am pleased to present the Vision-2050 document of the Institute which envisages challenges and opportunities in the country for forthcoming four decades, the document is useful for developing a research road map for enhancing water productivity in different agro-ecological regions of the country.

The institute has also made earlier efforts in developing Vision-2020, Vision-2025 and Vision-2030 documents which were quite useful in preparing five-yearly research proposals. The IIWM Vision-2050 gives an insight on water scenario, operating environment,emerging challenges and new opportunities. The document also emphasizes on goal and target for developing water management technologies to ensure food and nutritional security of the country.

I take this opportunity to express my sincere thanks and gratitude to Dr. S. Ayyappan,Hon'ble Secretary, DARE and Director General, ICAR, New Delhi for his invaluable guidance and inspiration in documenting IIWM Vision-2050.I am also indebted to Dr. A.K. Sikka, Hon'ble Deputy Director General (Natural Resources Management), ICAR, New Delhi for his guidance in writing the document.

I am grateful to Dr. B. Mohan Kumar, Assistant Director General (Agronomy and Agro-forestry) and Dr. S.K. Chaudhari, Assistant Director General (Soil and Water Management), ICAR, New Delhi for their valuable suggestions in preparing the document. I take this opportunity to thank all the contributors for their effort in preparing this document.

I hope this document will be useful to set the strategies in specific time frame for future water management research to achieve higher and sustainable agricultural growth of the country.

(S.K. Ambast)
Director

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Context

The natural resource scenario is changing fast both in terms of availability as well as quality. Looming climate change will alter the paradigm of natural resources in which our production system operates. Water is a critical natural resource and is being affected by increasing population, industrialization, urbanization, pollution, deforestation and above all climate change. Certainly the business as usual will not suffice. Thus it is essential to visualize the future scenario and prepare strategies for equipping ourselves with technologies which will provide solution for maintaining our food and nutritional security in changing/ projected scenarios. Thus, it was felt necessary to update the VISION 2030 to VISION 2050 for getting a glimpse of the shifting scenarios and challenges which we are going to encounter in next 40 years. This will give us an idea of institutional, technological and financial path to be followed to achieve the national objectives without endangering the sustainability of our production systems.

Indian Institute of Water Management (formerly Directorate of Water Management erstwhile Water Technology Centre for Eastern Region), Bhubaneswar was established in 1988 with the mandate of dealing with the problems of water management in the low yield high potential eastern region. Later, its mandate was expanded to cover whole country through coordination of two AICRPs on Water Management (25 centres) and Ground Water Utilization (9 centres). The institute has organized its research efforts in program mode through five research programs, *viz.* Rain Water Management, Canal Water Management, Ground Water Management, Waterlogged Area Management, and On Farm Research and Transfer of Technology with following mandates.

Mandate of IIWM

- To undertake basic and applied research for developing strategies for efficient management of on-farm water resources to enhance agricultural productivity on sustainable basis.
- To provide leadership and coordinate research to generate location specific technologies for efficient use of water resources.
- To act as a centre for training in research methodologies and technology update in the area of agricultural water management.

- To collaborate with the national and international agencies in achieving the above objectives.

The institute has successfully coordinated the activities of AICRP on Water Management and AICRP on Ground Water Utilisation. During the 12^{th} Five Year Plan, however it is proposed to merge both the AICRPs to form the AICRP on Irrigation Water Management with the following mandate :

- Assessment of surface water, groundwater and wastewater availability and quality at regional level and to evolve management strategies using Decision Support System (DSS) for matching water supply and demand in agricultural production systems.
- Design, development and refinement of surface and pressurized irrigation systems including small holders' systems for enhancing water use efficiency and water productivity for different agro-eco systems.
- Management of rain water for judicious use and to develop and evaluate groundwater recharge technologies for augmenting groundwater availability under different hydro-geological conditions.
- Basic studies on soil-water-plant-environment relationship under changing scenarios of irrigation water management including wastewater irrigation.
- To evolve management strategies for conjunctive use of surface water, groundwater and wastewater resources for sustainable crop production.

During the past 25 years of the institute's existence and 40 years of functioning of the AICRPs on Water Management, the technologies developed have brought out many changes in the agricultural production system of the country. Efficient use of water in its different domains has played an important role in enhancing food production beyond 250 M tonnes. The exponential growth of horticultural crop production has been possible only due to efficient and optimal water use technologies which not only provided more production per drop of water but also ensured quality and uniformity of produce. Some significant achievements of the past ten years are given below:

- Microlevel water resource development through tank cum well system.
- Two-stage rainwater conservation and multiple use of conserved rainwater in rainfed rice lands.
- Water budgeting in grow-out aquaculture of some commercially important fish and prawn species.

- Design and development of rubber dams for watersheds.
- Reclamation of upland acid soil by use of paper mill sludge and techniques for safe use of paper mill and distillery wastewater for growing agricultural crops.
- Design of secondary reservoir for efficient storage and utilization of rainwater.
- Integration of System of Rice Intensification (SRI) method of rice with fish culture.
- Planting techniques for different cash crops.
- Design of raised and sunken bed system for medium and low lands to achieve crop diversification and higher cropping intensity.
- Development of regional groundwater recharge and flow simulation model using soil-water balance approach & MODFLOW.
- Development and demonstration of a model for conjunctive use planning of irrigation through bore-wells, dug wells and ponds on farmers' participatory approach in canal command areas.
- Database on groundwater utilization, availability and its development, groundwater table depth, irrigation potential created and utilized for Odisha.
- Standardization of design and evaluation of sub surface water harvesting structures.
- Standardization of design of surface drainage system for doab areas in delta region with special reference to Kushbhadra-Bhargavi doab for enhancing drainage intensity.
- Standardization of package of practices for bio-drainage in waterlogged areas.
- Package of practices for cultivation of water chestnut and medicinal plants for productive utilization of both seasonally and perennially waterlogged areas.
- Development of contingent crop planning for post flood scenario in waterlogged areas.
- Development of strategies for suitable use of brackish water shrimp farming interfaced with paddy growing coastal area.
- Standardization and transfer of technologies on water use efficiency for 52 crops across different agro ecological regions in the country.
- Development of linkages between irrigation, agriculture, living and poverty in eastern India.
- Assessment of irrigation performance of Water User Associations (WUA) under Participatory Irrigation Management (PIM).
- Imparted training on enhancing water productivity in agriculture to about 5647 farmers including 857 women in Odisha.

- Development of water use efficient cropping systems for different 14 agro-ecological regions.
- Assessment of water demand and supply at distributary/minor/sub-minor levels in different reaches in 14 major command areas of India.
- Development of crop plans/cropping system for existing supply system and canal scheduling for proposed cropping systems.
- Development, refinement and standardization of drip fertigation technology for major cash crops and vegetables for different agro ecological regions.
- Alternate use and efficient cropping system in waterlogged areas.
- Conjunctive use of fresh water and poor quality water in canal commands.

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Challenges

India supports 17 per cent of the human and 15 per cent of the livestock population of the world with only 2.4 per cent of the land and 4 per cent of the water resources. Out of the total annual precipitation of 4000 billion cubic meters (BCM), the utilizable water resources of the country have been assessed as 1123 BCM, of which 690 BCM is from surface water and 433 BCM from groundwater sources. It has been projected that population and income growth will boost the water demand in future to meet food production, domestic and industrial requirements. The projected total water demand of 1447 BCM in 2050 will outstrip the present level of utilizable water resources (1123 BCM) out of which 1074 BCM will be for agriculture alone. Since the total projected demand will be 324 BCM more than the present level of utilizable water resources, the challenge will be to (i) produce more from less water by efficient use of utilizable water resources in irrigated areas, (ii) enhance productivity of challenged ecosystems, *i.e.*, rainfed and waterlogged areas, and (iii) utilize a part of grey water for agriculture production in a sustainable manner.

Assured irrigation in conjunction with other technological and policy factors has played a catalytic role in the growth of Indian agriculture over the years. Various estimates point to a substantial contribution from irrigated agriculture to overall agricultural production of the country. For example, the contribution from irrigated agriculture to total agricultural production in India ranged from 55% (World Bank, 1991) to 58% (Planning Commission, 1999) to 60% (Seckler and Sampath, 1985). Because of the yield augmenting impact, irrigation development has always been the priority area of the national agricultural development strategy in the successive five year plans with massive financial support. Consequently, the gross irrigated area in the country has increased from 22.56 million hectares in 1950-51 to 86.4 million hectares in 2009-10 (CWC, 2012). The positive impact of irrigation development was realized in the form of increased food grains production (from 51 million tonnes to 252 million tonnes) and cropping intensity (from 111 per cent to 138 per cent) during the same period. However, the irrigation sector in the country is suffering from several pitfalls. The utilization of already created irrigation potential is only 74 per cent and the gap between irrigation potential created (IPC) and its utilization (IPU) is increasing over the years. For the country as a whole, about 88 per cent of the ultimate irrigation potential (UIP) has already been developed through different major, medium and minor irrigation schemes, which limits further large scale expansion of irrigation infrastructure. Thus, improving the utilization of already created irrigation infrastructure by removing existing operational and maintenance inefficiencies will contribute positively for the agricultural growth in the country. Most of the irrigation projects are operating at an overall efficiency of only about 30 to 35 per cent against the achievable efficiency of more than 50 per cent. Thus, there is enormous scope to improve the productivity and efficiency of irrigation systems which can be achieved both by technological as well as social interventions. It is estimated that with 10 per cent increase in the present level of efficiency in irrigation projects, an additional 14 million hectare area can be irrigated from the existing irrigation capacities which would involve a very modest investment compared to what is required for creating equivalent potential through new schemes. The social and environmental costs involved will be an additional factor to be reckoned with this respect. Further, measures to alleviate the degradation of natural resources due to over-irrigation have to be taken in an economic and optimal manner.

Presently, groundwater is the largest source of irrigation contributing about 60 per cent of the net irrigated area of the country. Overall, only 58 per cent of the total groundwater resources have been developed indicating scope for its further development. However, there exists wide variability in its development across different geographical regions of the country. The over-exploitation of groundwater resources (higher withdrawal than recharge) in North-western states coexist with its under-utilization in the water abundant Eastern region. The 'tube well explosion' in many pockets of the country has raised sustainability issues on groundwater resources. Most of the groundwater development has taken place through private investment. Further, government policies of providing free/subsidized electricity and pumps in many states are adding fuel to the water crisis. Reduced farm profitability via increasing pumping cost, deceleration in productivity of irrigation water and equity issues in groundwater distribution are also being considered as major challenges in this context. Groundwater pollution is another emerging threat to the sustainability of water resources. Therefore, an understanding of interrelationship of hydro-geological, agro-climatic, socioeconomic and policy factors for sustainable development and equitable distribution of this precious natural resources needs due emphasis.

Presently about 350 Class I and Class II urban centres having

>50,000 population generate around 38,254 million litres per day (mld) of waste water out of which only 11,787 mld (31 per cent) get treated. It has been projected that wastewater generation will cross 170,000 mld (62 BCM) by 2051 in addition to 30 BCM wastewater generated per year from various industries (CSE, 2010). Recycling and reuse of this huge wastewater resource is a challenge for maintaining food security and restore health of the natural resources *vis-à-vis* the environment.

The country has huge area under two challenged ecosystems, *i.e.*, rainfed and flood prone/waterlogged areas which have low productivity. Presently about 78 Mha area is under rainfed and it is estimated that even with exploiting all utilizable water resources, approximately 55% of the gross cropped area will remain rainfed. Presently rainfed production system accounts for 91 % production of coarse cereal, 49 % of rice, 91 % of pulses, 80% of oilseed and 65 % of cotton and the situation will remain same in the next 40 years. Thus, to ensure food and nutritional security, it is essential that the productivity of rainfed areas is increased significantly. However, the approach cannot be uniform for whole rainfed areas. It is noteworthy that about 33% of rainfed area receives more than 1100 mm of rainfall and another 33% receives rainfall between 750-1100 mm. This institute has developed technologies of rain water management for providing reliable round-the-year irrigation in high rainfall areas. With refinement, enriching and fine-tuning of these technologies along with innovative new approaches for different agro-ecological regions, a significant area can be brought under irrigation and thereby pushing productivity from the present 1.0 t/ha to 4-5 t/ha per annum by enhancing cropping intensity from present 100% to 200%. This will contribute hugely to national food security. Enhancing productivity from this region will help in modifying the approach for other two rainfed zones receiving 500-750 mm and less than 500 mm rainfall. It has been found that in these two regions, farmers tend to go for water guzzling food/commercial crops replacing traditional crops which have more resilience against climatic variations. This has led to unsustainable cropping system leading to resource degradation as well as high volatility in yields/returns. This has adverse consequences on productivity and livelihoods during periods of crop failure.

The other challenged ecosystem is waterlogged areas which account for about 8.5 Mha in India. There are two types of waterlogged areas: one where the water table has risen due to over irrigation up to within root zone (approx 2.16 Mha) and another where water congestion occurs due to high rainfall coupled with land topography which hinders drainage. While the first situation can be remedied through efficient irrigation and creating drainage network, the second situation requires a multipronged approach of having an optimal mix of engineering, crop selection, crop management and aquaculture practices supported by market intervention, processing and value addition.

Indian Institute of Water Management, Bhubaneswar proposes to take up these challenges in a holistic manner in the next four decades to meet the food and nutritional requirements of the nation through development of technologies compatible to the socioeconomic conditions of different agro-ecological zones and capable of providing an inclusive growth. Institute will focus on basic, strategic and frontline research and generate locally suitable technologies for different agroecological zones through its centres of AICRPs. It will also address the issues pertaining to water governance and effective dissemination of the developed technologies to the various stakeholders.

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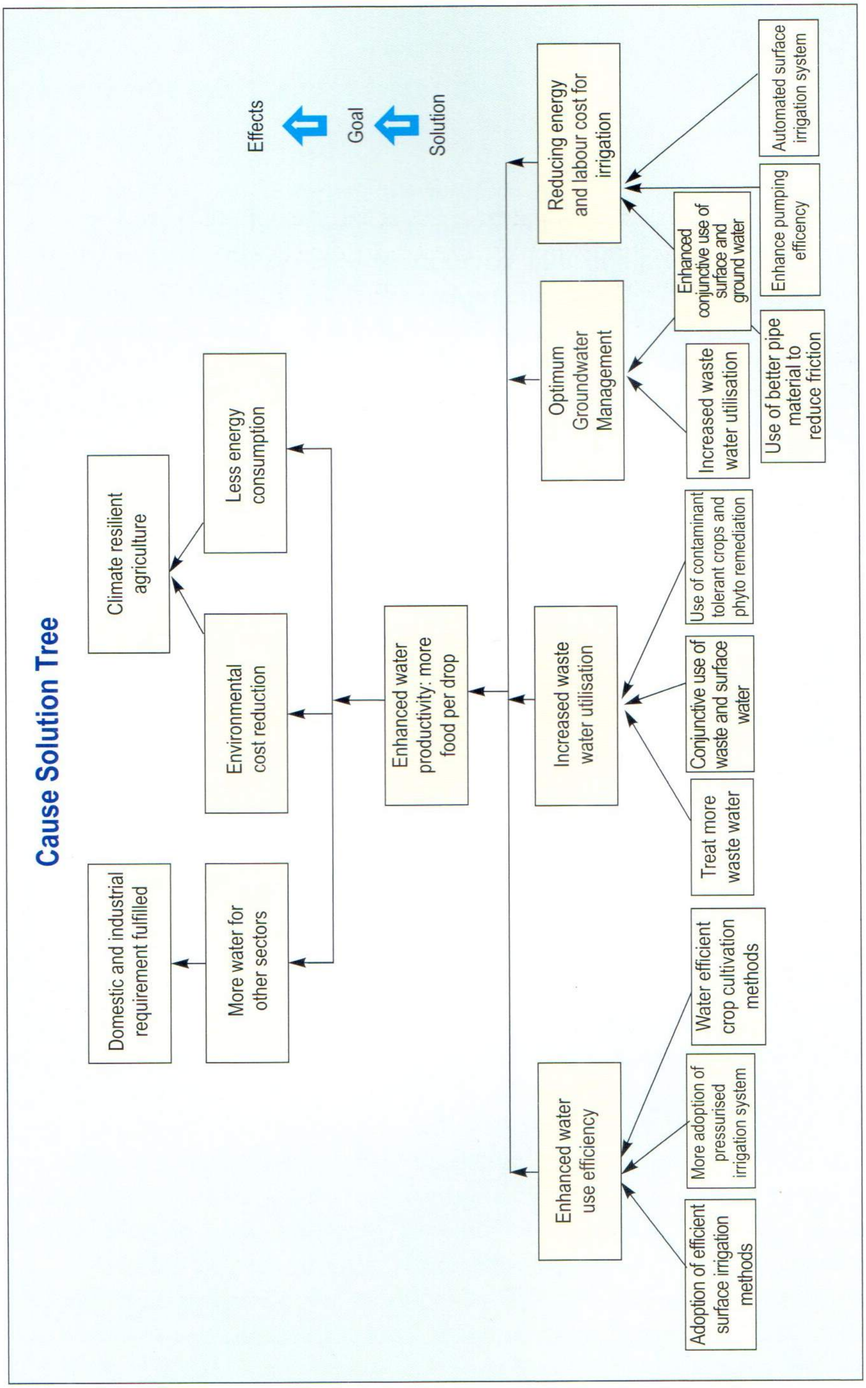
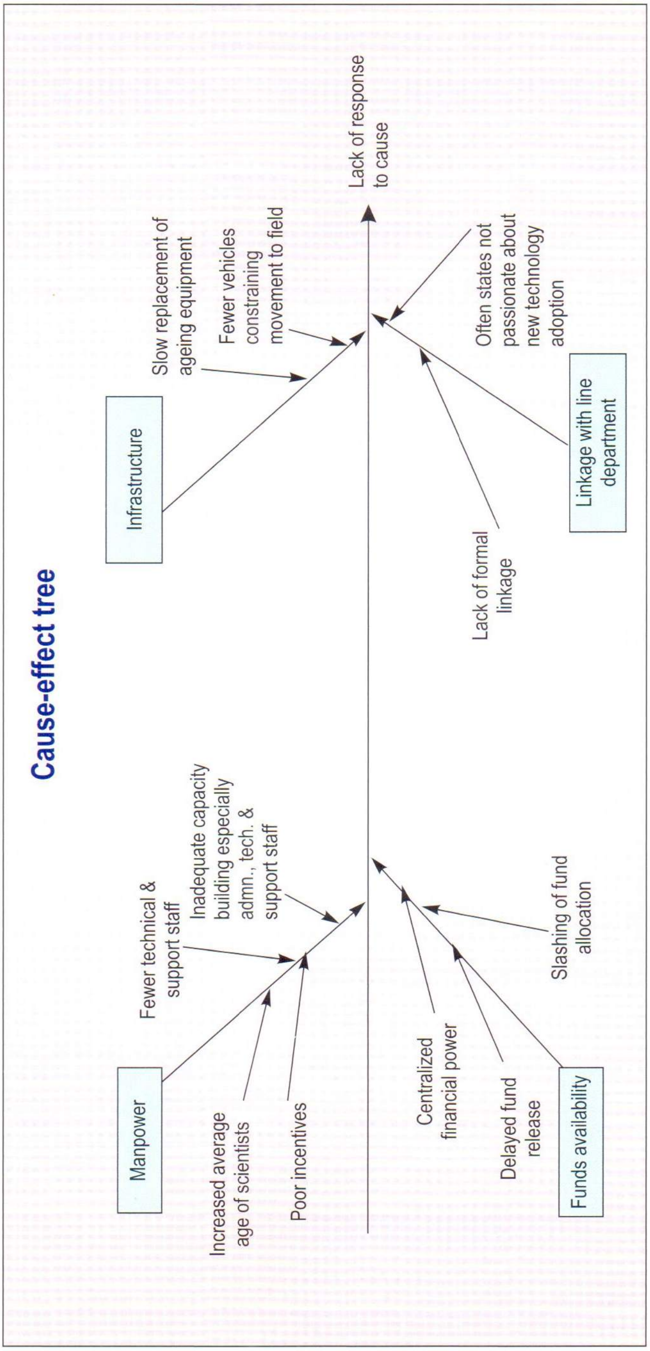
Cause Solution Tree




Cause-effect tree
Lack of response to cause
Infrastructure
Slow replacement of ageing equipment
Fewer vehicles constraining movement to field
Linkage with line department
Lack of formal linkage
Often states not passionate about new technology adoption
Manpower
Increased average age of scientists
Poor incentives
Fewer technical & support staff
Inadequate capacity building especially admn., tech. & support staff
Funds availability
Centralized financial power
Delayed fund release
Slashing of fund allocation

Operating Environment

The operating environment for research on water use in agriculture will include the competing demands from different sectors, waste water generation due to urbanization and industrialization, changes in institutional mechanism of water governance, mode of investment in water and finally climate change which is expected to affect both quantity and spatio-temporal variations. The opportunities and constraints under which the research efforts will have to function due to these factors is discussed below:

Water as commodity is finite in volume which will not vary in its availability with time. However, its quality as well availability to different sectors is going to change in coming years. This has got both global and national dimensions. Globally, the potential availability of water decreased from 12900 m^3 per capita per year in 1970 to 9000 m^3 in 1990, less than 7000 m^3 in 2000 and projected to hit as low as 5100 m^3 per capita by the year 2025. Eventhough, with standard living style at least 2000 m^3 per capita per year is required in densely populated Asia, Africa, Central and southern Europe, current per capita water availability ranges between 1200-5000 m^3. By the year 2025, about 3 billion people will be in water stress category with 1700 m^3 of available water (in scale of 500 m^3 – absolute scarce, 500-1000 m^3 – scarcity, 1000-1700 m^3 – stress and > 1700 m^3 – no stress). The availability of water for agriculture in India is expected to decline from 84% in 2010 to 74% by 2050 (Table 1). Even within agriculture, the water demand for different subsectors or farming systems will change significantly in the coming years. The additional water demand in domestic, industrial and energy sectors will need additional 222 BCM water by 2050 (Table 1). Under the scenario of producing 350 million tonnes food grain from shrinking water resources, this will put tremendous pressure on the existing water sources. This challenge can be met either by inter basin water transfer or by enhancing irrigation efficiency and water productivity or both. However, pressure on inter basin transfer can be eased through improving crop water productivity. It is estimated that 1% annual increase in water productivity (quantity per unit consumptive water use) would meet additional water demand for grain production and if it is further improved to 1.3%, water demand for all crops can be satisfied (Amerasinghe *et al.*, 2012). Since, presently the crop water

Table 1 Sector wise projected water demand in India

(Billion cubic meters)

Sector/Year	2000	2010	2025	2050
Irrigation	541	688	910	1072
Domestic	42	56	73	102
Industry	8	12	23	63
Energy	2	5	15	130
Others	41	52	72	80
Total	634	813	1093	1447

(*Source:* Central Water Commission, 2008 & 2010)

productivity is low and varies widely over different regions and land use pattern; there is scope for improving crop water productivity of food grain and other crops. Once achieved, this demand of water from other sector can be met with present water resources.

The major factor deciding the water demand will be governed by changes in the socioeconomic status of the population and the extent of urbanization and industrialization. In recent years, there have been significant changes in the consumption pattern and the share of non food grain items in food consumption is increasing. Due to this, there is sharp increase in the demand of such items, *i.e.*, milk, eggs, meat, vegetables and fruits. It is expected that this condition will continue and the gaps will further widen in the next 40 years unless corrective measures are taken to enhance production.

As indicated earlier, about 375 BCM of water will be required for uses other than agriculture, *i.e.*, domestic, industrial, power and others. Considerable proportion of this requirement is non-consumptive and is discharged with varying level of pollution. All these sectors through water use generate large amount of wastewater containing varying levels of contaminants, making them unfit for most of the uses. In the large peri-urban areas, these wastewaters are used either without treatment or partial treatment for growing horticultural crops, with potential health hazard to farmers as well as consumers. Similarly fodder grown (to meet demand of livestock, another prominent activity in peri-urban areas) with wastewater increases the chances of entry of heavy metals and other undesirable substances into the food chain. With water availability shrinking further, these instances are going to increase both in number and magnitude. This component of operating environment has to be investigated to create a data base on generation of wastewater and its quality (segregating in four classes: marginally poor, poor, highly degraded, unusable) to develop technologies for their reuse along with identification of sectors where it can be used.

Water governance in some part of the country has moved from totally government controlled system to participatory mode, PPP mode and private sector. While surface water sector governance is largely in public control (*i.e.* government), ground water sector is almost in private sector. There has been a significant shrinkage in public investment in water sector, which has declined from 23% to 8-10% of plan budget. It is expected that the government will further withdraw from this sector in the coming years, while empowered regulatory authorities would be expected to monitor the water resource system in next decades.

Drudgery in agricultural operations is a major cause of low preference of agriculture among labourers. Although there have been a lot of research efforts to reduce drudgery of agricultural operations, very little has been done in water application sector to enhance the convenience and comfort level in operations. Few reports suggest that the cost of irrigation labour varies from 30 to 50% of total cost. Increased aspiration of labour as well as competing opportunities of labour in other sectors will further aggravate this problem. Thus there is an urgent need to intensify research efforts to improve technology of surface irrigation system which requires less labour and is more efficient. This can be achieved by introducing some level of automation including estimating irrigation requirement through field sensors.

Climate change scenario will influence all our estimates and projections. The studies have suggested that rainfall in the tropical region will increase by 10-15%, and the extreme rainfall events will be more frequent leading to increased runoff, higher number of dry days and longer dry spells. Rising sea levels will increase salinization of coastal aquifers, as well as waters of rivers in the delta zone. These factors will affect our whole irrigation and drainage systems. Thus we will have to evaluate whether our existing irrigation and drainage systems are robust enough to cope up with expected changes in rainfall pattern. Further, what should be the changes in design and construction codes of soil and water conservation structures, irrigation and drainage systems so that they can withstand the unpredictability of weather during their expected life period.

Rising cost of energy and competing demands from other sectors will make it prudent to make agriculture more energy efficient. Irrigation is the second most energy intensive input after tillage operations and therefore the cost and availability of energy will be a guiding factor in future research programmes from both fossil as well as renewable sources. Declining ground water table will add further consumption and cost of energy. A one percent fall in ground water table will increase energy consumption 1.25-1.5%. Similarly an increase of 5% pumping efficiency will reduce the energy requirement in similar proportion. Both these factors will have to be accounted for in future research programme.

The increased feed grain demand to 38 Mt in 2025 and 111 Mt in 2050 will provide an opportunity of more productive utilization of our land resources in the ecosystems challenged either by quality of water or by soil and land resources. This will require identification of non-conventional feed resources which can be grown in these challenged ecosystems. This approach has a potential of altering the landscape of these ecosystems which will be more climate resilient as well as would prevent/reverse degradation of natural resources base.

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New Opportunities

The challenge in next four decades will be efficient as well as productive utilization of available water both in terms of food per unit of water and energy requirement, waste water utilization, sustainable and quality recharge of ground water, reduction in water use of crops and productive utilization of land and water resources in challenged eco-systems. The effort to take on these challenges will be substantially facilitated by advances in material science, bio-technology, electronics and geo-informatics which will alter the scenario. Few developments which will provide new opportunities of reworking our irrigation and drainage systems are:

The sensor technology along with communication technology is being upgraded continuously. A major constraint in automation and improving efficiency in surface irrigation system is combining sensors with operation of irrigation system for field conditions. A simpler and rugged sensor technology for estimating on-field surface irrigation requirement and coupled with control system will be a breakthrough in irrigation management. This can also be used for demand and supply management on real time basis in canal system.

A major problem in pressurized irrigation system is clogging of drippers, high energy requirement and higher cost. Breakthrough in material science will provide new materials which will be helpful in dealing with these problems. This issue will have to be dealt in close collaboration with R & D of private sector. Development of pressurized irrigation system for higher water requiring crops like rice, sugarcane etc. will be among other opportunities for exploration.

Most of the traditional crops which survive in stressed/challenged ecosystem are climate resilient. They are also nutritionally rich as well as contain phytochemicals and therapeutic compounds. However, lack of affordable technology to extract these nutrients/phytochemicals/ therapeutic compounds is a major hindrance for commercially viable and sustainable cultivation of these traditional crops particularly in stressed/ challenged ecosystem. If these technologies are made available then more climate resilient, sustainable and water efficient farming systems providing livelihood in challenged ecosystems can be developed. In view of share of ground water irrigated area being close to 60% and further increasing, improvement in efficiency of water lifting devices/equipment is needed to reduce cost of cultivation and conserve energy. The advances made by automobile industry to design efficient engines can be used as a base for improving the efficiency of pumps. At present, virtual water trade is from water scarce north western and southern region to water rich eastern India. This scenario is stressing the already stressed regions and therefore suitable policy measures should be taken to contain it. Since most of the food grain transfer takes place to meet the demand of Public Distribution System in deficit districts, a concept of creating Special Agricultural Production Zone in deficit districts will go a long way in correcting imbalance in virtual water trade.

Reuse of waste water to bridge the gap between availability and demand will become a more viable option in coming decades. Biotechnology and material science research are underway to develop new organisms, materials which can convert the waste water to usable one. These development/innovations would create a sea change in attitude/ technological options of using waste water of various qualities for food/fodder/timber production.

A viable option for enhancing the use of existing utilizable water resource will be recharge of ground water from runoff water, *i.e.* storing runoff water in underground aquifers. However, for maintaining aquifer's health, it is essential that the quality of recharge water is maintained as per acceptable standards. This will be a major challenge in the planning and designing of groundwater recharge structures. Advancement in material science has potential for developing filters which can take care of this problem, and this will alter the paradigm of groundwater recharge research.

One of the major areas is development of water use efficient cultivars of different crops through biotechnological approach. Both breeders and scientists from NRM division need to work together rather than developing variety first and then looking for its water management practices later, so that compatible design and operation of irrigation systems are developed simultaneously.

With an objective of enhancing productivity of water, applying the concept of deficit irrigation, can achieve greater economic gains under a water deficit scenario than maximizing yields per unit of water for a given crop. With increasing sectoral demands of water from industry, energy, urban development sectors, water scarcity in agriculture is increasingly felt. Aerobic rice is an emerging agronomical production system that uses less water than conventional flooded rice. Efforts would be made for standardizing water management practices for aerobic rice cultivation in irrigation commands providing space for other crops in terms of water availability. Timely DSR crop establishment during mid May to mid-June (or 15-20 days before commencement of monsoon) is a crucial determinant of success in crop and irrigation water management and needs standardization for successful implementation of the technology. Similarly use of modern tools like GIS, remote sensing and modeling tools will also be intensified for upscaling of the technologies at higher level.

The consumption pattern of Indian population is changing with animal products contributing in a major way. Thus the pressure on farm lands to grow more feed and fodder will increase further. The opportunity emerging out of this will be to utilize stressed/challenged ecosystem to fulfill the rising demand through water efficient crops, shrubs and trees. Technological innovations will be required to use non conventional feed sources.

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Goals and Targets

The goal of IIWM will be to develop a range of location/region specific water management technologies to ensure food and nutritional security of country with reduced availability of water. To achieve the target, the IIWM will aim for following :

- Efficient surface irrigation methods and small holder centric water management practices to improve irrigation efficiency.
- Efficient pressurized irrigation methods and fertigation protocols for different crops to achieve more output per unit of water by pressurized irrigation system.
- Enhancing water productivity of rainfed ecosystems through rain water management, alternate land use system/ farming and multiple use of rain water.
- Improving water productivity of challenged ecosystems including waterlogged and rainfed areas.
- Strategies for mitigation of drought, flood and other natural calamities in the changing climate scenario.
- A water–land–soil resource index map to demarcate critical target areas, which warrant immediate attention for NRM to ensure continuation of food and nutritional security along with decent livelihood from agriculture.
- Evaluation of new materials and products to improve the performance of water lifting devices and reduce energy consumption of pressurized irrigation system.
- A comprehensive technology package for utilization of waste water of different qualities including basin wise spatial and temporal mapping of availability of waste water of different qualities and sensor based water quality monitoring.
- Low cost, simple electronic devices for water application and irrigation scheduling.
- Expert system/decision support system for efficient water management.
- Developments of a dynamic institutional mechanism for water governance with inbuilt flexibility to adopt changing socio-economic scenario.

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Way Forward

To achieve the goals/targets in a changing scenario and given the emerging opportunities created by frontier research in other related fields, IIWM will chart a new course. This new path will involve much closer collaborations with other divisions of ICAR with special reference to horticulture, animal sciences and fisheries, in addition to other institutes of NRM, material science research organizations and other related research institutes. It will also undertake a gradual reorientation of the present institute research programmes as well as AICRP to enable them to be in tune with the goals and targets envisaged.

The major strength of any research effort is its manpower whose skills should be upgraded in a continuous manner. The capacity building and skill upgradation programme of scientific and technical manpower both at Institute as well as AICRP will be upscaled to make them ready to take up new challenges. The road map for the next four decades will lay special emphasis on exploring the potential of challenged ecosystems in terms of enhanced productivity as well as new livelihood opportunities without degrading the natural resource base. A systematic comprehensive HRD plan for both Institute as well as AICRP will be formulated to get exposed (training) in the emerging field/cutting edge technologies from world class institutions.

At international level, collaboration will be established with Wageningen University, The Netherlands, CEBAS-CSIS, Murcia, Spain for waste water utilisation. Collaborative Project of ICAR with University of Nebraska, Lincoln, USA will be developed for Global Yield Gap Analysis and Water Productivity Atlas. ICAR-ICRISAT collaborative effort will be strengthened for Tracking Changes in Rural Poverty in Household and Village level Economics. Collaborative projects will also be explored with organizations like IWMI, IRRI, ILRI, USDA for increasing irrigation efficiency as well as utilization of special materials in irrigated agriculture.

Further, as the number of stakeholders is very large and scattered, a technology demonstration and refinement programme will be launched in collaboration with more than 600 KVKs as well as NGOs and industries so that the ultimate client *i.e.* farmer get involved in this journey of technology development and its dissemination. The Institute will strive to get a feedback from the end users towards its technologies so that the updating can become a dynamic process with technologies having compatibility with changing socio-economic conditions of farmers.

Success of transfer of water management technology depend on a whole set of institutional arrangements and the willingness of state development departments as stakeholders to comply and enforce and/ or change the rules under evolving circumstances. Effective water governance and policies hold a key for the successful implementation of technological interventions/innovations and its adoption by the farmers. As use of productivity enhancing inputs in agriculture is often influenced by the available irrigation water regime, the other extension services need to be complemented for implementing efficient crop planning, synchronization of farm operations, linking farmers to other sources of knowledge, support and services and establishing effective forward and backward linkages. Similarly Common Property Resources (CPR) and eco-system service provided by the water resources are essential component of the sustainable water resources management. There is a strong need to strengthen the linkages among the CPR, eco-system services, markets and policies through systematic studies. Further networking of development departments, KVKs, and NGOs with the institute for sharing of information and expertise in a better manner, IIWM will strive hard to establish effective functional linkage mechanism to achieve this goal.

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