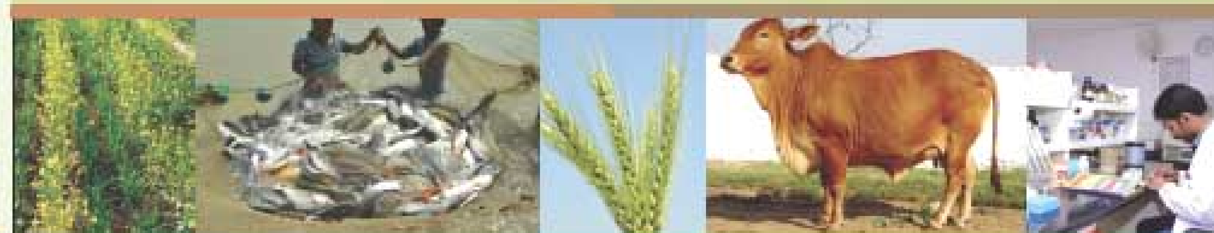
Vision 2050

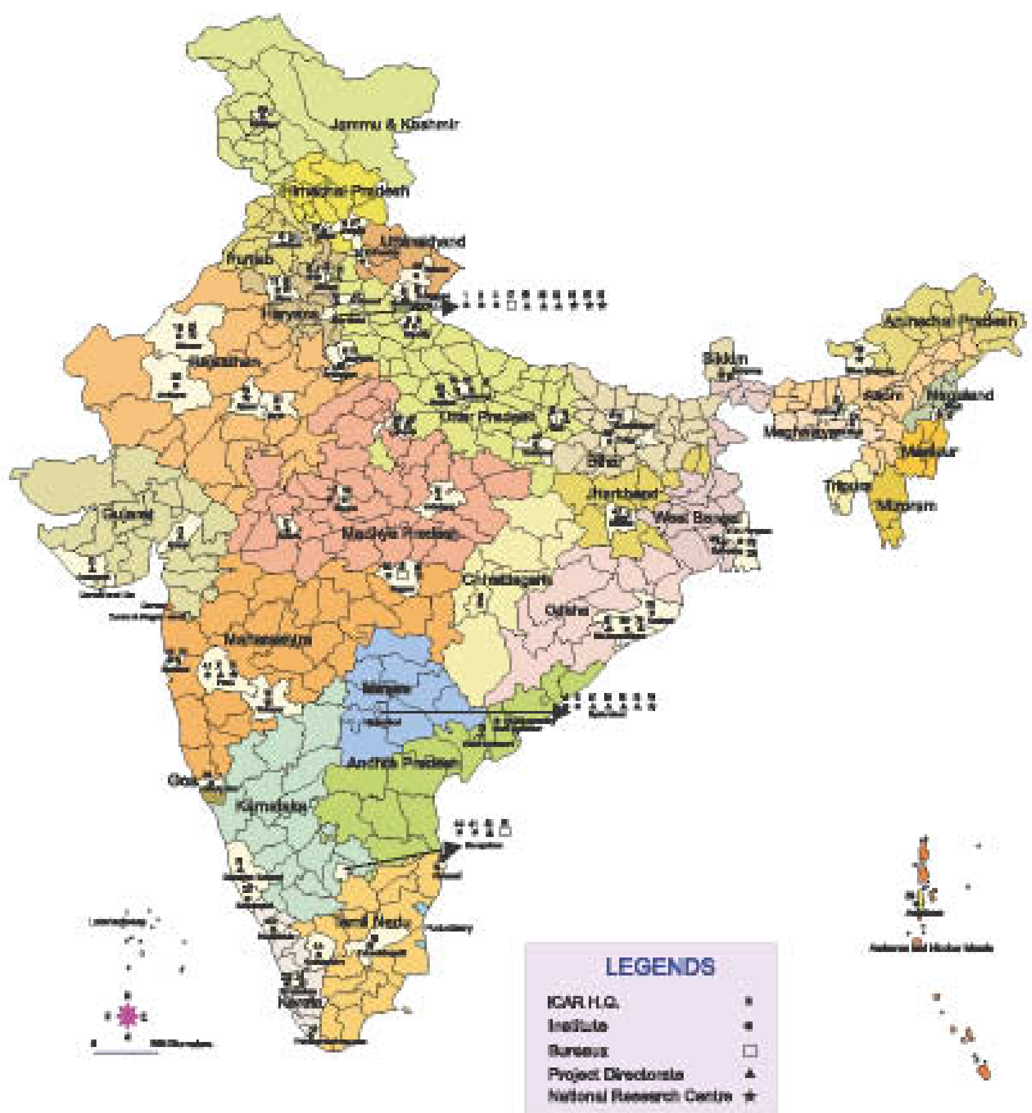


Indian Council of Agricultural Research

Krishi Bhawan, New Delhi

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Institutes, Bureaux, Directorates and National Research Centres



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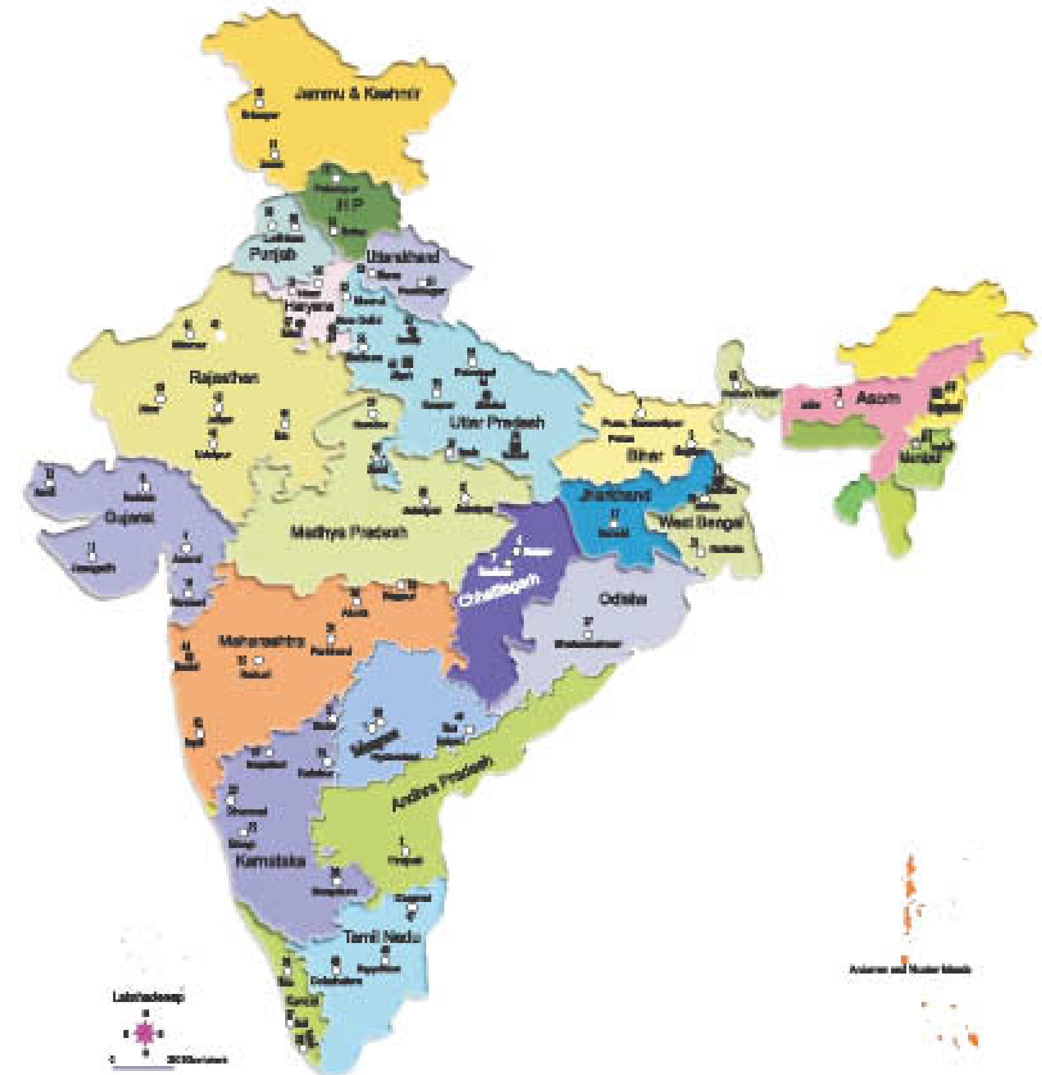

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Vision 2050

भाकृअनुप

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www.icar.org.in

Printed : July 2015

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

Preface

The Indian Council of Agricultural Research is an apex research organization of the country with a high standing amongst international agricultural research institutions. Since its inception in 1930, the Council has been spearheading agricultural research, education and extension activities for productivity enhancement and diversification of Indian agriculture.

The world as a whole is undergoing several transformative changes. Growing population, changing lifestyles, expanding urbanization and accelerated climate changes are creating new challenges for the national agricultural research system. Whereas in the past, the challenge was to supply adequate food, but now it is to provide adequate nutrients to promote health; and in the future, the challenge would be to provide optimal nutrients based on individual's genetic profile. Fortunately, along with challenges, the developments in science are creating new avenues for tackling the challenges. The Indian Council of Agricultural Research (ICAR) and the National Agricultural Research and Education System at large, are determined to harness the advances of science for the welfare of society. The Council is committed to transform itself into an organization engaged fully with the farmers, industry, entrepreneurs and consumers at large.

To keep pace with the changing environment, the ICAR has been updating its visions and strategies from time to time. The first systematic effort to envision the challenges and opportunities, and formulate its own strategy was undertaken in the last year of the 20th century by preparing 'Vision 2020 document'. The next attempt was after five years by bringing out the 'Perspective Plan' and the 'ICAR Vision 2030', coinciding with XI plan. The present document, 'ICAR Vision 2050', provides the strategic framework for innovation-led inclusive and sustainable agricultural growth in the country.

I would like to express my gratitude to the Hon'ble Union Minister of Agriculture for his invaluable guidance in preparing the ICAR Vision 2050. I am grateful to the Hon'ble Union Minister of State for Agriculture for his keen interest in this initiative. We are thankful to all the Members of the Governing Body of the ICAR for their valuable suggestions in finalizing this document.

I am sure that ICAR Vision 2050 would stir a new thinking in the researchers to harness science, in the policymakers to develop policies for sustainable development of agriculture to provide food, income and livelihood, and in the consumers an urge to tailor their lifestyle, keeping in view the planetary boundaries of the Earth's resource system.

(S. Ayyappan)
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Contents

Agriculture Scenario, Challenges and Opportunities

Humanity faces numerous challenges and most of them are linked to food security of the exploding population which is expected to cross the 9 billion mark by 2050. Globally, the contribution of agriculture to Gross Domestic Product (GDP) is declining, but agriculture still supports the livelihood of more than 2.6 billion people in the world, living mostly in rural areas. In low-income countries of Africa and Asia, potential for non-farm employment is limited, viability of subsistence agriculture of smallholders is under stress, and inequity is widening. The extraordinary progress in food production in the past half century was also accompanied by unsustainable levels of consumption in some countries and hunger and malnutrition in some other countries, largely in South Asia and Africa, leading to poor health, reduced earning capacity and degradation of environment. The fast emerging phenomenon of climate change is putting more pressure on the natural resources we depend on, and the safe space for operation within the planetary boundaries of earth's resource system is shrinking. It is time to rethink on how food is cultivated, processed, shared and consumed. There is a growing concern for development that ensures human happiness as embedded in the UN Millennium Development Goals and is the first principle of the 1992 Rio Declaration, which states, "*Human beings are at the centre of concern for sustainable development*" (UN, 1992).

Table 1 Status of selected global parameters

Parameter	Value	Parameter	Value
Population (2011)	7 billion	Area of agricultural land (2009)	4.9 billion hectares
Undernourished people (2010)	0.9 billion	Growth in agricultural production (1997–2007)	2.2% per year
People living on less than USD 1.25 per day	1.4 billion	Losses due to extreme climatological events	USD 11.4 billion
People living in dryland areas (2007)	2 billion	Food lost or wasted annually	1.3 billion tonnes

Source: Beddington et al. (2011).

A profound change in the global food and agriculture system will have to be incorporated, if we are to feed today's 925 million hungry people, of which 230 million live in India. About 2 billion people are expected to be added to this category by 2050, mostly in developing countries, if corrective measures are not applied. On the brighter side, food security and sustainable agriculture are now on top of the global development agenda (UN, 2012). Sustainable agriculture is central to everlasting development and the judicious application of science and technology can help to achieve "zero hunger" goal even much before 2050.

Indian Agricultural Economy

Currently, the agriculture sector contributes only about 13.7 per cent to the national GDP (compared to 30% in 1990), though agricultural production in 2013 was at all-time high of 264 million tonnes. High dependence on agriculture for livelihood support (more than 50% population) is the main factor responsible for the high share of poverty in rural population. The agricultural economy that grew at an average rate of 3.7 per cent per year during 2007-2012, is projected to grow annually at 4.0 per cent during 2012-2017, with growth in national GDP estimated at 8 per cent. However, it must be remembered that the GDP estimates do not take into account the costs of environmental degradation. Agriculture places considerable load on environment in the process of production of goods and services. A template for estimating green national accounts, which would measure national production while allowing for the negative effects on national resources, is contemplated.

Further, India is predominantly a small farm agriculture. According to 2010-11 Agriculture Census, the total number of operational holdings was 138.35 million with average size of 1.15 ha. Of the total holdings, 85 per cent are in marginal and small farm categories of less than 2 ha (GOI, 2014). These small farms, though operating only on 44 per cent of land under cultivation, are the main providers of food and nutritional security to the nation, but have limited access to technology, inputs, credit, capital and markets.

The current trends indicate that by 2035 the growth rate of rural population will turn negative, leading to increase in the size of cultivation units, tightening of rural markets and increased mechanization of agriculture. By 2050, very few well-trained and farmer-cum-entrepreneurs will produce food. Their production systems are likely to be more commercial-oriented, operating at high productivity levels in a highly mechanized environment. It is more likely that today's small holders will organize themselves into producer companies and will have more bargaining power. Therefore, the country's research and development agenda has to be re-oriented to develop and promote such technologies that would raise agricultural income and generate employment opportunities in the agri-supply chain. Though being limits on land-based agriculture's capacity to provide decent livelihood, the right course for growth of rural economy would be to ensure increased off-farm opportunities in bio-industrial complexes within the village clusters.

Drivers of Food and Agriculture Systems

The evolution of food and agriculture systems is complex and their numerous drivers have been traditionally viewed from one of two perspectives: multidimensional sustainable development perspective (environmental, social, economic, technological and policy-related dimensions); or essentially economic food demand-supply perspective. The need is to integrate both these perspectives across the research agenda of ICAR and NARES.

Drivers of Food Demand

The exploding population, expanding urbanization and rising incomes have raised a wide range of important issues linked to national food-security, including dietary preferences (higher demand for livestock products), consumption of more processed foods and crowding out of peri-urban agriculture which plays a significant role in the supply of perishable commodities (FAO, 2012). The population of India is projected to be 1.65 billion by 2050 with an average income of **₹ 401839/cap,** up from the level of **₹ 53331/cap** in 2010-11, with 50 per cent people residing in the urban areas (Table 2).

Table 2 Drivers of food demand and projections to 2050

Driver	2010-11	2050	Implications
Demand Side Challenges			
Population, million	1224.6	1650 (+24 %)	Changes in demography with shift towards urbanization and higher income will lead to changes in dietary composition with increased consumption of meat, dairy, egg and fish products having higher water and carbon foot prints
GDP at PPP (US$ billion) Average annual income (₹cap) Income distribution	4786 (WB) * **53331***** Inequitable	43180 (PWC) ** **401839***** Inequity may widen	
Urbanization (%)	31	55	
Calorie requirement (kcal/cap) Source: (Vegetables; Animal)	2500 (92:8)	3000+ (84:16)	
Food price	Rising trend	Rising trend will continue	
Functional food	It is at the initial stage	Demand will grow	
Social concerns over new technologies	Very strong	Will decline with proper communication and counseling.	
Food safety	Poor	Will improve	

Source: *World Bank (2014), **PWC, (2014), ***NCAP (2013)

The size of population in the middle-income bracket will exceed 600 million (about 30% of the total population) by 2050. It is projected that by 2050, the calorie consumption will reach 3000 kcal/cap, with rise in the share of animal-based calories from the current level of 8 per cent to 16 per cent. This will increase the demand for food grains. In many ways, the Indian diets may slowly come closer to the diets in developed countries, necessitating production or import of food commodities (functional and special foods), consumed previously only in Western societies. Further, urban population being more vulnerable to increase in food prices and price spikes, it may adversely affect the food security scenario. Food wastages and losses also constitute an important driver of food demand. The estimates though vary, the wastages and losses of perishable commodities (fruits, vegetables, fish, meat and milk) can be put on average in 15-25 per cent range, while loss of non-perishable commodities may be anywhere between 5-15 per cent and this puts a considerable pressure on natural resources. By 2050, these losses are expected to be reduced significantly due to better use of technology and establishment of value chains.

Food safety is an integral part of food security, because unsafe food has significant economic costs in terms of health problems as well as cross border trade, which is hampered by inconsistent/poor food safety standards. The latent demand for food safety among urban India is set to grow with urbanization and will also increase acceptability in the export market.

There are various projections of increase in demand for food commodities in India. According to one scenario (Kumar, 2015), at 7 per cent growth rate in national GDP, though the demand for food grains will only grow by about 50 per cent, the rise in demands for fruits, vegetables and animal products will be more spectacular, the range being 100-300 per cent (Fig 1). Achieving such a high productivity will entail increase in total factor productivity (TFP). One-third of TFP must contribute to the agricultural growth. The food production density (kcal/km^2/day) requirement in most parts of India will increase from 50,000-100,000 in 2005 to 100,000-500,000 by 2050, requiring a rise in foodgrain productivity from 25000/kcal/ha/day to about 46000 kcal/ha/day (Chaumet et al., 2009).

Supply Side Drivers

A general view is that close to 90 per cent of the growth in crop production is expected to come from higher yields (potential increase by biotechnology manipulations); and increased cropping intensity, which

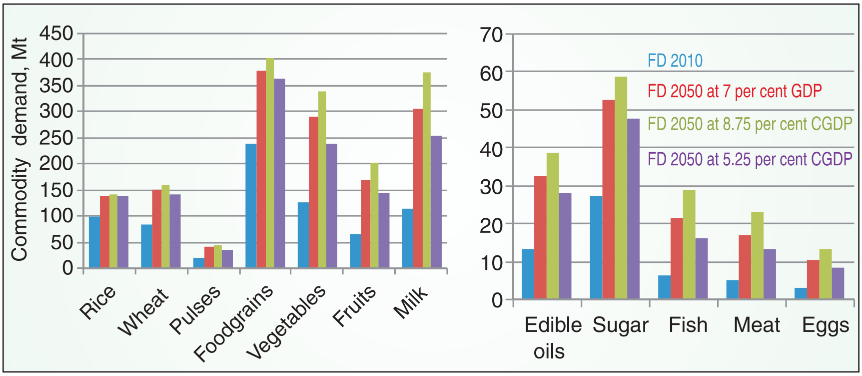

Fig. 1 Demand for various food commodities (FD) in 2010 and projections to 2050 at GDP growth scenarios of 7, 8.75 and 5.25 per cent
(*Source:* Personal communication from P. Kumar, 2015)

will mostly be possible in land facilitated with irrigation. It is expected that water-use efficiency would increase and groundwater withdrawals for irrigation would grow at a slower pace but still increase by almost 45 per cent by 2050. In medium-term, the economic growth is projected to continue at fairly sustained rates of 7-10 per cent. Due to food-feed-fuel conflict, the livestock rearing would be an intensive system with considerable reduction in numbers with simultaneous increase in productivity to meet the production targets. The supply side drivers can be grouped into three categories—environmental (e.g., climate, biodiversity, water resources etc.) economic (e.g. labour, energy, markets, investments etc.) and technology (e.g. biotechnology, nanotechnology, information technology, etc.) drivers.

Climate change: Climate change presents a major risk to long-term food security as it may have multidimensional debilitating effects on agriculture. The climatic impacts could lead to a dramatic scarcity of freshwater in the northern and peninsular regions of the country, fuelling the existing internal or interstate conflicts and heightening the competition among different users. Increasing seawater acidity and rising river water temperature will affect fish breeding, migration and harvest. Irrigated wheat and maize yields may decline by 5-10 per cent by 2050. Rain-fed agriculture, which covers 60 per cent of all the cultivated land in India, will be particularly hard hit. Except for the sates of Andhra Pradesh, Tamil Nadu and Karnataka, where yield of rain-fed rice is likely to go up by 10-15 per cent, rice yields will go down by 15-17 per cent in Punjab and Haryana and by 6-18 per cent in all other regions (CRIDA, 2013). In the longer-term, the production-depressing effects of climate change are likely to outweigh any production-boosting effects under business as usual (BAU) scenario. But, agriculture is also in a position to offer solutions to climate change; it could be a strategic asset as a major provider of environmental services (sequestering carbon, managing watersheds, and preserving biodiversity) and could provide a way to increase farm income with the introduction of payment for environmental services. Livestock has always acted as insurance during environmental stresses and is more dependable than crops. But it would require technological innovations to make them adapt to climate extremes.

Declining/degrading land resource: India is a land-scarce country with only 0.13 ha land/cap (in 2010-11), which stands to get reduced to 0.09 ha/cap by 2050, simply due to increase in population. Further, land is getting polluted with toxic waste waters and there is a large-scale degradation due to water and air erosions. Annually, India is losing 0.8 Mt of N, 1.8 Mt of P and 26.3 Mt of K. Growing nutrient deficiency and declining factor productivity are the matters of great concern. Overall, the land balance for India is negative, i.e. land classified as not suitable, is being made productive through human intervention and the most productive land is being lost to the urban and industrial sectors. Much of the remaining land suffers from constraints such as ecological fragility, low fertility, toxicity, and would require high input-use and management skills, and prohibitively high investments.

Water scarcity and quality: Changes in the large-scale hydrological cycles due to climate change are the indicators of a fast emerging water-deficit country. As against the projected total water demand of 1498 billion cubic metres (BCM) (2030 WRG, 2009), the available supply is only 1121 BCM (CWC, 2013) and close to 50 per cent crop agriculture is likely to remain rainfed. Further, natural water systems, on becoming hydrologically water deficit, will lose their dilution capacity, leading to a higher concentration of chemicals and other pollutants. These factors would create numerous water management challenges, in both rivers and groundwater across the country. Groundwater being a major source of irrigation, the inbuilt water and energy nexus will have a big impact on energy requirement. Most northern and peninsular regions are already water-stressed and, are fast becoming water-scarce, both physically and economically. This will further aggravate the existing internal or interstate conflicts besides heightening competition among different users. According to a study by the International Food Policy Research Institute, 45 per cent of the total GDP (US$ 63 trillion) will be at risk due to water stress by 2050 (Rosegrant *et al.*, 2005).

Biodiversity: Biodiversity of plants and livestock, which is so crucial for sustaining long-term productivity, is under threat. The rate of extinction is alarming, as only four crops provide about 60 per cent of global food, causing declines in genetic diversity among cultivated species. The genetically uniform systems are extremely vulnerable to external shocks under extreme weather conditions and emerging diseases and pathogens. Since 1900s, about 75 per cent of crop diversity has been lost from the farmers' fields. Similar is the case with livestock where the number of indigenous breeds with better adaptability, disease-resistance and feed-use efficiency is declining. Conservation and improvement of such breeds are foremost on the agenda of the Council.

Pandemic pest and diseases in animal and plant production: Movement of plant pests, animal diseases and invasive alien aquatic organisms does not recognize physical and political boundaries. Globalization of commodity and food trade has increased the bio-security risk, which threatens food security. It is estimated by FAO (2007) that 80 per cent of all wheat varieties planted in Asia and Africa, are susceptible to new virulent wheat fungus which spreads rapidly by wind. The spread of Severe Acute Respiratory Syndrome (SARS), blue tongue and avian flu in the livestock sector, and emergence of contagious human diseases from animals and the current epidemic of highly pathogenic avian influenza (HPAI), in densely-populated livestock-production areas around cities increase the production risks and present a major challenge to ensuring food security in the country.

To sum-up, environmental drivers like climate, water, land and biodiversity are extremely important for agricultural production, but are being degraded gradually making the food production systems increasingly vulnerable.

Economic Drivers

Food systems are vulnerable to macroeconomic trends such as stagnation, recession, commodity prices and exchange rates and therefore, to the terms of trade. The major issues are energy, labour and farm mechanization. Energy-use in agriculture for pumping water for farming is projected to increase at the rate of 1.78 per cent per year. The shifting paradigm of bioenergy, which creates new scarcities and threatens food supplies worldwide, may result in food insecurity. But, there is ample scope for harvesting solar energy for which countrywide efforts are underway. Though in absolute terms the energy consumption will go up, the energy-use intensity will have to go down. The increase in food prices may adversely affect food security. The share of labour in agriculture will decline through "push" of labour productivity improvement and "pull" of labour demand from other sectors. With industrial growth and consequent depopulation of the rural areas, the farm labour availability will decrease, causing faster mechanization of farm operations, which in turn will create need for skilled labour for operation and maintenance of farm machinery. It is expected that there will be a big increase in public spending on innovation and technology generation and therefore a mechanism to monitor its effectiveness will have to be put in place. Further, following the global trend, the private investment in agriculture, and more specifically in food research, will considerably grow in India also.

Technology Drivers

Technology advancements in agriculture and food sector will be characterized by the increasing convergence across bio, nano and info technologies. Innovations in the industrial sector will strongly influence advanced technology in agriculture and food processing, bringing in robotics and automatization in the food and agricultural sector. Mechanization of farm operations through energy-efficient and environment-friendly devices will compensate for the growing shortage of farm labour. Developments in biotechnology and other frontier sciences are creating tremendous scope and opportunities for use of agricultural products and by-products in innovative and unconventional forms. The Council, through its Bureaus, is the custodian of huge *in-situ* and *ex-situ* collections of genetic stocks of crops, animals, fishes, insects and microbes. These stocks will be useful in genetic improvement of agricultural commodities through conventional techniques and we will increasingly resort to frontier scientific techniques. Information technology (IT) systems are the core component in the transition from breakthroughs in labs to field-scale implementation. A combination of systems-research tools relating to information technology, geographic information systems (GIS), global positioning systems (GPS), remote sensing (RS); and climate smart resource management technologies, which enable practising precision agronomics, have become available. These technologies will help optimize land use to maximize calorie production per hectare on a global scale. As reported in the 2011 Global Agricultural Productivity Report, the average GPS-induced yield gains were of 10 per cent with an average input savings of 15 per cent in the USA (Global Harvest Initiative, 2011).

Smart sensors and new delivery systems will help combat viruses and other crop pathogens. Though some products and methods based on nanotechnologies, genetically modified organisms (GMOs), nutraceuticals and nutrigenomics have been introduced in the market, their impact on social organization environment, risks of pandemic diseases, and human health remain to be ascertained. Research on animal health also stands to benefit from the innovative developments in medical sciences. Further, liberalization in trade and global access will lead to greater movement of seeds/plants, planting materials and consequently, will enhance chances of introduction of exotic pests. An effective regulatory approval process for new technologies, which allows farmers to gain access to the latest technological advancements, will have to be put in place.

Markets and Value Chains

India's food processing sector is expanding in response to the changing demographics, availability of strong local and international brands, emerging modern retail chains and growing consumer demand for processed foods. The food processing sector accounted for 1.5 per cent of national GDP and was valued at US$ 14 billion during 2013-14. It was envisaged that the level of processing of perishable agri-commodities would be increased from 6 per cent in 2010 to 20 per cent by 2015, enhancing value addition from 20 per cent to 35 per cent. The public policies are geared towards diversification to high-value agriculture — fruits, vegetables, dairy and poultry, etc. — which can generate higher incomes on small farms by establishing shorter value chains and linking farmers to markets. Agri-food marketing systems are likely to undergo a significant transformation towards demand-driven, vertically-coordinated systems, managed by the agribusiness and marketing firms. Integrating small farmers into the demand-driven supply chain through appropriate institutions and policies would be a challenge. A national agricultural commodity market is proposed to be established to increase access to markets.

Growing Research Partnership and Private Sector Investment

There is an encouraging trend of forging partnerships amongst NARES and international research institutions. Globally, the share of private investment in agricultural research has become significant, as it now accounts for about a third of the total research investments; and is still rising rapidly. In the recent past, the ICAR has also graduated from aid-based research funding support to a loan-based funding such as the World Bank supported programs like National Agricultural Technology Project and National Agricultural Innovation Project, conducted in the PPP mode and making it more accountable. It is expected that in future research partnerships among public institutions, CGIAR institutes, foundations and private companies will grow, leading to a faster generation of technology and its dissemination to the stakeholders. Strict implementation of IPR and patent regime will create a favourable environment for a sizeable investment in research by the private sector companies.

Summing up, the productivity paradigm of the past 50 years will give way to a new paradigm of multidimensional approach to agricultural research with emphasis on environment, health, nutrition, consumer preferences and farmer livelihoods, in addition to productivity. The changes in the status of major supply side drivers by 2050 are summarized in Appendix I.

❑

National Agricultural Research System and ICAR

The Indian National Agricultural Research System is one of the largest systems in the world in respect of human source engagement and infrastructure, and the Indian Council of Agricultural Research (ICAR) is an apex body of this system. The Council administratively is an autonomous organization under the Department of Agricultural Research and Education, Ministry of Agriculture, Government of India. The ICAR coordinates, guides and manages research, education and extension services in agriculture, including crops, horticulture, agroforestry, fisheries and animal sciences.

Mandate

- To plan, undertake, aid, promote and co-ordinate education, research and its application in agriculture, agroforestry, animal husbandry, fisheries, home science and allied sciences.
- To act as a clearing house of research and general information relating to agriculture, animal husbandry, home science and allied sciences, and fisheries through its publications and information system; and instituting and promoting transfer of technology programmes.
- To provide, undertake and promote consultancy services in the fields of education, research, training and dissemination of information in agriculture, agroforestry, animal husbandry, fisheries, home science and allied sciences.
- To look into the problems relating to broader areas of rural development concerning agriculture, including post-harvest technology by developing co-operative programmes with other organizations such as the Indian Council of Social Science Research, Council of Scientific and Industrial Research, Bhabha Atomic Research Centre and the universities.
- To undertake any other activity considered necessary to attain the objectives of the Society.

Core Assets of ICAR

It has a vast network of 96 ICAR institutes, 77 All India Coordinated Projects/Networks, four deemed to be universities, two Central Agricultural Universities and 641 Krishi Vigyan Kendras (KVKs) spread across the country. In addition, there are 62 state Agricultural/ Veterinary/Horticultural/Fishery universities and 4 general universities with agricultural faculty, as part of the NARES. Extensive research infrastructure representing many agro-ecosystems and highly prized genetic resource apart, there is a critical mass of highly accomplished scientists with multidisciplinary knowledge. The Council has developed a fairly good national (SAUs, CSIR, IITs and industry) and international (CGIAR institutes, ACIAR, European Union etc) collaborative network. The public support and appreciation for the ICAR, by way of favourable research policies, funding and recognitions, is steadily growing.

Past Achievements

> "The ICAR has served our country with great distinction -----------------. The contribution of ICAR scientists in the achievement of national self-sufficiency in food grains and diversity in food production is truly enormous."
>
> Prime Minister of India, 16 July 2011

The past research contributions of ICAR and its partners have been exceptionally higher than of a similar organization in any other developing country in the world. The empirical evidence has shown that investment in agricultural research and development in India has been a win-win option as it was the largest contributor to the agricultural total factor productivity, which in turn significantly contributed to reducing rural and urban poverty (NAAS, 2009). During 1980-81 to 2006-07, the average internal rate of return to the investment in agricultural research was about 46 per cent, which is comparable to that obtained internationally (Chand and Kumar, 2011). The growth in total factor productivity (TFP) between 1980 and 2000 was estimated to be in the range of 1.4-2.0 per cent, which is equal to the growth observed in crop sector during the green revolution period. During post-green revolution period of 2000-2008, the TFP rose to 3.06 per cent which is commensurate with the growth in crop sector during the same period (Rada, 2013). The research programs under the umbrella of ICAR are designed and undertaken for harnessing the power of science and technology that promotes food, nutritional and livelihood security of vast population of our country. In the past, ICAR played an enabling role in ushering green revolution and also in the subsequent developments in agriculture. The ICAR along with its partners in the NARES through research and technology developments, enabled the country to increase the production of foodgrains by 5-fold, horticultural crops by 6-fold, fish by 12-fold (marine 5-fold and inland 17-fold), milk by 8-fold, and eggs by 27-fold since 1950-51. This sterling progress in production and productivity has made a visible impact on the national food and nutritional security. It has also played a major role in promoting excellence in higher agricultural education. The Council is engaged in cutting-edge science and technology development, and is internationally acknowledged for its leadership in the developing world.

The Council acknowledges the importance of partnerships and synergies of different stakeholders in providing technological solutions for agriculture. It has developed the organization's Intellectual Property Rights (IPR) domain, and has implemented its guidelines for Intellectual Property Management and Technology Transfer/Commercialization (ICAR, 2006). It is expanding its reach for generating and disseminating new knowledge across its wide range of stakeholders in the production and food value-chain. It is strengthening its partnerships with national and international organizations, various government departments, farmers and farmers' organizations, non-governmental organizations and the private sector involved in agri-business. Recognizing the importance of commercialization of innovations in partnership with industry, the ICAR has established 'Agri-Innovate India Ltd', a corporate entity for technology commercialization and consultancy services at home and abroad.

ICAR Today

- Leads with distinction one of the largest national agricultural research systems.
- Custodian of a huge collection of germplasms of plants, animals, fishes and microbes for future technology generation.
- Provides science-based agro-technology advisory services to the large farming community, free of charge.
- Supports agricultural education in the country through its deemed to be University Institutes and State Agricultural/Veterinary/Horticultural/Fishery universities on the pattern of University Grants Commission.
- Provides evidence based techno-economic recommendations to the Government of India for policy formulation for agriculture sector.
- Provides techno-economic and educational support to developing countries for increasing south-south cooperation.

The ICAR considers Indian farmers as its main client and benefactor, and is fully engaged with them. Towards this end the National Bioinformatics Grid and mobile extension services for a comprehensive approach from 'seed-to-market' have been put in place.

The ICAR/DARE is the first ISO-9000-2008 compliant Department as designated by the Quality Management System (QMS).

ICAR-2050

Globally, agricultural science, natural environment and the society are undergoing rapid transformations. ICAR is committed to reinvent, redesign and transform so as to address the complex changes and harness the domestic and global opportunities to become a leading agricultural research organization, which is responsive and sensitive to the needs of stakeholders.

Vision

Lead India towards attaining sustainable food, nutritional, environmental towards and livelihood security through agricultural research and education.

Mission

Harness the power of science and innovation for food security, food safety, farmer prosperity and enhance natural resources base to promote inclusive growth and sustainable development .

Guiding Principles

The ICAR accords highest priority to the changing needs of farmers of 2050; its entire philosophy is based on 'farmer first' which is part of its motto, with due consideration for other stakeholders in the entire value chain. The guiding principles that will provide direction to ICAR for determining its future research and education investment priorities and strategic framework are outlined in Box 2.

Focus Areas

The Indian National Agricultural Research and Education System (NARES) has to find solutions to the immediate problems of farming as well as keep its competence in technology development in the forefront, to address the continuously emerging problems. A National Fund for Basic and Strategic Research is functioning under the ICAR, with the objectives of building capacity and breaking yield and quality barriers through the partnerships of all. The Council is embarking on two missions, - *'Farmer FIRST'* and *'Student READY'*, as also the consortia platforms for bringing greater partnerships. Two major projects, viz. National Agricultural Education Project and National Agricultural Entrepreneurship Project, are being formulated. Value-addition to primary agricultural production in crop/horticulture/dairy/meat/fish, in order to make the agricultural sector competitive, will be a priority. Mechanisms

Guiding Principles for Future Research and Education

- Provide leadership in ensuring national food and nutritional security, farmers' prosperity, consumer health and enhancing the natural resource base of agriculture for future generations
- Ensure strategic competitive advantage of Indian agriculture to enable access to the existing and emerging markets, and address the emerging challenges
- Leverage the advances in other sciences, engineering and social science to enhance agricultural research
- Nurture scientific excellence and promote interdisciplinary, systems-based, knowledge-intensive, problem-solving research
- Promote economic opportunities for the rural community and society
- Promote complementary partnerships for value addition in agriculture and accelerate innovation
- Respond proactively to farmers, consumers, partners and policy makers
- Promote ethical conduct, scientific integrity and accountability of performance and decisions
- Promote organizational transformation to an efficient, effective, and responsive innovation system
- Support higher education and create educational environments that foster continuous learning

are also being developed for Agri-Innovation fund, Agri-Incubation fund, Regional implements fabrication and processing hubs, and Referral facilities. The major focus areas of research are outlined in Box 3.

ICAR 2050: Focus Areas of Research

- Genetic potential enhancement of agricultural commodities
- Agricultural productivity, efficiency and profitability improvement
- Resilience to climate change and abiotic and biotic stresses
- Improve nutritional food, and health security
- Risk management against climate change and market stressors
- Agricultural value chains
- Sustainability of natural resources base of agriculture
- Valuation of ecosystem services
- Agricultural markets, policies, and institutions
- Bio-security, especially the one emerging from gene piracy and cross-border vector-borne diseases
- New products and uses (eg, bio-energy, new crops, synthetic foods, special foods)
- New educational and learning systems and environments

Some transformation in intra-institutional arrangements for more efficient governance within the ICAR and the ICAR vis-a-vis state agricultural universities, as per need of the system will be required. The ICAR system has shown resilience in the past and has mechanisms in place for course correction.

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Harnessing Science and Innovations

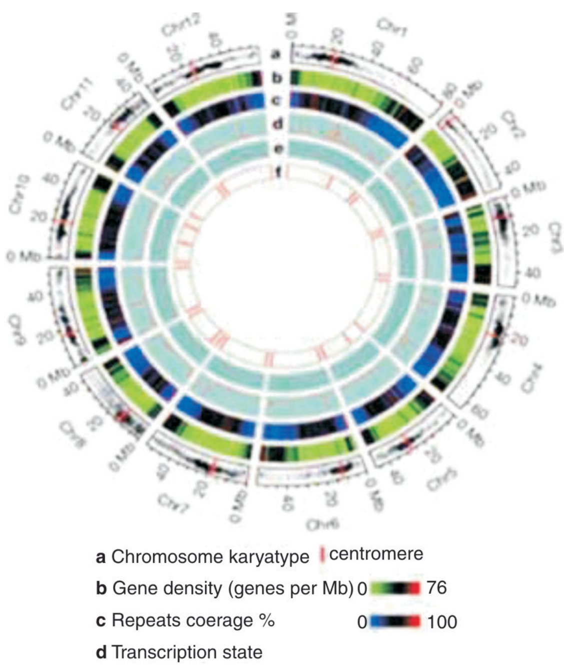
The ICAR is in the process of charting an innovative research agenda to fulfil its mission within the broad emerging science and technological trajectory, which is in harmony with nature and the goals and aspirations of society. Advances in science and technology help solve problems that have been in the realms of imagination. The Council has a vast mandate dealing with agriculture and food spanning across crops, natural resources, livestock and fisheries, and with all links in the value chain from primary production to processing – packaging –storage, etc. The technologies —new, currently in-use, in pipeline and awaiting harnessing — fall in three categories: generic or platform technologies (bio-, nano, info, and geospatial technologies), sector-specific technologies, and trans boundary research. There is a growing need to move towards trans disciplinary research, which has more to do with transgressing boundaries among disciplines and actors leading to a 'fusion' among disciplines and partnerships. The future research needs to support a profitable, more productive, and sustainable agriculture; laying emphasis on food and farm technologies that mitigate climate change impact and adapt to a low-carbon and low-water regimes, and highly modified biological responses to climate changes. The research vision in key areas of technology development are briefly introduced.

(1) Genetic enhancement of plants/animals/fish for higher productivity under increased intensity of biotic and abiotic stresses

Genetic enhancement is considered to be a major option to bridge the demand and supply gap under normal situations as well under projected scenarios of increased frequency and intensity of stresses. In agriculture, biotechnology has enabled the genetic alteration of crops, improved soil productivity, and enhanced natural weed and pest control. It should, however, be understood that genetically modified organisms (GMOs) may help solve some very difficult problems such as salinity or drought, but they do not present a miracle solution; and they are not automatically synonymous with sustainable foods. Emphasis is needed on green biotechnologies (concerning plants and their growing) as well as on the white biotechnologies (primarily focusing on use of biological organisms to produce or manipulate things).

Some of the important research issues in plant science include: improvement in productivity and resilience to climate change impacts and up scaling of technologies with the aid of bio-, nano, omic (genomics, proteomics and metabolomics etc) and geospatial approaches; deep sequencing-based, cost-effective and rapid diagnostic tools for DNA fingerprinting and IPR protection, genetic modification (GM) detection and plant taxonomic identification systems; DNA bar-coding in species delineation hyper spectral remote sensing; structural and functional diversity present in the both coding and non-coding regions of the plant genome; digitization of mapping and distribution of pests including insects, fungi, bacteria, viruses, nematodes and weeds of quarantine significance; development of designer grains/fruits/vegetables possessing desirable qualities for processing and increased shelf-life.

In the livestock and fishery sectors, research can be utilized in the frontier areas like stem cells, pharmacokinetics and nutrigenomics, transgenic animals, proteome analysis, siRNA technology, bio-sensor applications, targeted nano-delivery of drugs; IVF-ETT, etc. can be gainfully utilized for strengthening system efficiency. Some important issues for investigation are: livestock genetic improvement using phenomics, genomics and bioinformatics tools; breeding transgenic animals capable of producing tailor-made milk/meat to cater to the specific needs; understanding of the basis of genetic resistance in domestic species of livestock with DNA markers for disease-resistant



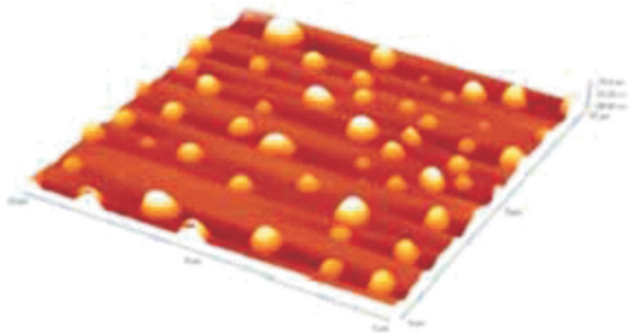
Potato genome for future use (Source: ICAR Annual Report 2012-13) genes and the ability to diagnose specific genotypic markers that correlate with susceptible and resistant phenotypes; regenerative medicine, micro- electro- mechanical systems (Bio-MEMS), pharmacy-on-chip, implanted body regulator, gene-based preventive medicine and bio-electronics; efficient nutrient delivery in animals through application of nano-technology; and development and strengthening of bio-safety capabilities. Cytogenetics and genotoxicity of fish and shellfish; extraction and characterization of bio-molecules having therapeutic and industrial significance; identification of biosynthetic gene clusters in aquatic bacteria for production of novel bioactive compounds are some other frontier areas for research.

(2) Productivity enhancement through sustainable intensification

The earth's planetary resource system is reaching the tipping points in terms of anthropogenic eco-footprints; and under Business As Usual (BAU) scenario, it may require not one, but two such planets to remain within the safe operating space. Sustainable agricultural intensification, which holds promise in the twin roles — a major food security insurer and protector of natural resource base — has therefore rightly become central to the post-2015 research and development agenda.

Technologies and practices of sustainable intensification are context specific, and so are the research needs. It should, however, be understood that significant intensification is an option but only where enough water is available. Some broad issues are: a globally retrievable geo-spatial national portal on land, water, vegetation/animal/fish/microbes resources information system for resource inventorying and planning; understanding of enhanced agro-ecological adaptation of domesticated crop plants/animal/fish to abiotic and biotic stresses using novel and emerging technologies to develop low-input and low-carbon technologies; up scaling of water, nutrient, energy and knowledge smart technologies including conservation and precision agriculture to enhance land productivity in terms of kcal/ha/day; novel fertilizer formulations and delivery systems to improve nutrient-use efficiency, integration of crops, livestock, fish and forestry systems leading to higher productivity and lower negative impacts; waste management systems including extraction of nutrients from domestic and industrial waste waters, improved recycling of wastes to improve soil organic matter and soil health, microbial inoculants for biofertilization and disease control. The innovations in organic farming, particularly in dry lands and hills, where low input agriculture is practiced, are required for taking advantage of the growing market for organically grown food products.

Livestock feed, healthcare and management are to be addressed in an integrated manner for ensuring intensification in the animal sector. Changes in livestock production increase the potential for new pathogens to emerge, grow and spread from animals to humans on a global scale. Effective phytosanitary and animal health regimes aided by new vaccines, diagnostic products and tools, and epidemiological information are necessary to survive in the emerging regulatory regime.



Three dimensional image of 0.01per cent trypsin nano-encapsulated in **0.04 per cent chitosan** (Source: DARE/ICAR ANNUAL REPORT 2013–14,page 78**)**

Cobia (*Rachycentron canadum*) has potential for cage farming

The fisheries sector has shown a stellar growth in recent years, but recent studies cataloguing the global collapse of human-dominated marine ecosystems indicate that the marine fishery is experiencing accelerating loss of populations and species, with largely unknown consequences (Worm et al., 2006). Except for small tank based aqua-culture, the situation is not different in case of riverine and coastal aqua-culture which suffer from high level of pollution. This is largely because aquaculture in most cases does not have dedicated water bodies. But, the good news is that fish stocks can recover, if ecosystems are protected and biodiversity gets revived. Therefore adoption of ecosystem-based approach to coastal as well as riverine aquaculture and diversification in terms of species, low in the food chain and developing aquaculture systems which are based on biofloc technology- utilizing the nitrogenous waste it produces, would be most appropriate.

(3) Productivity enhancement through mechanization of agriculture and food system

The end objective of farm mechanization is to enhance the overall productivity to save labour and automate field operations for lowering the cost of production through improved timeliness of operations and precision in the application of inputs; producing high quality and value-added products; and developing and saving energy. Intelligent sensing and monitoring systems equipped with crop and bioinformatics will be the new innovations in machines used for different operations. Machines for large-scale precision farming green fishing vessels' will have to be developed. In the post-field state, logistics, large-scale processing, and supply chain management are the key factors. Information technology in association with GIS and automation are set to make a major difference at different stages (Fig 2). Optimization of production systems and farm work sites with vehicle and machine systems that can sense and control; systems that are capable of collecting, storing, and transferring information about the crop, field, and machine state at the time of field operation are likely to materialize in the country towards the end of the 4th decade.

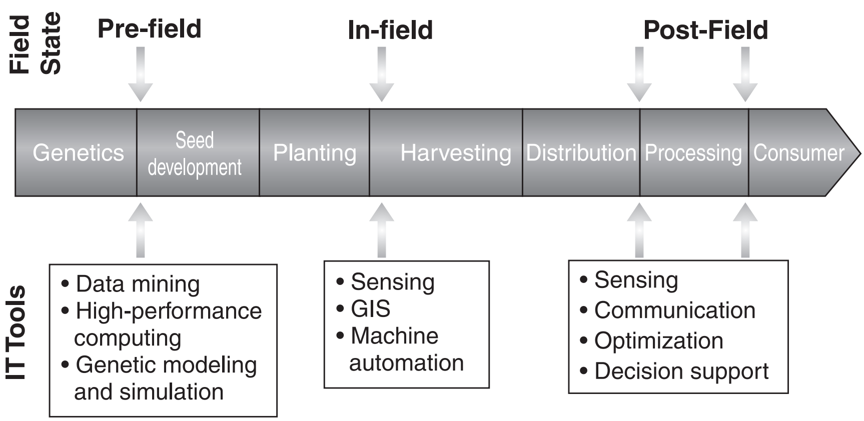


Fig. 2 Harnessing innovations in computing science, geospatial sciences and information technology (*Source:* Ting et al., 2011)

(4) Enhancing value, safety and income through food processing

Globally, India is a major producer of fruits, vegetables, milk, meat and fish, which are all perishable in nature. But the level of processing in India is rather low, and exists in unorganized form with high losses in supply chain. The emergence of new tools, methods, techniques and approaches offers promise of technological breakthroughs to augment food security and income from agriculture enterprise by increasing secondary, tertiary and quaternary processing levels to at least 50 per cent. New opportunities are emerging with the opening of the international trade. Therefore, issues related to sanitary and phyto-sanitary measures would need to be appropriately addressed. Multi-disciplinary and multi-stakeholder research for agri-commodities, especially post-harvesting engineering, horticulture, dairy, livestock and fish, would be required.

Life cycle assessment (LCA) of products and processes in harvest and post-harvest constitutes an important area of future investigation. As value chains and markets get better organized and demand for specialized processed food grows, the focus will gradually move from primary and secondary processing to higher level of processing. Some important issues needing attention are: development of a library with documentation of desirable characters/attributes suitable for processing in developing designer crops; intelligent cool chain systems to transport produce from farm to retailer; adaptive control of storage conditions with biological sensors; rapid detection of food adulterants, fungal and bacterial toxins and other contaminants, using bio-sensors/nano-bio-sensors/molecular markers; application of robotics, artificial neural networking, nutri-genomics, non-destructive and/or online testing techniques, supercritical fluid extraction for production of high-value products; ethical and safety issues related to GM foods and nanotechnology; and development of bio-polymers for packaging and bio-composites for structures based on nano-technological development. The private sector has made considerable advances in food processing and therefore exploration of niche areas only would be more rewarding.

(5) Energy development and management

Energy is central to the economic growth in all the sectors including agriculture. In view of the dwindling and limited availability of fossil fuels, plants which exist through photosynthesis are a renewable source of carbon. Bio-fuels, therefore, appear to be part of the solution to the problem of energy shortage, but the development of more efficient bio-fuels remains a crucial issue. The agricultural fuel resources include animal manure and crop residues, derived primarily from maize, corn, small grains and seeds of oil-bearing plants (e.g. Jatropha). In India, bio-fuels would largely be based on nonfood crops and unused crop materials containing lignocellulose (stems and leaves). Therefore, development of engineering plants of different capacities, using waste material with lignocelluloses, is a priority. Researches in solar energy, aiming at increased capture of solar radiations are opening vast opportunities for increasing availability of nonpolluting energy at low cost. In future, decentralized solar power for agricultural applications like pumping water, drying of grain and fruits, chilling of milk, will be financially attractive propositions. Efforts at innovations in development of appliances for rural areas need attention.

(6) Computational initiatives in agricultural research

Agricultural research is becoming highly quantitative and computational. Therefore, high performance computing (HPC) is becoming a requirement for manipulation of very large data sets, particularly related to agricultural genomics, proteomics, geo-informatics and climate change. An 'Integrated National Agricultural Resources Information System' (INARIS) and 'Knowledge Management of Agricultural Research and Technologies' (KMART) portals have been established. But, as the demand for national agricultural portal on bio informatics grid (NABG) grows, creation of higher super computing framework will have to be undertaken.

(7) Innovations in policies and institutions

Harnessing advances in agro-biological research in the form of technologies requires a favourable policy environment and the facilitating institutions. Research needs to reframe the conceptual maps regarding agriculture, environment, competitiveness, markets and state interventions. Further, agricultural research policy needs to address the mechanisms of generation of new sources of knowledge. Technology forecasting is of utmost importance. Foresight on research priorities, potential impacts of emerging technologies and consumer preferences in technology generation process, intellectual property regimes and seed systems, etc. needs to be generated. It would also be useful to develop agribiome platform (it takes into account the totality of food biomasses and uses calories as units), to generate information on regional food production, trade and uses of biomasses on eco-regional basis. All these issues require effective and need-based institutions to accelerate innovations and link farmers with different stakeholders to harness the emerging opportunities. Innovative institutional models, pro-agricultural policies and regulatory mechanisms would have to be evolved for accelerating innovations.

(8) Education and human-resource development

Higher education is crucial to maintain and sustain growth in agricultural productivity, as it promotes research capabilities and skills to assimilate and adapt the current technologies, and develop the new ones. Enhancement of NARES' human resources for agricultural research and development is a priority issue for the Council. Considering the fact that globally the state of agriculture is in a flux, the ICAR institutes need to be geared up to respond to new and rapidly changing economic, ecological and technological environment. There are concerns in respect of both quality as well as the number of qualified human resources to meet the exploding demand. There is a need of paradigm shift in education — from 'teaching to learning', and of expanding the reach and opportunity for learning which will necessitate going beyond the current initiative of establishing new central agricultural universities and upgrading some of the existing institutes as deemed to be universities.

Agricultural research, education and extension for development (AREE4D) should be mainstreamed into national agricultural policy. There will also be a need to change the way in which we do science so that we may respond faster to societal demands. This may require re-structuring of the organisational model of research units, divisions from rigid ones to flexi-program mode dynamic research consortia led by program leaders on the pattern of international organisations. There is an urgent need to leverage developments in technology to improve the outreach and delivery of education. In future, improvement and expansion of platforms such as AgEd Open Course ware, International Platform for Asian Agricultural Education and E-Learning to meet the demand for formal and informal education for capacity building, will be undertaken.

(9) Innovations in technology transfer system

The ICAR has been engaged in development of efficient and effective technology transfer systems for shortening the time lag between technology generation and adoption. The motto of the Council, "*Agri Search with a Human Touch*", speaks volumes of the importance that the Council attaches to transfer of technology to its main client— the farming community. But, its clientele now extends to industry, business community and the consumers at large. There have been continuing efforts to evolve innovative pathways for disseminating breakthroughs in technology to farmers and the industry such as Agricultural Technology Management Agency (ATMA), Agri-clinics, Agri-business centres, Krishi Vigyan Kendras, E-chaupals, etc. The capacity building of community-based organizations and farmers' groups for acquiring knowledge and its transfer is being put in place for a faster dissemination. The rapidly extending mobile telephone network is facilitating the shift from kiosk based information dissemination to mobile-based communication. The bundling of services approach such as insurance and credit agencies participating in agro technologies and weather advisory service, which has been successful abroad, has good prospects. Information and communication technology (ICT) with 3G and 4G technologies which are capable of delivering detailed text and pictures through the mobile phones, would revolutionalize the technology dissemination process. A number of knowledge platforms, such as Smart Knowledge Agriculture Corridor (SKAC), Agropedia, Directorate of Knowledge Management in Agriculture(DKMA), Agricultural Websites and Agriculture Knowledge are some of the new models of technology transfer, which will be out scaled in future for a faster dissemination among masses.

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Opportunities & Strengths

India, at present is an agriculture-based transforming country, where agriculture does not have a major share in the GDP growth, but livelihood and poverty remain overwhelmingly rural. The Vision 2050 visualises India as a developed country with a bulging middle class having reasonably high income and more than 50 per cent people living in urban areas. Therefore, the research strategies have to, some extent, be aligned with the future development goals. The research initiatives will aim at: zero net land degradation, 20 per cent increase in total food supply-chain efficiency– reducing losses and wastages from field to fork; 20 per cent increase in water and nutrient efficiency in agriculture–more nutrition and crop per drop; and enhancing food safety.

The Council's strategy for revitalising research agenda to provide technology, policy and institutional support will be based on leveraging knowledge and core strengths of ICAR for transforming and creating new institutions and hubs of scientific excellence and attract the best talents to agricultural research. The five important objectives are: create and accelerate sustainable increases in the productivity and production; conserve, enhance, and sustainably use natural resources and biodiversity; incentivise value addition; increase income and livelihood opportunities; evolve evidence based recommendations for policy and institutional changes which will stimulate agricultural growth and equity; and promote excellence in agricultural research, education and extension for sustained food and nutritional security (AREE4FNS).

Important Issues Linked to Approaches

Following are some of the linked issues:

- Upstream research for advancing frontiers of science for up gradation of technology taking advantage of the unprecedented advances in biological (biotechnology) and allied disciplines (nano, info and geospatial).
- Product differentiation (identification, development and optimization of niche markets) for global competitiveness
- Strategic management and prioritization of research needs at all levels in the agricultural sector to ensure that research resources (human, financial and infrastructure) are allocated as per new priorities (e.g., stronger demand for competitive and quality-conscious agriculture).

- Strengthening collaboration and partnerships with CGIAR institutes, in-country science and technology institutions and private sector to capitalize on opportunities for collective action and pooling of innovative capacity in agricultural production and value chains.
- Commercialization of agriculture through value chains and well-functioning national markets, for increasing rural income and supporting large urban and industrial population.
- Reforming NARES by establishing centres of agricultural research excellence to address strategic priorities and effective networking of cutting-edge institutions for attracting and nurturing talent, restructuring of the administrative structure and decentralization and financial devolution; and overhauling of technical services on the lines of ARS.

Approaches and performance indicators

The strategy to achieve the mission AREE4FSN is based on earnestly engaging in the task of harnessing the power of new science and technology, through planning, designing, implementation, monitoring and evaluation of the research outputs. Their efficacy will be ultimately judged by the outcomes and impacts. The approaches and indicators of performance linked to the AREE4FSN goal/objectives are outlined in Table 3.

Table 3 Strategic framework for Agricultural Research, Education and Extension for Food and Nutritional Security (AREE4FSN)

Goal / Objective	Approach	Performance Indicators
Improve food, nutritional, health security	Sustainable intensification of production system to increase food production Developing agriculture for improved nutrition and health outcome — nutrients fortified crops, animal products and fish products Development of rapid disease diagnostic systems, and drug delivery techniques Improved processing, packaging, storage and transportation for reduction in food losses from farm to fork Better assessment of supply and demand drivers	Increase in per capita food and nutrients availability/AGDP Reduction in malnutrition/decrease in poverty over the base line(%) Reduced mortality of animal/fish (%).
Create and accelerate sustainable increases in agricultural productivity and production	Genetic improvement of the leading food crops/ livestock/fish resources using frontier scientific advancements in bio-, nano-, omic sciences. Introduction of crop and landscape smart machines for precision agriculture Development and out scaled adoption of water/ nutrient/energy/weather/knowledge technologies Improvements in livestock/fish husbandry Improvements in livestock/poultry health through efficient drug delivery system	Increased productivity by (X) per cent/ha/year Increased production by (Y) Mt/year Reduction in water, energy, carbon intensity per unit of production Increased production kcal/ha/year Eradication of some of the economically important diseases

Improve and sustain health of natural resources	In-situ and ex-situ conservation of biodiversity of plant/animal/fish genetic resources Innovations in water- and nutrient-use technologies Better understanding of the impact of climate change and devising strategies for its adaptation and mitigation Improvements in policies for accounting ecosystem services; ecological economics; trade in carbon credits; virtual water trade	Reduction in extinction rate number/million() Decrease in rate of water diversions from ground and surface sources Reduction in water or energy or carbon intensity per tonne of production Carbon sequestration (Mt CO_2e/ha)
Increase income and livelihood opportunities for rural population	Diversification of production systems integrating crop/ livestock/forest/fishery Development of models for commercialization of smart value chains and markets; and organize intellectual property rights and benefit-sharing system Introduction of bio-safety and sanitation regimes through automation, and development of standards	Increase in farm income (Rs/ha/year) Increase in volume of commodities processed over base line (%). Density of markets/cold chain established,(No./thousand ha) Standards developed and implemented.
Promote policy and institutional changes that will stimulate agricultural growth and equity	Policies for commercialization of technologies and food processing Addressing market risks through improved market intelligence and insurance products Policies and institutional arrangements to address climate change impact; disaster relief and bio-security	Improved market and will get piloted Spread of voluntary purchase of insurance cover by the farming community
Promote excellence in agricultural research, education and extension	Establishing centres of excellence in education and academic research Undertaking organizational reforms Research priority setting for optimization of resources (human/infrastructure/financial) Institutionalization of management information system (MIS) Fostering collaborations and partnerships Introduction of performance-based work-culture Follow participatory approaches; use of ICT Develop effective delivery systems and models for engagement with stakeholders Increasing investment in AREE4D	Increase in research publications with high impact factor/patents/ commercialized technologies Increase in technology adoption index Systems developed and implemented Increase in resource allocation(% AGDP)

The ICAR is basically a research organization; and therefore for retaining a sharp focus and research leadership, it is important that a proper balance is maintained between research portfolio and technology diffusion, which sometimes gets mixed with field extension. Further, for implementation of transformative research agenda more efficiently, some changes in intra-organizational set-up, inter-organizational linkages and responsibilities, investment in research and funding support from public and private sources will have to be undertaken. The ICAR has institutionalized mechanisms for ushering in such changes and will be in a position to reform the system as per the changing needs in the country. ❑

Epilogue

The Indian Council of Agricultural Research (ICAR) is committed to enhancing agricultural production and productivity in the country through science-led and technology-driven approach. The Council firmly believes that agricultural research is meaningful only if it addresses the challenges faced by the society. The outputs of research must translate into increased productivity, improvement in quality of life and creation of wealth for the society at large, and small farmers in particular. The unfolding data revolution allows us to assess our present state, fixes the 2050 goal posts and indicates the direction for movement. The science-based, action-oriented agenda outlined in this ICAR Vision 2050 document, which integrates all the four interdependent dimensions of sustainable development (economic, social, environmental and governance), will be vigorously pursued.

A core program in the efforts to secure national food security is the promotion of gene revolution aiming at lowering the net production costs, raising the yields and net farm incomes, reducing the use of pesticides and herbicides, and thereby lowering the consumer prices. The second component of national research program deals with the development of new replicable models of sustainable production operating within the safe operating space, and respecting planetary boundaries of earth resources system. It requires creation of a wider ecosystem which connects small farm holders with knowledge, technology, well-managed value addition and marketing network for operating sustainable and remunerative agriculture and food systems. Therefore, research efforts aimed at developing appropriate models for commercialization of agriculture through value chains and market linkages form the third arm of AREE4FNS.

It is being realized that generation of technological solutions to address the challenges in production and processing activities throughout the value chain and the cost at which these are created, depends on the capacity built in the system. Capacity building in the NARES therefore, is a significant focus area. The capacity of the ICAR in serving the society also depends on its financial resources, which are provided mainly by the government. There is a vast difference in the public spending on agricultural research in India and the developed countries like Americas, Australia and in the European Union. It is envisaged that with development of partnerships in certain areas, the public funding support will get augmented by the investments to be made by the industry and agri-business. The research outputs of ICAR institutes will be benchmarked to assess the system's performance in the context of similar national and international organizations.

Innovations in every endeavor that the Council pursues will be the hallmark criteria, with a firm conviction that innovations enable the organizations to pursue their specified goals efficiently. Appreciating the fact the institutions provide the environment within which innovations spurt, appropriate policy and institutional innovations (issues such as strategic planning, priority setting, R&D management, financing, monitoring and evaluation, etc.), will also be accorded due attention.

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APPENDIX I

Major supply side drivers (social, economic, environmental and technological), for agriculture and food system research 2010-11 and 2050

Driver	2010/11	2050	Implications
Climate change	Impacts in terms of heat waves, erratic rainfall and extreme events are visible	The rise in atmospheric temperature beyond 2°C under Business as Usual (BAU) scenario	Reduced productivity, rise in sea level, acidification of ocean, increase in frequency of floods/ droughts
Water resources	Water resources are under stress in terms of quantity as well as quality	The situation may go beyond control under BAU scenario	Need for water smart technology will grow
Land			
Cultivated land	142 Mha Close to 2 million ha agricultural land has been lost to urban & industrial sectors	150 Mha In the absence of land use planning, the situation will get further aggravated	Need for vertical intensification will become urgent; and conservation agriculture will get prominence
Land and Soil health	Progressive increase in soil erosion and chemical degradation, loss of organic matter	Under BAU, situation will get worsened	Increased efforts for designing and implementation of watershed programs
Biodiversity	Species disappearing at the rate of more than 10/ million/year	Rise in extinction rate under BAU	Concerted efforts are needed to improve the situation
Technology			
Genetics, bio-technology, nutri-genomics, and systems biology.	Strong advancements in genomics and proteomics. Until now only few new varieties have been produced	This group of technologies will become the dominant means of increasing productivity	Lead to transformative improvements in productivity and reduction in cost
Nano-technology	There are promising prospects	The range of applications in agriculture and food systems, moreso in animal science will grow	Some social health concerns may arise
Appropriate farm machinery	The trend towards mechanization has already set in	Fast development of ICT-supported robotics and automation	Mechanization will grow Higher energy-use efficiency
Demographic trends in rural areas	Aging of rural populations as youths migrate to cities		Reduction in agricultural labour availability
Alternative food chains	Process is at the beginning stage	Will grow rapidly	There will be better links with markets and increase in farm income
Inputs and energy prices	High	May go higher	Force adoption of efficient technologies

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APPENDIX II

Food demand drivers and response strategies

Drivers / Strategy	Increased food demand	Climate change impacts	Declining and degrading natural resources	Declining bio-diversity	Energy demand	Techn-ology requir-ement	Invest-ments
Genetic enhancement	✓	✓	✓	✓	✓	✓	
Intensification	✓	✓	✓	✓	✓	✓	
Value addition & marketing	✓				✓	✓	
Mechanization	✓	✓	✓		✓	✓	
Energy development & management	✓	✓	✓			✓	
Innovations in policies and institutions	✓		✓				✓
Innovations in HRD	✓					✓	✓
Innovations in technology transfer system	✓		✓			✓	

Note: ✓ Indicates that the requirements imposed by a particular driver can be met through the identified strategic actions

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Laser typeset at M/s Print-O-World, 2568, Shadipur, New Delhi 110008 and printed at M/s Royal Offset Printers, A-89/1, Naraina Industrial Area, Phase-I, New Delhi 110 028.