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Vision 2050

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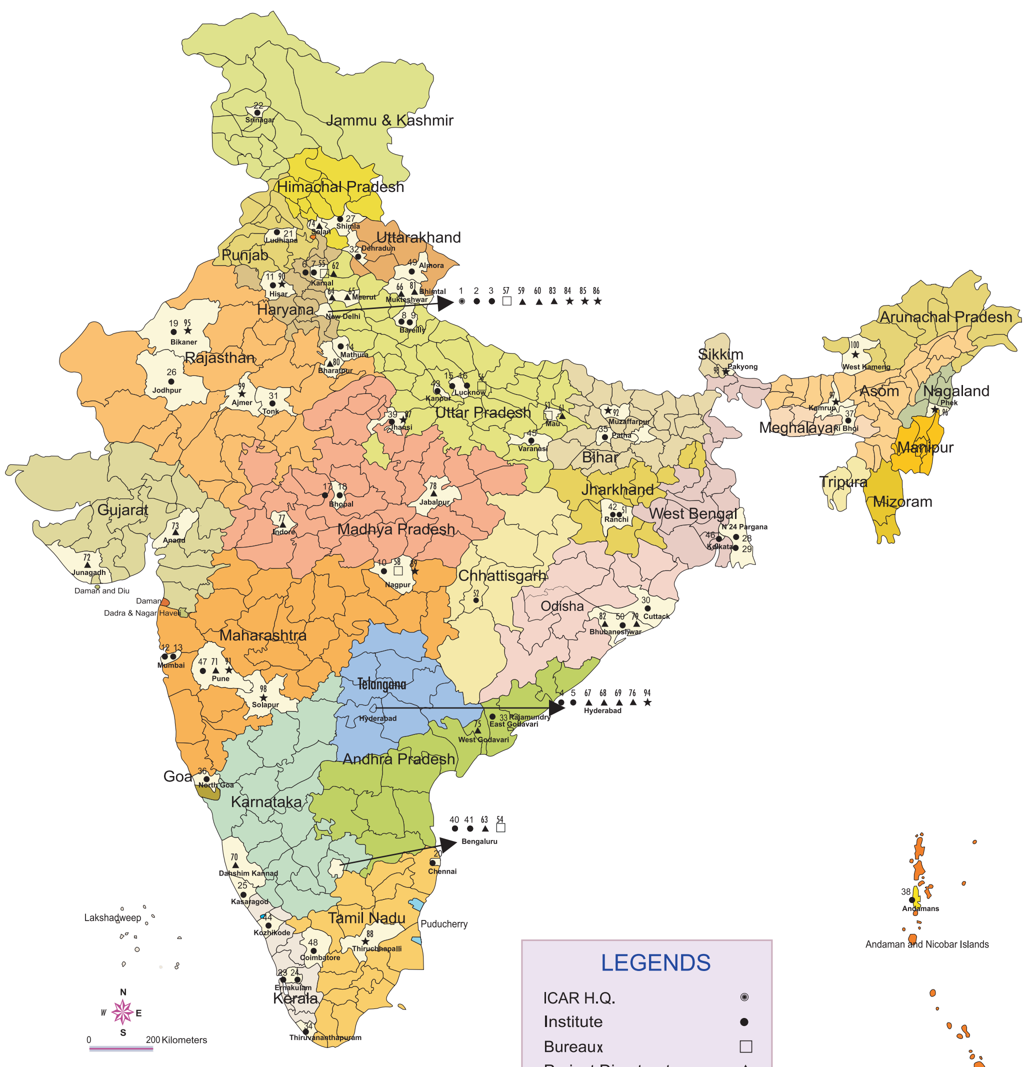

LEGENDS

- ICAR H.Q. ◉
- Institute ●
- Bureaux □
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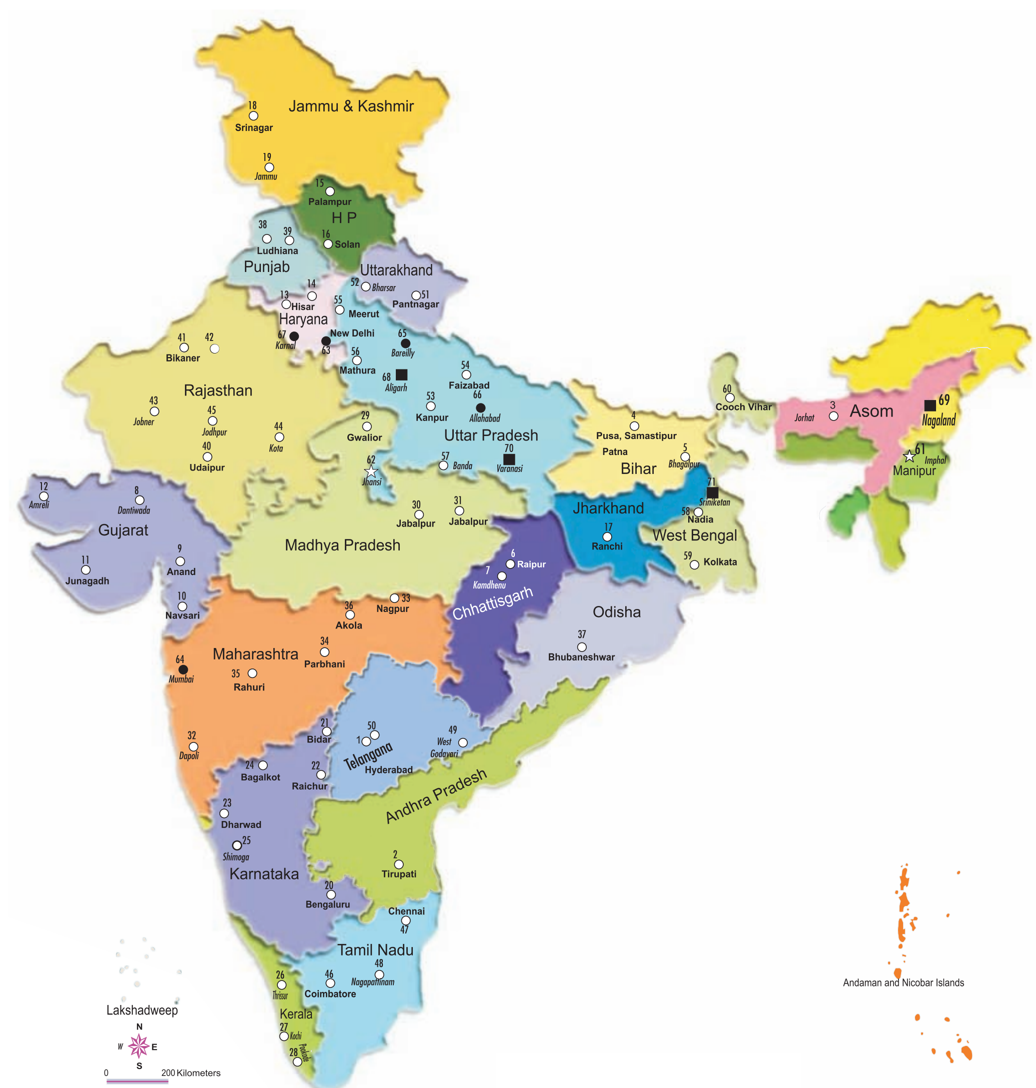
INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Agricultural Universities



LEGENDS

- State Agricultural Universities ○
- Central Universities with Agricultural faculties ■
- Central Agricultural Universities ☆
- Deemed Universities ●

Vision 2050

Central Institute of Freshwater Aquaculture
(Indian Council of Agricultural Research)
An ISO 9001 – 2008 certified Institute
Kausalyaganga, Bhubaneswar 751 002

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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 कई 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-Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar 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)
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Preface

Agriculture would remain important in the livelihood of a considerable section of India's population for several decades to come even with a reducing share in the country's GDP. Indian agriculture is beset with several challenges. Drudgery, natural uncertainties, low productivities, low profitability, climate change, and low professional esteem are all driving the present day youth away from agriculture. Technology, skills and the policies must lift the weakest farm holder above the national per capita income threshold. It is in this context that engineering inputs to agriculture in India have begun to be appreciated. Farm mechanization, land and water management engineering, energy management in agriculture, protected agriculture, post-harvest loss minimization and value addition in production catchments and knowledge empowerment through ICT have all been found essential individually as well as collectively for the growth of Indian agriculture and rural sector.

Population growth, increasing affluence and changing dietary habits have led to rapid rise in global demand for food, and a report of FAO (2009) forecasts the need to increase food production by over 40% by 2030 and over 70% by 2050. However, the agriculture sector at global level is facing stiff challenges with decelerating profitability and reduced annual growth rate. In Indian context, Indian Council of Agricultural Research (ICAR) is taking all-out efforts to enhance agricultural production and productivity through science-led and technology-driven approaches. There is a need for the agriculture sector to continuously evolve to remain ever responsive to manage the change and meet the growing and diversified needs of different stakeholders in the entire production to consumption chain. According to latest statistics, global fish production stands at 143.6 million tonnes, of which about 40% is contributed by aquaculture sector. Global capture fishery is at crossroads, with over 70% of the resources being exploited. Indian fisheries sector has made great strides in the last five decades showing eight-fold increase; from 0.75 million tonnes in 1950-51 to 9.45 million tonnes in 2013-14. Inland fisheries contribute to over 50% of this production, of which 90% of the production comes from aquaculture. The growth rate of this sector is almost 7 percent, and could certainly make good stagnating production trends shown by capture fisheries. Fisheries contribute significantly to our national economy, with about 1.1% of national GDP and 5.4% of agricultural GDP. Food and nutritional security, employment and livelihood support, and uplifting the economic status of fishers are the cardinal services offered by Indian fisheries. Having said that, commensuration with the increasing population and demand for fish, a real-time analysis of the scenario is required along with a mission-mode approach to realize our available vast potential as a means of enhancing fish production in the country.

The ICAR-Central Institute of Freshwater Aquaculture had its beginning as the Pond Culture Division of the Central Inland Fisheries Research Institute, which was established at Cuttack, Orissa during the year 1949. The Division was later upgraded to Freshwater Aquaculture Research and Training Centre (FARTC) which was established at Bhubaneswar in 1976 with UNDP/FAO assistance. Further, the Centre attained the status of an independent Institute under the organizational plan of ICAR during 1986 and the functional existence of the Institute came into effect from 1st April, 1987. The Institute is recognized as the Regional Lead Centre on Carp Farming under the Network of Aquaculture Centres in Asia-Pacific (NACA), which is now an intergovernmental organization, based in Bangkok, Thailand. ICAR in its own wisdom has made a systematic effort to envision the challenges and opportunities to chart the strategy for taking agriculture forward in the 21st century through the preparation of 'Vision 2020'. The ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar also made effort under the caring guidance of ICAR to prepare visionary document for 2020 which was upgraded to "CIFA Perspective Plan – Vision 2025" to address the challenges those had taken place. Then 'CIFA Vision 2030' was born based on scenario planning, and it enlists the priorities and strategies envisaged in the coming 20 years to overcome the challenges and harness the power of science and technology to address issues on increasing fish production and productivity, tackling the decreasing natural resource base, encountering the impending climate change, and above all providing food and nutritional security to the populace. The present document 'CIFA Vision 2050' is a temporarily extended version of its predecessor, giving due importance to the sectoral requirements while developing and extending enabling technologies from the institute.

Water is going to be the most critical factor for future development and sustenance of freshwater aquaculture. Consolidated research on water budgeting, water use efficiency, multiple use of water, participatory water use, recycling of water, integrated farming with agri-horticulture crops, fish culture in reservoirs, irrigation canals, flood plains and sewage/waste water, rain water harvesting and fish culture, use of seasonal water for short term fish culture, fish culture in peri-urban areas, culture of water resilient fish species and identification of abiotic stress tolerance genes and their use in developing more resilient and hardy fish species for culture, pricing of water, water legislation and incentives for efficient use of water and capacity building will go a long way in conservation and optimum use of water. By 2050, India has to produce about 17.5 million tonnes of fish/year and the 80% of the total production must come from the aquaculture and therefore, it is essential to estimate the water requirement for increasing three folds our seed and fish production from the present level. Management of resources has to be done in such a manner that the average fish productivity from ponds and tanks would increase to 4-10 t/ha/year from the current level of about 3 t/ha/year. Research pursuit on system and species diversification should continue, and about 50 species are expected to be included in production. National brood stock up gradation, national dissemination programmes, round the year production of fish seeds, farm made feeds prepared from locally available feed resources, disease surveillance and remedy to crippling diseases, such as argulosis, impact assessment, aquaponics, peri-urban aquaculture etc. are some of the future research priorities of the institute. Capacity building of human resources including scientists, farmers and other stakeholders is always a priority to us in order to be globally competitive and ensure food and nutritional security of the country. Further, modern developments in genetics and biotechnology have great potential to increase food production efficiency in the context of aquaculture.

I am grateful to Dr. S. Ayyappan, Secretary DARE and DG, ICAR for the invaluable guidance and encouragement in preparing this document. I am thankful to Dr. B. Meenakumari, DDG (Fy.) and Dr. S.D. Singh, ADG (I. Fy.) for constant encouragement and valuable suggestions. I appreciate the efforts of my team of scientists, notably Dr. P. Das, Dr. P.C. Das, Shri. N.K. Barik, Dr. K.N. Mohanta, Dr. P.N. Ananth, Dr. J. Mohanty and Dr. P.K. Sahoo in developing this document. I am convinced that 'CIFA Vision 2050' document will be a strategy document to enlist the skills and capabilities, knowledge exchange and translation, and to promote innovation in freshwater aquaculture research.

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Contents

Context

Freshwater aquaculture is an integral part of the agriculture in India. It is one of the fastest growing subsectors in the country which has registered a growth rate of 5.1 per cent per annum in last 60 years. During this period, the fish production in the country has increased from 0.75 million tonnes (MT) in 1950-51 to 9.45 MT in 2013-14 of which the major contribution has been from aquaculture as the sector has grown from 0.37 MT in 1980 to 5.1 MT at present. The consumption demand for fish is rising over a period of time primarily due to the growing population, expanding urbanization and changing food habits. In future freshwater aquaculture sector holds the key as around 85 per cent of the additional food fish demand could be met from the freshwater sector. The 12th Plan growth target for agriculture sector has been set at 4 per cent taking into account growth rate of fisheries sector at 6 percent. Thus, the pressure is on freshwater aquaculture to accelerate growth rates to meet consumption as well as growth targets. In a long term perspective, it is important for the aquaculture sector to grow at a faster pace to contribute meaningfully to the economic development of the country. However, the changing scenarios and factors operating within and beyond the sector as cited below will determine the freshwater aquaculture developments in coming decades.

The world population crossed 7 billion mark in 2011 and is expected to rise to 9 billion by 2050. India will be the most populous country in the world with population of 1.5 billion by 2030 which will further rise to 1.7 billion by 2050. Liberal estimate suggests that 40% of the populace is fish eaters in India. At present about 0.5 billion people are fish eaters and by 2050 additional 0.2 billion fish eaters will be added.

Projected fish production in India (MT)

	2010	2020	2030	2040	2050
Total fish (MT)	7.9	10.3	12.7	15.1	17.5
Aquaculture (MT)	3.9	6.2	8.6	10.9	13.3
Capture production (MT)	4.1	4.1	4.1	4.2	4.2
Per capita fish consumption (kg/yr)	5.6	6.2	6.6	7.1	7.6

The world economy is projected to grow at an average rate of just over 3% per annum from 2011 to 2050, doubling in size by 2032 and nearly doubling again by 2050. India is expected to grow at 5.9 % per annum with average per capita increase of 4.3 % per year. This leap would produce an Indian economy of around Rs. 5,250 trillion up from Rs 250 trillion in 2010. The per capita income is expected to increase from present 0.5 lakh rupees to 7.7 lakh rupees during this period which is about 15 times more than that at present. In 2050, size of Indian economy will be equal to US economy which will be next to China. As the economy is transformed from low income to medium to high income country, the demand for the food will be higher. The high income and urbanization will result in higher demand for the fisheries products.

In the recent times, the food consumption trend has shifted towards fisheries product away from cereals as evidenced from higher demand for horticultural and animal protein products. The per capita consumption of cereal grain has stagnated whereas the rate of growth for the milk, fish, meat, egg products etc has increased significantly. This trend will continue with the change in income leading to higher demand for these products. Freshwater fish constitutes the main source of animal protein in most parts of rural India and more so in the land locked states. Almost half of our population is fish eaters and average fish consumption by the rural and urban population is 3.2 and 3.0 kg/capita/yr, respectively, whereas Indian Council of Medical Research recommends 11 kg per capita consumption. In contrast, the average per capita consumption is more than 25 kg in developed countries. Therefore, a paradigm shift in the fish consumption is very much anticipated.

Increased population and expanding economies together are expected to influence the situations with regards to land, water, energy, labour and ecosystems which are much likely to worsen in coming decades. The average size of operational holdings has diminished progressively from 2.28 ha in 1970-71 to 1.55 ha in 1990-91 and 1.23 ha in 2005-06. As compared to present situation, the per capita land holdings will be much smaller by 2050.. Agriculture currently uses 70 percent of freshwater resources. Competition for resources such as demand for global energy and freshwater could double by 2050. Freshwater availability in 30 per cent of the world's rivers is expected to be reduced due to increased water abstraction and climate change. Quality of water available for fish culture will pose more problem than the quantity in the coming days. By 2050, India has to produce about 17.5 MT of fish/year.

Temperature rise is the major effect of global warming and the trend is likely to continue in the foreseeable future. The Inter-Governmental Panel for Climate Change (IPCC) report indicated that many of the developing countries are vulnerable to extreme climate disturbances and thus may have an adverse impact on animal production system including fish farming. The climate change may result in damage to both fish and fish habitat directly. Fishes, being poikilothermic in nature, are prone to physiological changes pertaining to global warming. Climate changes and the impacts of climate change affect ecosystems in a variety of ways viz., the water scarcity in riverine sources, ecosystem degradation, pollution, loss of biodiversity, etc. The IPCC estimates that 20-30% of the plant and animal species evaluated so far in climate change studies are at risk of extinction if temperatures reach levels projected to occur by the end of this century. Climate change and bio-risk cause adverse impact on production target due to several factors viz., cyclone, flood and drought etc. caused by global warming. Sometimes such adverse environments are responsible for occurrence of pathogens and parasites leading to outbreak of diseases as well. The aquaculture sector needs to adapt to these factors in order to both compensate for the loss of the natural fisheries as well as to improve the productivity of aquaculture.

ICAR-CIFA has been involved in research, training, education as well as extension in the freshwater aquaculture sector and is credited with more than 16 technologies covering several aspects of freshwater aquaculture viz. captive breeding of many important cultivable fish species, multiple breeding of carps, seed production and grow-out culture, selective breeding of rohu for higher growth and disease resistance, milt cryopreservation, portable hatchery, pearl culture, wastewater aquaculture, several feed formulations, disease diagnostics and therapeutics etc. which are at different stages of adoption by farmers and aquaculturists.

The ICAR-CIFA Vision 2050 has been drafted by taking into account the existing knowledge on the sector. Attempt has been made to forecast the sector in the long term perspective and devise the possible response to the challenges in the future as well as to give direction to the R&D effort on freshwater aquaculture in India.

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Challenges

The aquaculture sector foresees a variety of challenges in order to meet the increasing demand for fish in coming decades towards providing nutrition and food security to more than 1.7 billion people in India by 2050. Far and wide, the challenges to the sector need to be responded to by Research and Development sector. Even though the research provides the technical support to meet the challenges, an equally important role may need to be played by policy development. Some of the challenges to the aquaculture as cited below provide guidelines for shaping the response in future.

Utilization and Management of Resources

One of the major challenges for sustainable development is judicious exploitation and management of natural resources viz., land, water, biodiversity, etc. FAO has defined sustainable development as the management and conservation of the natural resource base and the orientation of the technological and institutional change in such a manner as to ensure the attainment of continued satisfaction of humane needs for present and future generation. Aquaculture sector has grown rapidly over a period of time but during the process of development, the sector has focused mostly on the short term gains at the expense of long term aspirations, leading to imbalance in utilization of resources and thereby increasing the pressure on the natural resources. In the context of increase in the population and the ensuing resource crunch on the other, catering fish protein to the growing needs of the future generation has become a great responsibility for the scientists, planners and farmers.

Water is the most indispensable resource for ecological sustenance. Only a tiny fraction of our planet's abundant water resource is available to us as freshwater. As the population grows, there will be a proportional reduction in the per capita availability. Again, on the other side, because of improvement in living standards and rise in agricultural and industrial growth, India is likely to approach a regime of water stress in the foreseeable future. The per capita water availability was 5500 cubic meter in 1955 and it has reduced to 1850 cubic meter in 2008 and would be further reduced to 1250 cubic meter by 2050. This warrants an urgent need for making the aquaculture activity sustainable for a long term basis. The challenges will be to use diverse water resources like seasonal ponds, irrigation water, open wells and other stagnant water bodies for aquaculture production; to reuse water through recirculation and wastewater recycling as well as to manage and budget rain, surface and ground water in hatchery, culture, processing and value-addition, seed and brood stock transportation, fish feed production, etc. comprehensively for increasing productivity by obtaining more values per unit water used. In addition to this, water quality is going to be a great concern for agriculture in general and aquaculture in particular. Chemical contaminants enter aquatic environments in the form of agrochemicals in run-off water, urban and industrial drainage and precipitation. Such chemical contaminants can persist in the environment, enter the food chain and can bioaccumulate in fish tissue over time. Thus, to assess and mitigate the aquatic environment of such contaminants is going to be a challenge.

Conventional expansion of food production systems will have severe impact on ecosystem and biodiversity. Ecosystems provide regulating as well as supporting services that are essential for agriculture and fisheries. Despite its crucial role in providing food, agriculture remains the largest driver of genetic erosion, species loss and conversion of natural habitats. By 2050, a business-as-usual harvesting of ecosystems could lead to the loss of up to 11% of the world's natural areas that remained in 2000, primarily to agriculture and development. Another 40% of the land currently under low-impact forms of agriculture may be converted to intensive, high-impact agricultural use, with further deterioration of biodiversity,

Availability of Quality Seed

Fish production in a pond largely depends on the availability of quality seed for stocking. The quality seed of fish refers to the seed to be robust in terms of its genetic material as well good in size and health at the time of stocking. Captive breeding after using same population over the years known as inbreeding depression results in poor genetic base leading to retarded growth and low disease resistance. The number of fish and shellfish hatchery established in the country are more than 1700 for carps, 35 for freshwater prawns, 260 for brackish water shrimp and few numbers each for magur, tilapia and stripped catfish. Often seed from these hatcheries are prone to physical contamination. To maintain the quality seed a comprehensive protocol need to be followed. Providing adequate isolation to prevent contamination, testing of genetic purity and adopting seed certification system may be some of the important measures to achieve this. When a farmer buys a seed from any recognized institute or company, he expects to receive a good quality seed that would perform well in aquaculture ponds. To avoid admixture in seed of a particular variety the buyer need to be protected by appropriate seed regulation laws. In many countries “seed testing and certifying laboratories” are established to monitor genetic purity of seed. Such regulatory mechanisms need to be established in India in order to supply quality seed materials to the farmers.

Secondly, availability of right kinds of seed, viz. fingerling of carps and catfish, post larvae of shrimp, juveniles of freshwater prawn, etc. has been a constraint for the grow-out farming in the country. Among the several factors responsible, non-availability of sufficient seed rearing infrastructure and inadequate awareness among the farmers about seed rearing as a profitable venture are the major reasons. Since availability of quality fish seed in more quantity is the precursor, hence, accelerated aquaculture growth is possible with immediate creation of more infrastructures for fish seed production.

Fish Nutrition and Feed

At present about 46.1 percent of the total global production of farmed aquatic animals and plants, is dependent upon nutrient inputs in the form of fresh feed, farm-made feeds or commercial pelleted feeds. In India, the fed fish culture is about 20% of total freshwater production and to increase the fish production three times by 2050, the fed fish culture practice is to be increased at least 4 times of the present level which would be a major challenge for the researchers, extension functionaries, fish feed industries and the administrators in the future. In India, currently the aquaculture sector uses nearly 20% of total available concentrated feed and by 2050, about 23 MT of feed would be required considering the three-fold increase in aquaculture production. Farm-made aquafeed plays an important role in the production of low-valued freshwater fish species. More than 97% of the carp feeds used by Indian farmers are farm-made aquafeeds and they are the mainstay of feed inputs. At present about 7.0 MT of ingredients are being used for farm-made fish production. The total volume of manufactured feed sold in the country in 2010 was 60,000 T of pelleted fish feed and 3,72,000 T of extruded floating feed. The fish feed ingredients are the finite resources and many of these ingredients are having multiple uses by other animal production systems such as dairy and poultry and it is envisaged that there will be acute shortage of ingredients in the days to come. The fish feed resources are mainly comprised of the by-products of the agro-processing industries and the availability of these by-products depends on the production of the main crops like oilseeds, cereals and pulses which in turn depend on the success/failure of monsoon. During last decade, the price of the most of the fish feed ingredients had increased significantly to the tune of 3-4 times in the country. Therefore, identification of alternate feed ingredients and their use in the fish feed would be one of the major challenges in the future.

Bio-safety and Bio-security

Biosafety refers to policies and procedures adopted to ensure application of modern science in agriculture and medicine without endangering public health and environment. In the event of emerging use of biotechnological tools and techniques by many countries the concerns for biosafety emerged as a major issue. Appropriate guidelines for laboratories, containment, field trials and risk assessment are highly essential. An equally challenging concern is biosecurity which is a system of cumulative steps for the prevention, control and eradication of infectious diseases to protect the farm stock. This requires to be stringently implemented from the hatchery to the grow-out stage. Aquaculture is becoming more and more plagued with disease problems resulting from its intensification and commercialization.

Various factors contributing to the disease in aquaculture include increased globalization of trade and markets, intensification of fish-farming practices through the movement of brood stock, post larvae, fry and fingerlings; introduction of new species for aquaculture development; expansion of the ornamental fish trade; enhancement of marine and coastal areas through the stocking of aquatic animals raised in hatcheries; unanticipated interactions between cultured and wild populations of aquatic animals; poor or lack of effective biosecurity measures; low awareness on emerging diseases; misunderstanding and misuse of specific pathogen free (SPF) stocks; climate change; and other human-mediated movements of aquaculture commodities.

The diseases are responsible towards bringing 10-15% loss to the sector and it would rise further during the process of intensification. The non-availability of standard and farmer friendly diagnostics, active/passive surveillance system, vaccines and environmental friendly chemotherapeutics would remain as major bottlenecks for the sustainability of the culture systems.

Building Value Chain and Global Competitiveness

A value chain refers to various steps a business takes to produce a product or service and deliver it to the consumer from its conception to its end use and beyond. This includes activities such as research and design, production, marketing, distribution, and support to the final consumer. Reductions in communication and transportation costs and the emergence of new technologies have enabled firms of all sizes, from anywhere in the world, to market products and services internationally. This has increased both the scope and scale of competition. Adjusting to this new international marketplace requires that businesses change the way they are organized and operated. Corporate sector is attaching major importance to supply chain management as a key tool in improving operational efficiency. Supply chain map has to be performed for all species that will be used as an analytical tool to identify where action has to be taken to alleviate barriers to sustainability within the supply chain. Adding value to fish will be a thrust area for micro and macro enterprises in aquaculture industry. The challenges in the forthcoming years will be towards exploiting the future marketing channels and mapping out actors in the chain.

Policy Support

Developing and implementing policy for sustainable aquaculture for conservation of resources and promotion of this practice will be crucial in future. Compatible land and water-use rights will be decisive in future with articulating strong policy for aquaculture development. A vision of fast growing sector amidst the challenges requires policy support. Convergence of ideas for policy implementation has to be vital to create a befitting environment to attract more entrepreneurs and protect the sector. Such support warrants development of the policy information from R & D system and effective communication to the policy makers. This critical area is often termed as policy research and communication, which needs to be strengthened to support the sector. In the context of the future developments, the fine tuning of the policies and support towards leasing out of various types of water bodies for fish farming, allocation of water for aquaculture and other purposes, technology transfer and others are crucial.

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Operating Environment

The ICAR-Central Institute of Freshwater Aquaculture (ICAR-CIFA) is a premier institute in freshwater aquaculture in the country under the administrative control of the Indian Council of Agricultural Research (ICAR), New Delhi. With the sprawling campus of 147 ha the institute has over 380 ponds of assorted sizes, specialized hatcheries and nurseries, feed mill, wet labs and other yard facilities for research, training, education and extension in different aspects of freshwater aquaculture. It has four Regional Research Centres operating in different parts of the country to cater to the specific needs of the regions. These are: Regional Research Centre, Rahara (West Bengal), Regional Research Centre, Bengaluru (Karnataka), Regional Research Centre, Anand (Gujarat) and Regional Research Centre, Vijayawada (Andhra Pradesh). Apart from these, the Institute also has one Krishi Vigyan Kendra (KVK) located within the campus. There are 79 research scientists and fully equipped laboratories in the disciplines of finfish and shellfish breeding, aquatic chemistry, microbiology, fish physiology, nutrition, genetics, biotechnology, pathology, ornamental fish breeding and culture, engineering, economics, statistics and extension to cater to the need of freshwater aquaculture development in the country.

In view of the increasing demand of fish foreseen for the future in the backdrop of changing global trade scenario, decreasing natural resource base and impending climate change, aquaculture research for the next couple of decades needs to be reshaped and reoriented to convincingly meet the emerging challenges. This can be brought about through responsible science and concerted efforts by researchers, NGOs, social organizations, environmentalists and above all the farmers, the end users.

ICAR-CIFA is committed to conduct basic, strategic and applied research in freshwater aquaculture, to enhance production efficiencies through incorporation of genetics and biotechnological tools, to undertake studies on diversification of aquaculture practices with reference to species and systems; and to provide training and consultancy services towards excellence in research for developing sustainable and diversified freshwater aquaculture practices for enhanced productivity, quality, water use efficiency and farm income in order to make Indian freshwater aquaculture globally competitive through eco-friendly and economically viable fish production systems for livelihood and nutritional security.

Freshwater aquaculture sector is primarily driven by scientific and technological progress made in the R & D sector. It is noteworthy that the freshwater aquaculture sector started its journey with the development of the two epoch making technologies viz., induced breeding and composite fish culture in sixties. Since then, an array of aquaculture technologies have been developed and in use in the sector. The salient features of the sector can be summarized as below.

- Two important technologies viz. induced fish breeding and composite carp culture triggered the growth of carp culture in the country.
- Carps, catfishes, prawns and ornamental fishes form important components of freshwater culture practices.
- A large number of new species like Pangas, tilapia, pabda, magur, murrels, anabas, minor carps etc have been added to the production system of the country.
- Technologies available for breeding and culture of the above fishes are being improvised and adopted to a greater extent.
- Improved rohu *Jayanti* with a 17% higher growth realization per generation through a selection breeding programme has already been developed. The new trait, disease resistance has been added to the growth performance of Jayanti.
- With an adoption of the carp culture technology the mean fish production level across the country has crossed 2.9 t/ha/year, while several farmers are able to achieve much higher production levels (8-10 t/ha/year).
- The success in farming technologies of freshwater prawns (*M. rosenbergii* and *M. malcolmsonii*) has already attracted the attention of farmers. The genetic improvement programme on the species has produced fourth generation of improved stock.
- A multiple and off-season breeding of carps has enabled seed availability at different times of the year. This technology has the potential to break seasonal barrier in aquaculture.
- Cutting edge science in the field of aquaculture has explored the possibilities of developing genomics resources to assist traditional genetic improvement methods.
- Nutrient requirements of commercially important freshwater fish viz. carp, catfish and prawn led to the development of generic feeds for the different life stages of these fish.
- Brood stock diet (CIFABROOD™) specifically formulated for carp has resulted in better fecundity and hatching rate.

- The research on the fish health management has opened up the possibilities of using newer molecular and field level diagnostics to tackle transboundary pathogens and treatment regimes for various fish diseases.
- Technology transfer has been a key area in aquaculture which has improved substantially with the support from the central and state government through involvement of the agencies like National Fisheries Development Board (NFDB), Department of Animal Husbandry Dairy and Fisheries (DAHDF) and other state agencies.
- The application of the plastics in the aquaculture has greatly improved the sector by developing and using of the gadgets like FRP carp hatchery, FRP magur hatchery, FRP mini carp hatchery, demand feeder, automatic feeder, live fish transportation system, etc.
- There are improvements in policy response to the sector by better communication across the farmers, industry, scientists and policy makers.
- The IT revolution has influenced the sector to a great extent by using ICT in the communication, extension and interactions in the sector.

Therefore, forecasting vision 2050 is an exercise to develop a long-term perspective for the sector by taking cue from the past developments and present trends.

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Opportunities

By 2050, India has to produce about 17.5 MT of fish/year. It may be emphasized that the marine fish production over the years has been hovering around a production level of 3.0 to 3.5 MT while the inland capture is in the range of 1.0-1.2 MT. In recent years efforts have been made in the form of resource conservation, implementation of suitable regulations and promotion of culture based capture fisheries in the inland waters. However, much production improvement cannot be expected from this sector because of socio economic constraints and anthropogenic pressure on these water bodies. Fish production through mariculture and brackishwater culture of few fishes and shrimps would mostly target towards the export market. Thus, the freshwater aquaculture sector would be the only sector to increase the fish production in the country to meet mostly the domestic market demand and nutritional security of around 1.7 billion people in 2050. As per the projected requirement, the freshwater aquaculture sector has to produce minimum of 13.5 MT fish to meet the market demand of fish. However, with this level the per capita consumption will still be around 7.6 kg/capita/yr which is much lower than the international standard.

Due to the differential nature of resources, productivity of pond, level of adoption, demand and supply, investment capacity of farmer and social status of farmer, strategies for adoption of one or two blanket technologies would not be appropriate for the overall improvement of fish production of the country. In this context, it may be appropriate to have a strategic roadmap for development based on the resource potential and implementing them in a systematic manner to harvest opportunities offered by the sector. Robust technological development, economic liberalization, increasing interest of private entrepreneurs, freshwater fish biodiversity and diversified production systems, improved economic status and increased demand for quality products etc. will lead to investment and employment opportunities, export of diversified value added products, entrepreneurship development and thereby an expansion of the aquaculture sector.

Opportunities available in the freshwater aquaculture sector will primarily be realized through the technological developments in seed, feed, fertilizer, medicine and processing of the diversified species. These technological development need to be backed-up by strong scientific and basic research through application of modern biotechnological tools. The research in the social science hold the key in generating information to the policy makers for effective dissemination of the technology, formulation of the programmers and supportive developmental policies. Development of new institutional mechanism for technological dissemination and policy implementation will be the critical factor in realizing the potential available on the freshwater aquaculture sector.

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Goals and Targets

The goal is to ensure food and nutritional security as well as to provide livelihood support to fish farmers in the country by 2050. The onus of ICAR-CIFA is to contribute exclusively to the freshwater aquaculture development of the country by setting following targets.

1. Tripling fish Production

As per the projection, the freshwater aquaculture production in the country will be about 13.5 MT. In other words, there will be a 3 fold increase in freshwater aquaculture production in the country from the present level by 2050. This is arrived at a situation when the global capture fishery is stagnant or at its maximum. Broadly, there are two strategies that have to be adopted to achieve this target along with several allied ones supporting to it. One is horizontal expansion of area under culture and the other one is vertical expansion in terms of increasing the productivity per unit area. Under culture expansion, renovation and management of resources have to be done in such a manner that the average fish productivity from ponds and tanks would increase to 4-10 t/ha/year from the current level of about 3 t/ha/year. Intervention in the form of renovation of resources would not only help in increasing the fish productivity, but also would considerably increase the water harvest and groundwater recharge. While increased pressure of urbanization and industrialization has been shrinking the water availability for agriculture, our gross irrigated area needs to be increased from the present level of 97 mha to 140 mha in order to ensure food grain production of 450 to 500 mt to feed the 1.7 billion populations target by 2050. Resource allocation for achieving the production target by 2050 is provided below.

Resource allocation for tripling fish production in 2050

	Pond area allocation with fish productivity	Area (m ha)	Expected production (MT)
1	20% of the existing culture area (2.414 mha) with productivity 10 t/ha	0.483	4.344
2	30% of the existing culture area with productivity 6 t/ha	0.724	4.830
3	30% of the existing culture area with productivity 4 t/ha	0.724	2.896
4	20% will be under traditional farming with productivity 1 t/ha	0.483	0.483
5	Total Projection from existing pond resources	2.414	12.553
6	Creation/inclusion of new water bodies with productivity 2.0 t/ha	0.500	1..00
7	Grand Total (Production)		13.553

Assumption: (1) All the existing 2.414 mha of identified potential area will be used, (2) Creation/identification of new water bodies at least 0.5 mha with a production target of 2 t/ha and (3) 1.0 MT to fill the shortage in the above target.

Under vertical expansion, increased unit area productivity is intrinsically linked with intensive practices involving increased use of inputs and scientific management practices. In-situ modifications of the various inputs of the fish farming system in the forms of species diversification, system diversification, breed improvement, etc. will be emphasized.

2. Fifty species aquaculture

Freshwater aquaculture in India is mainly carp-based. The carps together contribute to more than 82% of total aquaculture production. However, since carp is considered as a low-valued fish, there is a need to make the aquaculture activity more remunerative to keep the fish farmers in the business for a long period. One of the possible ways for realization of the higher profit is through introduction of high valued species into the carp culture system. Fortunately, the country is blessed with rich diversity of potential cultivable fish fauna which includes minor carps and barbs having regional market preference, freshwater prawn, murrels, catfish, etc. There are almost two dozen of species for which seed production and grow-out culture technologies have already been standardized and field tested with considerable increase in the farm income. About two dozen more species are expected to be brought into the culture system by 2050 in order to reach the target production. Emphasis has to be given to bring in water resilient fish species as well as species of regional importance.

3. Breed improvement

Improvement of trait performance such as growth, resistance to disease, feed conversion efficiency, meat quality etc. is a key area to be strategized for sustainable aquaculture. Prioritization of species, development of a broad genetic base thereof and subsequently development of improved strains through selective breeding should be a priority in the coming decades. Controlled breeding after using same population over the years results in poor genetic base leading to retarded growth and low disease resistant variety due to inbreeding depression. Therefore, replacement of parent fishes should be mandatory at every two years while in use for commercial purpose. Selective breeding for at least 10 cultivable fish and prawn needs to be taken up in similar fashion as that of rohu, Jayanti which has more than 17% higher growth per generation. Effective dissemination of the improved stock has the potential to contribute significantly to the aquaculture production. The role of the fast growing, disease resistant and feed efficient stocking material will bring efficiency to the sector.

Genomics resources are highly complementary to the conventional genetic improvement programs. Essential genomics resources in the form of DNA marker data base, experimental populations, linkage and QTL maps, cDNA microarray, SNP array genotyping platforms etc. have to be generated for prioritized fish and shellfish species of commercial importance by taking advantage of next generation sequencing and allied technologies. Markers linked to performance traits in fish can lead to marker assisted selection (MAS) and genome wide marker effects for a performance trait can lead to genomic selection (GS). Therefore, integration of these resources into selective breeding program needs to be done for MAS and/or genomics selection.

4. Ensuring quality seed supply

Since brood stock is one of the most critical production components directly related to the seed quality and productivity, it emphasizes the need for improving their quality and ensuring the availability. At its present requirement level, the country is self-sufficient in terms of production of 35 billion carp fry and 7 billion post larvae of shrimp which are the two major requirements for the aquaculture sector. However, to cope up with the future requirement of quality seed as projected below, all round efforts and strategy have to be in place for assured round the year supply. Using gamete cryopreservation technique has to be popularized among the hatchery owners to overcome the inbreeding deficiency of the brooder and to establish genetically viable

Seed requirements & associated feed requirements

Requirements/percentage of existing area	20	30	30	20	100	New	TOTAL
Proposed Area	0.4828	0.7242	0.7242	0.4828	2.414	0.5	2.914
Fingerling Stocking no./ha	14000	9000	6000	2000		7000	7000
Total fingerling Requirement	6759	6518	4345	966	18588	3500	22088
Total fry Requirement (million)	13518	13036	8690	1931	37176	7000	44176
Rearing Area Requirement (ha)	45061	43452	28968	6437	123919	14000	137919
Spawn requirement (million)	33796	32589	21726	4828	92939	28000	120939
Nursery area Requirement (mha)	6759	6518	4345	966	18588	56000	74588
10 t/million fry Rearing (T)	135184	130356	86904	19312	371756	70000	441756
0.18 t/million spawn) 180 nursery (T)	6083	5866	3911	869	16729	5040	21769

brood fish population. National brood bank and broodstock upgradation program should be a reality. Production of stunted fingerlings, which has become popularized in recent years, needs to be promoted for round the year seed availability. Although multiple breeding and success in offseason breeding through controlled gonadal maturation in carps have been able to extend the breeding period, further efforts are necessary to bridge the gap and extend such breeding program in other species.

Assumptions: (80% Assumed survival from fingerling to table fish; Total available water area 2.414m ha; 0.900 kg avg wt attainment of the three IMC per year; Survival from fry to fingerling is 50%; Stocking density in rearing fry to fingerling is 0.3 million fry/ha; 40% survival from spawn to fry; Stock density in nursery is 5 mill/ha; Feed req. in nursery @180 kg/million spawn)

5. Assuring additional quality feed supply

Feed constitute more than of 60% of the production cost and efficiency in the feed use has a strong bearing on the cost-benefit ratio of the aquaculture operation. Globally the fed aquaculture constitutes about 75% of the current production from aquaculture. In China, more than 90% of the aquaculture production comes through feed based aquaculture, but in India, the fed fish culture is less than 30%. Even the less developed neighboring countries like Bangladesh and Sri Lanka, the proportion of fed fish culture is higher than India. At present about 7.5 MT feed ingredients are being used for formulating the fish feed. As per the projection, about 23 MT of feed will be required by 2050 for nursery, rearing and grow out phases. So, an additional 15.4 MT feed ingredients are required of which about 40% should be from oil cake (protein source) and 60% from maize and bran (carbohydrate source). To achieve the production target by 2050, the fed fish culture in India has to be raised to at least 70-80%. It is also necessary to convert 10-15% of the aquafarms of the country to intensive aquaculture

Feed requirement for achieving targets in 2050

Percentage of existing area (2.414 mha)	Proposed Area	Target Production/ha	Anticipated Prod (MT)	Anticipated FCR	Feed require (MT)
20	0.483	10	4.830	1.8	8.69
30	0.724	6	4.344	1.6	6.95
30	0.724	4	2.896	1.6	4.63
20	0.483	1	0.483	1.0	0.483
New area	0.500	2	1.00	1.6	1.60
Total			**13.553**		**22.36**

systems such as raceway culture, running water culture, recirculatory aquaculture, etc which are the complete feed based aquaculture. While promoting establishment of feed mill with low wastage and efficient feed management, efforts have to be made to find alternate ingredients and to improve feed conversion efficiency of the diet. While promoting the establishment of feed mill will result in low wastage and production of high quality feeds, the efforts are to be made to find out alternate feed resources and to improve the feed conversion efficiency of the diet.

6. Health management and production of Specific Pathogen Free Fish

Health management has to play a pivotal role in the coming years for sustainability of semi-intensive or intensive systems of aquaculture. The misuse and drawbacks in antibiotics, problems of emerging pathogens, transboundary diseases, poor quarantine etc. are further adding up to these issues for moving into better health management practices. To meet the challenges of newer and emerging pathogens, there is a need to emphasize on the development of newer molecular-based, specific, sensitive and farmer-friendly disease diagnostics. Exploration of immune system of major cultured candidate species and understanding pathogenesis of important diseases would pave the way in developing suitable immunoprophylaxsis using latest molecular approaches. Diseases like argulosis, edwardsiellosis, herpes viral diseases etc. that pose major threats to the industry would be given priority using novel approaches of prevention or control. The potentiality on use of nanomaterials in diagnostics and vaccine development will also be explored. Emphasis will also be given on computerized disease and farm management strategies for better control over emerging and reemerging pathogens. Raising of SPF stocks for important viral diseases of prawn (e.g. nodavirus) has to be an option in future in case of reemergence of the pathogens. Emphasis would be directed to map the diseases in major freshwater aquaculture systems of the country to prioritize the diseases that are causing major economic loss to the sector. Further, targeted active surveillance and health management practices would be taken up to prevent those diseases through development of molecular diagnostics and vaccines.

7. Optimization of water use and increasing water productivity with more crops per drop

A study made by the International Water Management Institute (IWMI) reveals that by 2025 nearly 1/3rd of world's population would live in the regions of severe water scarcity and the same proportion of population in India could face absolute water scarcity. The common notion that "Water is a free commodity" is no more a reality. Therefore, major focus will be on the judicious management of this natural resource and to develop strategies for its efficient and multiple uses. Development of the recirculatory aquaculture system (RAS) for fish farming, integration of fish and other aquatic organisms into existing farming systems in addition to diversification to agri-horticulture crops, and fish farming in reservoirs and open waters, flood-prone ecosystems and rice fields will be emphasized. Waste water (Sewage)-fed aquaculture which has been practiced in Kolkata since long without prior chemical or biological treatment has been playing a great role in water quality improvement. The mechanical and chemical processes are widely used for treatment of domestic sewage; the latest one is the Up flow Anaerobic Sludge Blanket (UASB) process. Therefore, it is important that wastewater be recycled for production of fish wherever possible since fish raised in such a system may be the cheapest and best source of edible animal products thereby imparting economic, biological and environmental benefits accrued from waste.

8. Export oriented production system and post-harvest processing

While intensification of the aquaculture practice could trigger environmental concern, practice of responsible aquaculture, best management practices and HACCP are some of the themes that need to be stressed upon on the freshwater aquaculture sector. Processing and post-harvest technology in the field of freshwater aquaculture followed by value addition has not yet received much attention in freshwater aquaculture sector. Aquaculture produce being highly perishable food items, a huge quantity is wasted in the process of transfer from farm to the consumer. Efforts are highly essential to minimize such loss during transportation while technology should be developed for value addition to realize greater profit and consumers' satisfaction. Creation of standard post harvest processing units, cold chains and certification systems for assuring product quality have to play important role in facilitating export oriented production system.

9. Bringing at least 20% of the resource under organic farming

Due to the increased health consciousness and increased purchasing power of the consumers, preference for organic fish has increased in recent years. Though few studies on the organic fish production have revealed quality fish production and good environmental sustainability, efforts in this area need to be intensified to ensure mass scale production in future while minimizing the degradation of environmental quality. Further, suitable mechanism should be evolved to establish the organic standards for fish farming and certification of the organic fish as that followed in agricultural and horticultural produces.

10. Mechanizing farm operation

In view of the impending labor scarcity, aquaculture is going to face major challenge in terms of farm operation in the coming years if timely steps will not be taken in terms of mechanization and automation. Though technology of mechanization and automation for many of the fish farming activities are already in place in other countries, many of such systems may not be cost effective to use in the low valued carp culture. Therefore, there is an urgent need to develop indigenous farm mechanization and automation technology and implements so as to reduce the operational cost and drudgery. Hi-tech aquaculture with use of automatic pond environment monitoring, oxygenation, monitoring of feeding, water exchange and efficient health management aimed at high fish production is almost non-existent in the country. Effort is needed in this regard to develop state of the art technology for high scale fish production in controlled environment.

11. Harnessing ICT and Space Technology for Aquaculture

The full power of Information Communication Technologies (ICT) is yet to be utilized in the aquaculture sector. Technological information can be delivered to an aquafarmer in the last mile with the help of farmer friendly mobile applications. Hence an ICT based information delivery system has to be evolved. Space technologies like the Geographical Information System (GIS) offers immense scope to develop highly effective decision making models for policy makers for future aquaculture development and management.

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Way Forward

With a view to accomplish the vision and mission of the institute, ICAR-CIFA emphasizes several programmes to enhance fish production through culture expansion and vertical increase in terms of resource renovation and management, system & species diversification, breed improvement and technology interventions. National brood stock upgradation, national dissemination programmes, round the year production of fish seeds, farm made feeds prepared from locally available feed resources, disease surveillance and remedy to crippling diseases, such as argulosis, impact assessment, etc. are some of the future research priorities of the institute. Capacity building of human resources including scientists, farmers and other stakeholders is always a priority to us in order to be globally competitive and ensure food and nutritional security of the country.

Consolidated research on water budgeting, water use efficiency, multiple use of water, participatory water use, recycling of water, integrated farming system research, fish culture in reservoirs, irrigation canals, flood plains and sewage/waste water, rain water harvesting and fish culture, use of seasonal water for short term fish culture, fish culture in peri-urban areas, culture of water resilient fish species and identification of abiotic stress tolerance genes and their use in developing more resilient and hardy fish species for culture, pricing of water, water legislation and incentives for efficient use of water and capacity building will go a long way in conservation and optimum use of water. By 2050, India has to produce about 17.5 MT of fish/year and the 80% of the total production must come from the aquaculture and therefore, it is essential to estimate the water requirement for increasing three folds seed and fish production from the present level. Emphasis will also be given to increase the productivity in future by stock manipulation, ecosystem management including water quality, minimizing disease loss and further improving the water productivity by waste removal through bioremediation, mechanical means, nanotechnology and using controlled indoor production systems.

Deadly bacterial, viral and parasitic diseases that pose major threats to the industry would be given priority using novel approaches of prevention or control. Raising of specific pathogen resistant fish and shellfish stocks for important diseases has to be taken up in case of reemergence of the pathogens. While promoting establishment of feed mill with low wastage and efficient feed management, efforts have to be made to find alternate ingredients for low cost farm-made feed and to improve feed conversion efficiency of the diet. Selective breeding for prioritized cultivable fish and prawn needs to be taken up in similar fashion as that of rohu, Jayanti which has more than 17% higher growth per generation. Effective dissemination of the improved stock has the potential to contribute significantly to the aquaculture production. The role of the fast growing, disease resistant and feed efficient stocking material will bring efficiency to the sector. Genomics resources are highly complementary to the conventional genetic improvement programs. Essential genomics resources in the form of DNA marker data base, experimental populations, linkage and QTL maps, cDNA microarray, SNP array genotyping platforms etc. have to be generated for prioritized fish and shellfish species of commercial importance by taking advantage of next generation sequencing and allied technologies. Therefore, a way forward should be to evolve genetically improved varieties of fish and shellfish through an integrated cost effective marker assisted selection and genomic selection programs at national level for prioritized species.

The sustainable development in aquaculture is always linked with policy support and proper strategies for technology transfer and adoption for effective resource utilization, market linkage, post-harvest product processing, etc. We hope to succeed in all fronts with the given strategies and targets.

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