



INTERNATIONAL
FOOD POLICY
RESEARCH
INSTITUTE

IFPRI

IFPRI Discussion Paper 01711

February 2018

**Scaling Up Innovations through Adaptive
Research: An Institutional Analysis and
Lessons from Farm Science
Centers in India**

P.N. Ananth

P.R. Sahoo

S.C. Babu

N.K. Barik

J.K. Sundaray

Director General's Office

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI), established in 1975, provides evidence-based policy solutions to sustainably end hunger and malnutrition and reduce poverty. The Institute conducts research, communicates results, optimizes partnerships, and builds capacity to ensure sustainable food production, promote healthy food systems, improve markets and trade, transform agriculture, build resilience, and strengthen institutions and governance. Gender is considered in all of the Institute's work. IFPRI collaborates with partners around the world, including development implementers, public institutions, the private sector, and farmers' organizations, to ensure that local, national, regional, and global food policies are based on evidence.

AUTHORS

P. N. Ananth (ananthkvk100@gmail.com) is senior scientist and head of Krishi Vigyan Kendra (KVK), Indian Council for Agricultural Research–Central Institute of Freshwater Aquaculture (ICAR-CIFA), Bhubaneswar, Khordha District, Odisha, India.

P.R. Sahoo (sahoo_prs@yahoo.com) is a subject matter specialist in fisheries at KVK-Khordha, ICAR-CIFA, Bhubaneswar, Khordha District, Odisha, India.

S.C. Babu (s.babu@cgiar.org) is a senior research fellow and head of capacity strengthening at the International Food Policy Research Institute, Washington, DC, and an extraordinary professor in agricultural economics at the University of Pretoria, South Africa.

N. K. Barik (nageshbarik@hotmail.com) is a scientist at ICAR-CIFA, Bhubaneswar, Odisha, India.

J.K. Sundaray (jsundaray@gmail.com) is director of ICAR-CIFA, Bhubaneswar, Odisha, India.

Notices

¹ IFPRI Discussion Papers contain preliminary material and research results and are circulated in order to stimulate discussion and critical comment. They have not been subject to a formal external review via IFPRI's Publications Review Committee. Any opinions stated herein are those of the author(s) and are not necessarily representative of or endorsed by the International Food Policy Research Institute.

² The boundaries and names shown and the designations used on the map(s) herein do not imply official endorsement or acceptance by the International Food Policy Research Institute (IFPRI) or its partners and contributors.

³ Copyright remains with the authors.

Contents

Abstract	v
Acknowledgments	vi
Acronyms	vii
1. Introduction	1
2. Scaling Up through Adaptive Trials: A Conceptual Framework	3
3. Study Area, Methods, and Data	7
4. Results and Discussion of Six Aquaculture Technologies	9
5. Institutional Lessons for Scaling up Technologies through Farm Science Centers	22
6. Concluding Remarks	26
References	27

Tables

Table 4.1	Trial results for replacement of normal rohu with Jayanti rohu in composite fish culture	9
Table 4.2	Trial results for incorporation of medium carps and barbs in a polyculture system	12
Table 4.3	Trial results for using CIFABROOD™ to increase spawning response in carps	14
Table 4.4	Trial results for polyculture of Indian major carps (catla and rohu) with prawns	16
Table 4.5	Trial results for preparation of farm made feed from locally available feed ingredients	18
Table 4.6	Trial results for utilizing seasonal fallow ponds for carp fingerling production	20
Table 5.1	Institutional constraints on scaling up aquaculture technologies after adaptive research trials	23

Figures

Figure 2.1	Patterns of aquaculture innovation flow in India, from researchers to extension providers to end users	3
Figure 3.1	Map of the study area, Khordha district, Odisha, India	8

ABSTRACT

Scaling up and mainstreaming proven technologies remains a major challenge for extension and rural advisory systems throughout developing countries. As a result, most of the relevant technologies, even when they are proven through farmer field trials, go “back to the scientists’ shelves,” partly due to a lack of appropriate institutional mechanisms to translate successful innovations and technologies to farmers’ fields on a wide scale. This obstacle seems to exist equally across the various types of extension and advisory services those in the public and private sectors, those offered by nongovernmental and civil society organizations, and those that take place from farmer to farmer. Developing the needed institutional mechanisms requires better understanding of the following: contextualization of the technological innovations depending on the current institutional capacity; institutional support for scaling up new technologies at the district, block, village, and farm levels; the existence and role of back-end institutions, including input suppliers, to sustain the technological innovation; the existence and role of front-end processing and value-addition opportunities from either the government, farmer cooperatives, or the private sector; and institutional support for translating adaptive trial results into mainstream extension messages and materials for farmer training and capacity development programs. Such institutional challenges and constraints have been little studied in the context of scaling up technologies and even less understood in the context of improving both the linear and nonlinear dynamics of research-extension-farmer linkages.

This study uses a two-plot trial comparing 6 new technologies with traditional farmer practices in 34 fish farmers’ ponds in the Khordha district of Odisha state, India. The results indicate that the 6 technologies are location specific and feasible; however, some of the required inputs are out of reach for a small-scale fish farmer. The study also reveals that constant institutional support is required to keep farmers using the new practices until an incubation period has been completed. It suggests ways in which the mainstream extension system can address farmers’ constraints in order to promote more widespread adoption of new technologies. The study illustrates the challenges of conducting adaptive trials in farmers’ fields and of reaching more farmers with the proven technologies. Finally, it suggests ways to improve the technology generation system and the institutions that organize adaptive trials, as well as areas for improvement in linking results such as these to mainstream extension. Very few studies have analyzed the results of adaptive trials and their utility for both the extension system and end users.

Keywords: Institutions, Adaptive trials, Farm science centers, Aquaculture technologies, Odisha, India

ACKNOWLEDGMENTS

This work was undertaken as part of the CGIAR Research Program on Policies, Institutions, and Markets (PIM) led by the International Food Policy Research Institute (IFPRI).

The authors thank the farmers who were involved for their esteemed cooperation in conducting these adaptive trials. Thanks are due to the Indian Council of Agricultural Research, New Delhi, for supporting the study with funds through Krishi Vigyan Kendra–Khordha.

ACRONYMS

ATMA	Agricultural Technology Management Agency
CIFA	Central Institute of Freshwater Aquaculture
ICAR	Indian Council for Agricultural Research
IMC	Indian major carps
KVK	Krishi Vigyan Kendra (farm science center)
NFDB	National Fisheries Development Board
R&D	Research and Development

1. INTRODUCTION

Technological innovation often remains in the research laboratories due to either poor relevance or inadequate efforts to scale up the technologies. Extension and rural advisory services aim to increase the reach of farmers, yet rural adoption of innovations remains low due to lack of full understanding of the institutional challenges to scaling up proven technological innovations. Several basic questions continue to confront extension functionaries in developing countries: how to scale up technologies that show promise through adaptive field trials, how to identify the technology-specific institutional constraints, what role adaptive research trials play in identifying challenges farmers face, and what the implications are for institutional interventions toward bringing actors and players in extension and rural advisory services together to meet the challenges of mainstreaming technological innovations. To address these fundamental questions, this paper presents a case study of adaptive research on aquaculture innovations in the Indian state of Odisha.

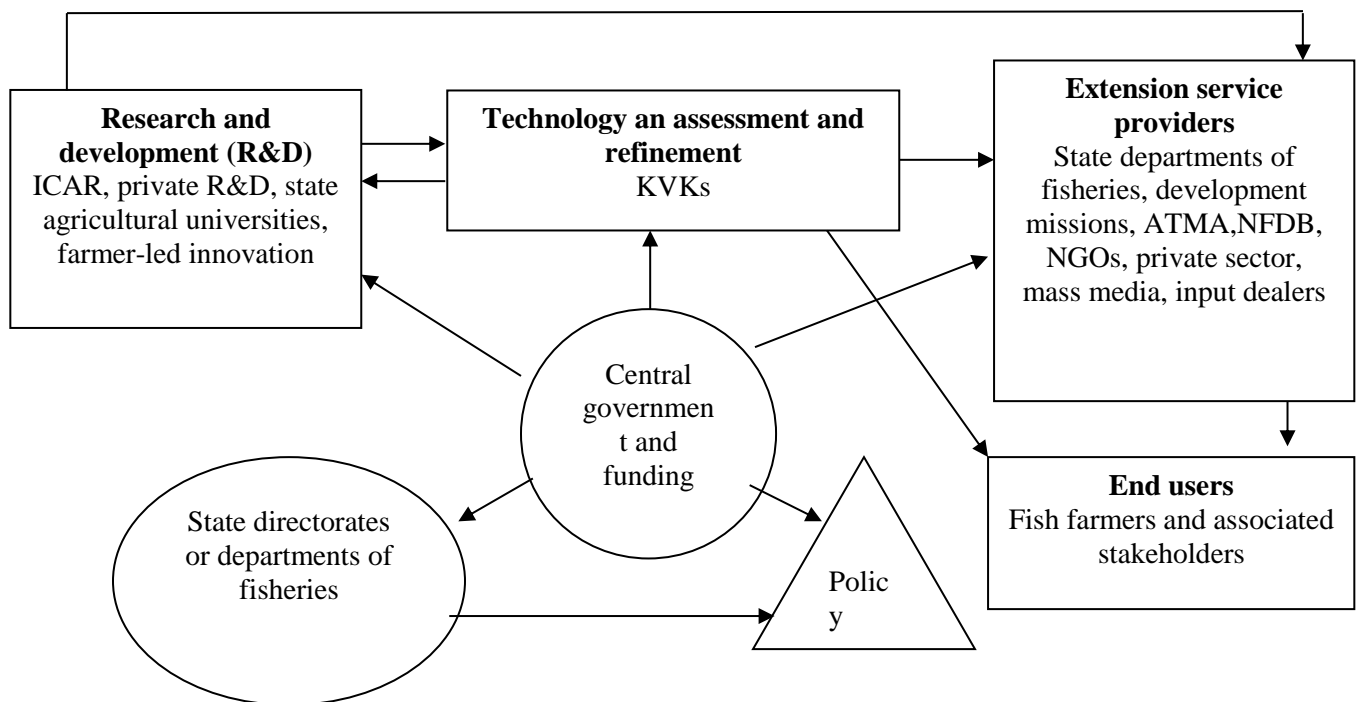
In India, farm science centers (locally called Krishi Vigyan Kendras, or KVKs) are the pivotal district-level institutions that translate innovations from the lab to farmers' fields through locality-specific trials. This paper documents a case study and lessons learned from an attempt to scale up a set of aquaculture innovations through adaptive research trials involving small-scale fish farmers in Odisha. KVKs conduct adaptive research trials of innovative technologies in farmers' fields before these technologies are scaled up through extension and rural advisory services. The paper describes challenges in organizing adaptive trials and in getting mainstream extension workers to promote the technologies. In the federal-state system of governance in India, because aquaculture is a state-mandated sector, much of the technology transfer and adoption takes place through state-level institutions dealing with extension and advisory services. Although this case study explores institutional constraints on scaling up aquaculture technologies, it also identifies potential areas of policy and program intervention for improved functioning of the institutions at all levels.

The objectives of this paper are threefold: first, identify the characteristics of a technology that make it suitable for adaptive research in the farmer's field; second, identify technology-specific institutional bottlenecks in the process of scaling up the identified technologies; and third, develop technology-specific solutions for scaling up technologies through integrating institutional interventions at the district level. The rest of the paper is organized as follows. The next section presents an institutional mapping of technology transfer mechanisms in the context of Indian aquaculture. The study methods and data are presented in Section 3. Results and discussion on six different aquaculture technologies are given in Section 4. Section 5 offers institutional lessons learned from the adaptive research trials. Concluding remarks make up the last section.

2. SCALING UP THROUGH ADAPTIVE TRIALS: A CONCEPTUAL FRAMEWORK

In the context of the federal-state system in India, technology transfer and extension delivery happens through a pathway that involves various intermediary institutions such as KVKs. Yet understanding the institutional challenges in organizing the delivery of innovations at the farm level requires a full understanding of the various actors and players in the innovation system. Figure 2.1 presents a conceptual framework to trace the pathways through which technological innovation reaches farmers.

Figure 2.1 Patterns of aquaculture innovation flow in India, from researchers to extension providers to end users



Source: Authors ' compilation.

Note: ATMA = Agricultural Technology Management Agency; ICAR = Indian Council for Agricultural Research; KVK = Krishi Vigyan Kendra (farm science center); NFDB = National Fisheries Development Board; NGO = nongovernmental organization.

The system whereby innovations reach end users in India involves multiple actors playing different roles, as illustrated in Figure 2.1. In aquaculture, research and development (R&D) is dominated by the public sector, followed by a few private R&D centers, state agricultural universities, and other universities. Once innovations are ready, they are commercialized by specific bodies within the R&D

system, such as research institutes of the Indian Council for Agricultural Research (ICAR) as well as the private sector. The technology is then commercialized and made available to the public and the KVKs. The KVKs help identify, assess, and deliver location-specific technologies along with education about their economic feasibility in the farmer's field, regularly transmitting assessment results to both the research system and the extension system. In most cases, they also share these results at state-level research-extension linkage meetings organized by state agricultural universities.

As shown in Figure 2.1, extension service providers are the state departments of fisheries, specific fisheries development missions, the district-level Agricultural Technology Management Agency (ATMA), the National Fisheries Development Board (NFDB), non governmental organizations, the private sector, mass media, input dealers, and so on. KVKs act as a semi-extension agency, playing a key role in providing advisory services using information and communication tools, personal home and farm visits, and other methods. Too often, however, research-extension linkage at the district level has no concrete framework, and extension is loosely organized. As a result, innovative technologies assessed by the KVKs are seldom accepted by the state extension system. The challenge is to link the results of technology assessment to mainstream extension, and to formalize the latter for better reach and effectiveness.

Aquaculture is one of the promising livelihood options for millions of farmers all around the world. Employment in the sector has grown faster than the world's population. Aquaculture is one potential pathway for poverty alleviation and social and economic development (Belton et al. 2011; Haque 2007; Karim et al. 2011; Little et al. 2012). A recent report by the Food and Agriculture Organization of the United Nations (FAO 2014) indicated that world aquaculture production continues to grow, albeit at a slowing rate.

There has been a substantial increase in freshwater aquaculture production worldwide, perhaps due to the severe decline in marine fish production. India is a major producer of fish through aquaculture, ranking second in the world after China (FAO 2014). During 2013/2014, India was the second largest producer of fish in the world contributed 5.68 per cent of global fish production. Fish production is not

only a source of livelihood for more than 14 million of India's people but also a necessity for its socioeconomic development, contributing US\$470.02 million a year to the country's economy. The vast resources of both inland and marine fisheries are indicative of the immense growth potential of the sector (*Handbook on Fisheries Statistics* 2014). The adoption of innovative technologies, coupled with state-level development programs for fish farmers, has been one of the prime movers of the sector's achievements. The Food and Agriculture Organization (FAO 2014) indicated that improved science, technology, and governance are all combining with greater global understanding and commitment to help meet the goals of responsible and sustainable use of aquatic resources.

In response to reports that agricultural technologies were often irrelevant to small-scale farmers, farming systems research arose in the 1970s as an effort to consider sociological and other local factors in agricultural R&D (Sutherland 1987). Fliert and others (2010) found that in Indonesia, agricultural research has had limited impact in farmers' fields because innovations are often not suited to local conditions. Lado concluded that "where useful technologies exist, their spread has been very limited, and where they have been adapted, the benefits only accrue to a small segment of the community" (1998, 165). Studies carried out in India and other countries have indicated that new technology (often developed at experimental stations) at times is inappropriate for the farmers for whom it was intended (Asopa and Beye 1997). In the Solomon Islands, a participatory action research approach was used to conduct on-farm trials with farmers to develop relevant and improved ways of farming and maximizing productivity of the resident exotic tilapia (Harahou et al. 2016).

Subsistence fish farming dominates in India, with the average fish farmer possessing a pond less than 0.1 ha and with scarce adoption of modern practices. Although R&D organizations have developed technological options and commercialized them through a process, the reality in the farmer's pond is different from that at the research station. Location-specific adaptive trials are essential to feed the mainstream extension system with technologies that more fish farmers will adopt. The district-level KVK has the prime mandate of technology assessment through on-farm trial, refinement, and demonstration of technologies for agriculture and allied sectors. According to Venkatasubramanian et al (2009), an on-farm

trial conducted by a KVK aims at testing a new technology or idea in farmers' fields, under farmers' conditions and management, using farmers' existing practices as a control. Further, such a trial should help to develop an innovation consistent with local farmers' circumstances, compatible with their actual farming system, and corresponding to their goals and preferences.

KVKs test commercialized technologies and farming practices on farmers' fields and provide feedback to state development departments. These assessment trials help researchers understand the feasibility of a technology at the micro farming level, where conditions, as mentioned, are different from those at experimental stations. Even so, some robust technologies that are successful in on-farm trials nevertheless fail in practice because the required critical inputs are not cost-effective.

The KVK in Khordha district, Odisha, under the administrative control of the Central Institute for Freshwater Aquaculture (CIFA), itself a part of ICAR, trials at least 20 technologies per year from agriculture and allied sectors. This paper presents the results of 6 aquaculture technologies assessed and demonstrated by KVK-Khordha in order to understand the feasibility of the technologies and assess the feedback provided to the mainstream extension community for larger adoption.

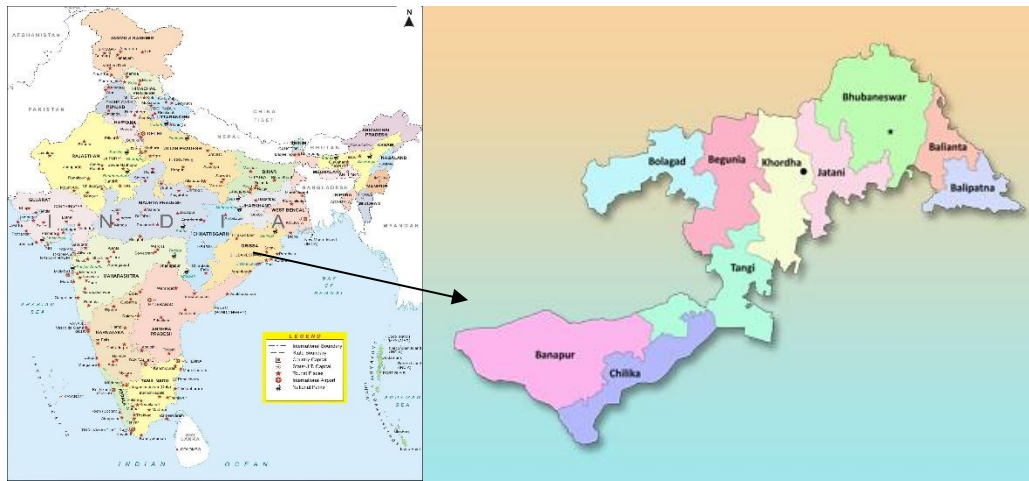
3. STUDY AREA, METHODS, AND DATA

The case study presented in this paper is based on the district-level implementation of adaptive research trials in the Khordha district of Odisha state, India. Khordha is endowed with natural resources for providing livelihoods in both the rural and urban sectors. Agriculture is the mainstay and plays a vital role in the economic development of the district, with animal resources supporting the livelihoods of a majority of the farming community. Fisheries also serve as a major livelihood option for rural residents of the three blocks of the district where freshwater resources are accessible. The area under freshwater aquaculture in the district is 1,929.24 ha, which mainly comprises tanks and ponds and produces fish of 15,760 MT as in 2015 (DFO 2015).

Institutional Analysis through Adaptive Trial and Demonstration

The KVKs' adaptive research trials are based on a technology assessment and refinement approach approved by ICAR. "Technology assessment and refinement" refers to a set of participatory procedures aimed at developing recommendations for using a recently released technology in a particular agro climatic situation or location (Venkatasubramanian et al. 2009; Tripp 1992; Box and van Dusseldorp 1992). In the context of the Indian extension system, KVKs assess and refine technologies before they are disseminated in a new production system. With these principles in mind, the Khordha district KVK selected 6 aquaculture technologies developed by ICAR- CIFA for assessment and demonstration by 34 farmers in 8 blocks (Figure 3.1). The institutional analysis presented here is based on stakeholder discussions during the adaptive trials of these technologies and the potential challenges to scaling them up. Such analysis is crucial for the design and implementation of the extension service delivery strategy.

Figure 3.1 Map of the study area, Khordha district, Odisha, India



Source: Maps of India.com

Farmers were selected for their innovativeness, progressiveness, and level of influence in the village. Willingness to take some risk was also important because the technology being tested may or may not yield better results than the farmer's usual practice. The district KVK provided farmers with the critical inputs for each selected technology and trained them using a participatory approach. KVK scientists regularly visited the farmers' ponds to collect data and to apprise the farmers about the condition of the ponds, inform them of the next stages of implementation, and observe any individual and institutional challenges they encountered with the technology. Inventor scientists were also involved during various phases of some of the assessments and demonstrations. The trials were conducted from 2010 to 2015 with financial assistance from ICAR, New Delhi. A pretest interview was developed to collect primary data based on the parameters for each technology. Secondary data from development departments and details on each technology were collected from ICAR-CIFA.

4. RESULTS AND DISCUSSION OF SIX AQUACULTURE TECHNOLOGIES

Technology 1: Replacement of Normal Rohu within Improved Strain of Rohu in Composite Fish Culture

Carps in many Indian farm ponds experience a low growth rate due to low-quality seed and lack of scientific management. Among the Indian major carps (IMC), rohu has a good market demand and growth potential in Odisha, including urban districts such as Khordha. A genetically improved variety known as Jayanti rohu, developed through a selective breeding program by CIFA in collaboration with the Norwegian Institute of Food, Fisheries and Aquaculture Research, looks morphologically similar to rohu. After four generations, however, the new strain reportedly shows a 17 percent higher growth rate than normal rohu; it is now making an impact on production output at the farm level (Ayyappan and Jena 2006). The technology package from ICAR-CIFA indicates that Jayanti rohu can be incorporated in the culture system for higher production per unit of area. In 2012/2013, KVK-Khordha successfully tested incorporating the improved strain through on-farm trial and demonstration programs in the district. It is anticipated that replacement of normal rohu with Jayanti rohu can usher in a revolution in fish production in the district. The results of the trial are presented in Table 4.1.

Table 4.1 Trial results for replacement of normal rohu with Jayanti rohu in composite fish culture

Name of the technology	Replacement of normal rohu with Jayanti rohu in composite fish culture
Problem identified	Slow growth rate of normal rohu
Year of assessment	2012/2013
Source of technology	ICAR-CIFA
Details of technology	Stocking of catla, Jayanti rohu, and mrigal fingerlings at 10,000/ha in 30:40:30 ratio. Supplementary feeding with groundnut oil cake and rice bran (1:1 ratio by weight). Feeding at 5 percent of stocked biomass in the initial months and 2–3 percent of stocked biomass in subsequent months. Application of lime in phases plus fortnightly application of manure increases the plankton level in pond water
Characteristic features of the technology	Jayanti rohu exhibited a 17 percent higher growth rate than the normal rohu, thus shortening the culture period
No. of farmers involved in the assessment	3
Coverage blocks	4 (Balianta, Balipatna, Bolagarh, Begunia)
Results of the assessment compared with farmers' practice	Jayanti rohu grows 15.2 percent more than normal rohu in farmers' ponds, yielding an average additional income of US\$568.75/ha
Source of critical inputs for the technology	ICAR-CIFA ; Odisha Directorate of Fisheries, Kausalyaganga
No. of farmers benefited through demonstrations	40

Source: Authors

Note: ICAR-CIFA = Indian Council for Agricultural Research–Central Institute of Freshwater Aquaculture.

In the trial, Jayanti rohu grew 15.2 percent more than normal rohu, not far out of line with research station findings of a 17 percent higher growth rate (Ayyappan and Jena 2006). The trial result is also in line with the finding of Dey and others (2010) that on an average farm in India the improved carp strain had a 15 percent higher body weight at harvest than an unimproved strain (36 percent higher in Bangladesh). Das Mahapatra and colleagues (2007) reported that in field trials in different parts of India, the improved rohu showed a significantly greater growth rate in comparison with the control consisting of normal rohu.

Constraints on Scaling Up the Technology

The field trial generated an additional income of US\$568.75/ha, a key argument for scaling up at the district level. Thus, we highly recommend replacing normal rohu with genetically improved Jayanti rohu in composite carp culture in the district to increase the productivity of individual and community ponds. Dey and others (2013) added that adoption of genetically improved carp strains will increase production of carp as well as other fish, resulting in enhanced profitability of fish farming, lower carp prices, increased carp consumption, and improved economy of households as well as the nation.

Though the technology has been shown to be viable, we note several institutional constraints. The most important of these is the availability of the improved strain. Kumar, Dey, and Barik (2008) pointed out that production of the improved strain requires intense effort at the nucleus, multiplier, seed, and grow out units, as well as support at the policy level. The nucleus unit for the improved strain is situated at ICAR-CIFA in Khordha district. The district needs a multiplier unit for production of seeds (fry to fingerling) and to supply farmers. For further dissemination of the strain, the government should provide brooders to hatchery owners on a subsidy basis. Input subsidies, output purchase programs, input quality certification and control systems, public credit provision, and overall support for the sector (Kohl, Foy, and Zodrow 2017) would help in scaling up the technology. Another option would be a public-private partnership to open specialized outlets, as suggested by Kumar, Dey, and Barik (2008). Contract farming in fingerling production (fry to fingerling) would remove constraints on the supply of seeds to farmers,

because hatcheries concentrate mostly on spawn production. Above all, because adoption of the improved strain will benefit farmers through higher productivity, the brooders should cost more, in keeping with the R&D investments made by the government. The larger impact at the district level will be the replacement of normal rohu with a strain production, productivity, and gains. Finally, the government should take steps to fix a premium price for improved strains such as Jayanti rohu.

Technology 2: Incorporation of Medium Carps and Barbs in a Polyculture System

In pond ecology, the concepts of carrying capacity and standing biomass play a major role in increasing the production per unit of area. Judicious use of these factors provides the opportunity to incorporate medium carps and barbs in an IMC culture system, increasing its diversity. According to Das and Mishra (2016), many minor carp species available in the natural waters of India have culture potential and regional importance due to high consumer preference. Being categorized as local fish by consumers, these minor carps also command a 20–30 percent higher market price than IMC, depending on regional demand. Theoretically, the initial higher growth rate of medium carps and barbs increases the production and income potential of culture ponds. Besides their good market demand and consumer preference, these fishes play an important role in species diversification and conservation. KVK successfully tested this technology in farmers' ponds with positive results. The details of the technology, results, and recommendations are presented in Table 4.2.

Table 4.2 Trial results for incorporation of medium carps and barbs in a polyculture system

Name of the technology	Incorporation of medium carps and barbs in a polyculture system
Problem identified	No intermediary income during culture period; low yield due to single harvest with Indian major carps
Year of assessment	2012/2013
Source of technology	ICAR-CIFA
Details of technology	Stocking of Indian major carps (catla, Jayanti rohu, and mrigal) at 8,000/ha. Partial incorporation of 10–15 percent. <i>P. gonionotus</i> and <i>P. saranaas</i> bottom dwellers and <i>L. fimbriatus</i> and <i>P. gonionotus</i> as column feeders. Harvesting of the latter in 5–6 months, allowing the major carps to grow further
Characteristic features of the technology	The initial higher growth rate of medium carps gives an opportunity to utilize the pond's carrying capacity, providing opportunity for additional production and income
No. of farmers involved in the assessment	6
Coverage blocks	2 (Balianta, Balipatna)
Results of the assessment compared with farmers' practice	Production increased from 3.23MT/ha to 3.58 MT/ha, and net income increased by 15.25 percent
Source of critical inputs for the technology	ICAR-CIFA; Odisha Directorate of Fisheries, Kausalyaganga
No. of farmers benefited through demonstrations	15

Source: Authors

Note: ICAR-CIFA = Indian Council for Agricultural Research–Central Institute of Freshwater Aquaculture.

In the assessment trials, production increased from 3.23MT/ha to 3.58 MT/ha, with a 15.25 percent average increase in farmers' net income (Ananth et al. 2017). Incorporation of medium carps is a feasible technology for larger-scale adoption. Common carp, owing to its early maturing and pond breeding habit, may upset the population balance, resulting in poor growth of other component species (Sinha et al. 1985). Incorporation of *L. calbasu* in place of common carp may be a better strategy to avoid this problem. The incorporated fishes also enjoy good market demand and consumer preference in the district (Borah, Gogoi, and Rahman 2014). Results of the trial were in line with those of Das and Mishra (2016): the multispecies carp-barb system with minor carps and barbs as the main component yielded higher fish production than did the system with major carps alone or as the main component.

Constraints on Scaling Up the Technology

The no availability of quality brooders, lack of a market for diversified species, and lack of awareness about raising and marketing these species (because they are a regional consumer preference) are the constraints on scaling up the technology. The district has to exploit the potential of introducing these

species in the community ponds, small reservoirs, and other water bodies for increasing adoption. The partial returns that farmers gain by incorporating minor carps along with IMC are an additional benefit. Although consumers in other Indian states prefer the minor carps, consumers in Khordha district demand IMC. Export to other regions and additional income to farmers will be the key benefits if the technology is scaled up in the district. Private entrepreneurs should be encouraged to culture minor carps because the markets are well identified and a value chain can be created for them as farmers gain experience. Private partnerships will surely enhance the scaling up of this technology, in line with the study of Kohl, Foy, and Zodrow(2017), who found partnerships with the private sector to be useful in scaling up technologies that are largely commercial. In addition, unexploited water bodies such as seasonal ponds and derelict water bodies can be used for the production of minor carps along with major carps (see Technology 6).

Technology 3: Use of CIFABROOD™ to Increase Spawning Response in Carps

IMC generally breed during the monsoon season (June–August). Early breeding and seed production of carps can reduce the culture time and provide additional income to seed producers. Research has shown that it is possible to breed IMC in the off-season, but the technology has not been tried in farmers' ponds. CIFABROOD™, an exclusive carp brood stock diet developed and commercialized by ICAR-CIFA, is suitable for multiple or repeated breeding, out-of-season gonad growth, and post-spawning recovery. KVK-Khordha was the first to test the product in three hatcheries of the district and successfully bred IMC in the month of April during high summer temperatures. The details of the technology, results, and recommendations are presented below in Table 4.3.

Table 4.3 Trial results for using CIFABROOD™ to increase spawning response in carps

Name of the technology	Performance of CIFABROOD™ to increase spawning response in carps
Problem identified	Less recovery of healthy spawn; breeding only in monsoon (June–August)
Year of assessment	2013/2014
Source of technology and year	ICAR-CIFA, 2012
Details of technology	The rate of feeding is 3–5 percent of total body weight during vitellogenic phase
Characteristic features of the technology	CIFABROOD™ is an exclusive carp brood stock diet, adequately rich in essential nutrients. It advances gonad growth and maturation, facilitates early spawning, and significantly increases spawning response. It is suitable for multiple or repeated breeding, out-of-season gonad growth, and post-spawning recovery
No. of farmers involved in the assessment	5
Coverage blocks	2 (Baliana, Banapur)
Results of the assessment compared with farmers' practice	Maturation of brood in 35–40 days and more than 88.14 percent fertilization rate during the month of April/May. The benefit-cost ratio was 4.7
Source of critical inputs for the technology	Aisharya Aquaculture Pvt. Ltd., Kolkata
No. of farmers benefited through demonstrations	4 hatchery owners

Source: Authors

Note: ICAR-CIFA = Indian Council for Agricultural Research–Central Institute of Freshwater Aquaculture.

In the assessment trials, the brood matured in 35–40 days, with an 88.14 percent fertilization rate during the month of April/May. With a benefit-cost ratio of 4.7, CIFABROOD™ is highly recommended for off-season carp seed production. Besides ensuring the availability of fish seed from April to September, seed produced early fetches a higher price and reduces the length of the culture cycle. In another study, Pankaj and Jagdish (2012) found that out of 45 pairs stocked in November, 34 pairs of fishes had matured by April under improved bloodstock management practices and intermittent doses of pituitary gland extract.

The perceived attributes of an innovation are one important factor in its rate of adoption (Rogers 1995). Sahoo et al. (2017) studied CIFABROOD™ in relation to the five attributes of innovations relative advantage, compatibility, complexity, trialability, and observability in trials with participant and nonparticipant hatchery owners. All five attributes were associated with an anticipated future high rate of adoption of CIFABROOD™.

Constraints on Scaling Up the Technology

Concerns about CIFABROOD™ center on its cost. Whereas traditional feed costs about 0.48 US\$/kg, CIFABROOD™ runs about US\$1.20/kg. Nandi and others (2014), however, found that the estimated expenditure for feeding 1,000 kg of brood stock was about US\$1,406.25 and that a farmer could earn an additional US\$16,406.25 by using CIFABROOD™.

Another apprehension is the improved feed's availability. ICAR-CIFA commercialized the technology through feed manufacturer, but there is no marketing linkage with hatchery owners. The technology is a breakthrough; however, the end product, off-season fish seeds, fetches the same price as conventional seeds produced in the normal season. R&D efforts should be made toward reducing the cost of the feed, and the government should fix a special price for the off-season-bred fish seeds. The feed could be included in the state scheme, and the government should consider providing incentives to hatchery owners who produce year-round seeds using this feed. If the technology is scaled up, the district will be self-sufficient in seed production and benefit from an increased number of production cycles. By and large, the advantage for the district will be that fish seeds can be produced irrespective of the erratic monsoon, likely making CIFABROOD™ a climate-resilient and sustainable technology.

Technology 4: Polyculture of IMC (Catla and Rohu) with Prawns

Freshwater prawns are a cash crop with very good demand on the local market due to consumer preference. In India, prawns are produced in a monoculture system at a commercial scale for export markets. A viable technology of stocking ponds with prawns along with IMC (catla and rohu) can fulfill the local demand for prawns and increase the financial security of poor fish farmers. KVK successfully tested this technology in farmers' ponds and saw an increase in their incomes. The details of the technology, results, and recommendations are presented in Table 4.4.

Table 4.4 Trial results for polyculture of Indian major carps (catla and rohu) with prawns

Name of the technology	Polyculture of IMC (catla and rohu) with prawns
Problem identified	Culture of IMC only
Years of assessment	2011/2012 and 2012/2013
Source of technology	ICAR-CIFA
Details of technology	Stocking of catla and rohu fingerlings at 5,000/ha, stocking of juveniles at 10,000/ha in the nursery. Supplementary feeding with groundnut oil cake and rice bran in 1:1 ratio through provision of check tray
Characteristic features of the technology	Stocking of IMC without mrigal provides a good niche for the prawns to grow without competition. Providing hideout space facilitates molting and reduces cannibalism of prawns
No. of farmers involved in the assessment	8
Coverage blocks	3 (Balianta, Balipatna, Begunia)
Results of the assessment compared with farmers' practice	Production increased from 2.4 MT/ha to 2.76 MT/ha, with an average 22.3 percent increase in net income
Source of critical inputs for the technology	ICAR-CIFA
No. of farmers benefited through demonstrations	12

Source: Author

Note: ICAR-CIFA = Indian Council for Agricultural Research–Central Institute of Freshwater Aquaculture; IMC = Indian major carps.

In the demonstrations, production increased from 2.4 MT/ha to 2.76 MT/ha, and farmers saw an average 22.3 percent increase in net income. Polyculture of IMC (without mrigal) with prawns provides additional income per unit of area due to high demand for prawns in the market. Rouse and Stickney (1982) observed higher net returns on prawns in a polyculture system than in monoculture.

Constraints on Scaling Up the Technology

The biggest constraint faced by farmers in the district is the lack of availability of prawn seeds (juveniles) for culture. Only two hatcheries in the district produce prawn seeds (that is, post larvae)—ICAR-CIFA and the district office of the Odisha Directorate of Fisheries—and they cannot meet the demand. It is not feasible for a smallholder fish farmer to establish a freshwater prawn hatchery due to the technical intensity involved in bringing in seawater and the other laborious steps to be followed. The government should invite private entrepreneurs to invest in establishing freshwater prawn hatcheries to meet the demand. Throughout the country, there has been a threat to freshwater prawn culture due to the introduction of white leg shrimp (*Litopenaeusvannamei*). Promoting freshwater prawns in a polyculture

system for small-scale farmers will keep the demand up for this species. Farmers can also earn income by rearing post larvae procured from hatcheries to juveniles, because the mortality will be high during this phase as practiced in carp seed production. As with the other technologies, incorporation of prawns in a polyculture system will also need to have a special mention in the state scheme. Apart from these considerations, if the technology is scaled up, the district will reap the advantages of opening a new market for prawns, a high-value species that can also be consumed by fish farmers. The practice of incorporating prawns will also raise income per unit of area.

Technology 5: Preparation of Farm-Made Feed from Locally Available Feed Ingredients

Feed cost constitutes 50–60 percent of the total cost involved in any aquaculture operation. Protein is the costliest nutrient in a formulated feed. Hence, reduction in the protein cost in a feed reduces the overall feed cost and ultimately reduces the input cost toward fish culture. Fish farmers use groundnut oil cake as the main protein-rich ingredient, along with rice bran, in their fish feed preparations. Over the years, the cost of groundnut oil cake has been increasing gradually. ICAR-CIFA has developed many fish feed preparations from combinations of cheap, locally available ingredients, which have reduced the cost marginally. One of these combinations was tested in farmers' ponds. The details of the technology, results, and recommendations are presented in Table 4.5.

Table 4.5 Trial results for preparation of farm made feed from locally available feed ingredients

Name of the technology	Preparation of farm-made feed from locally available feed ingredients
Problem identified	Lack of knowledge about preparation of balanced feed from locally available feed ingredients, increasing cost of groundnut oil cake (alarming)
Year of assessment	2012/2013
Source of technology	ICAR-CIFA
Details of technology	Farm-made feed is a low-cost, balanced fish diet formulated cheap, locally available ingredients. The feed is prepared from sesame til oil cake (30 percent), mustard oil cake (30 percent), rice bran (39 percent), and a mineral mixture (1 percent)
Characteristic features of the technology	Utilization of locally available feed ingredients and reduction of protein cost in feed, thus increasing the profit margin
No. of farmers involved in the assessment	8
Coverage blocks	3 (Balianta, Balipatna, Tangi)
Results of the assessment compared with farmers' practice	Production increased from 2.85 MT/ha to 2.94 MT/ha, with a 9.47 percent average increase in net income
Source of critical inputs for the technology	ICAR-CIFA
No. of farmers benefited through demonstrations	8

Source: Authors

Note: ICAR-CIFA = Indian Council for Agricultural Research–Central Institute of Freshwater Aquaculture.

During the trial, production increased from 2.85 MT/ha to 2.94 MT/ha, and the average farmer saw a 9.47 percent increase in net income. Hence, it is recommended that farmers adopt the technology and those extension providers create awareness among fish farmers that it leads to higher production with lower inputs.

Constraints on Scaling Up the Technology

The success of any aquaculture operation is likely due to the use of quality seed, feed, and other critical inputs. Feed, as one of the major inputs, also has a major share in the cost of the operation. Any technology that can reduce the feed cost will be remunerative for small-scale farmers, and the technology described here is one of these. To scale up this practice, there needs to be extensive effort from the extension agencies to raise awareness of the cheap, locally available ingredients that can be made into feed. Moreover, the practice requires certain skills, so large-scale demonstrations need to be performed to enable farmers to adopt this technology. The government should map out the common cheap and locally available ingredients suitable for farm-made feeds and subsidize other critical inputs. Even though

farmers using farm-made feed are more likely to be profitable than those using commercial, pelleted feeds, they may still desire the convenience of pellets. To encourage fish farmers to adopt this practice, the government could provide small feed pelletizer machines as an incentive.

Scaling up this technology in the district as recommended by KVK could decrease the cost of inputs by as much as 60 percent. Nandeesh (1993) observed that inadequate availability of some recommended ingredients at an affordable cost is also a factor in non adoption by farmers. The price of groundnut oil cake, the most common protein that farmers use to prepare fish feed, is increasing day by day, and quickly becoming unaffordable. The trial clearly shows that farm-made feed is viable as a recommendation to the district extension system.

Technology 6: Utilization of Seasonal Fallow Ponds for Carp Fingerling Production

Aquaculture is considered one of the fastest-growing animal food-producing sectors, and the availability of quality seed is a prerequisite for its rapid expansion and growth. Khordha district has typical homestead ponds and many unutilized seasonal water bodies that dry up every year. Technology such as fry to fingerling production takes two to three months and fetches a good return. Keeping these factors in mind, a trial was conducted to study the feasibility of producing fingerlings in otherwise fallow water bodies. The technology was assessed in terms of fingerling survival rate and additional income generation that might attract pond owners to take it on as a profitable enterprise. The details of the technology, results, and recommendations are presented in Table 4.6.

Table 4.6 Trial results for utilizing seasonal fallow ponds for carp fingerling production

Name of the technology	Utilization of seasonal fallow ponds for carp fingerling production
Problem identified	No utilization of seasonal ponds
Year of assessment	2010/2011
Source of technology	ICAR-CIFA
Details of technology	Pond manuring with groundnut oil cake, raw cow dung and single super phosphate. Stocking of IMC fry at 200,000–300,000/ha. Supplementary feeding with groundnut oil cake and rice bran in 1:1 ratio at 8–10, 6–8, and 4–6 percent of stocked biomass during the first, second, and third months, respectively
Characteristic features of the technology	Fry to fingerling production takes 2–3 months and can be undertaken in seasonal fallow ponds as a short-duration activity
No. of farmers involved in the assessment	4
Coverage blocks	3 (Balianta, Balipatna, Tangi)
Results of the assessment compared with farmers' practice	A survival rate of 73.25 percent and average additional net income of US\$1,205.05/ha was achieved
Source of critical inputs for the technology	KVK-Khordha, ICAR-CIFA, Odisha Directorate of Fisheries, and private seed producers
No. of farmers benefited through demonstrations	20

Source: Authors

Note: ICAR-CIFA = Indian Council for Agricultural Research–Central Institute of Freshwater Aquaculture; KVK = Krishi Vigyan Kendra (Farm Science Center).

Demonstration ponds showed a fingerling survival rate of 73.25 percent and additional net farmer income of US\$1,205.05/ha. Because fry to fingerling production in seasonal fallow water bodies is a profitable enterprise within a short period, it is recommended that farmers be encouraged and attracted to produce fingerlings in unused seasonal ponds. The demonstration results are in line with those of Sahoo and others (2015) that the technology was positive based on farmers' perception. Thus, it is expected that seasonal pond use can be adopted as an additional income-generating activity to strengthen the livelihood of rural farmers.

Constraints on Scaling Up the Technology

Increasing the water resources available for aquaculture will be a Herculean task for governments, and investments will be huge. Often there are green areas that are untouched, and one such resource is the seasonal and derelict ponds in the district. These water bodies are not utilized properly, and fish seed production is a viable option for them. The state's development policies and schemes address community ponds, reservoirs, and other bodies, but they neglect seasonal ponds. We recommend mapping out these

resources and bringing them into the discussion along with mainstream water resources. These ponds could be leased out to landless farmers, as suggested by Gupta and Rab (1994). Landless farmers can also benefit from this technology by culturing fish in common-property roadside ditches. There is a need for a strong campaign to raise awareness of bringing these water bodies under fish culture. The district will benefit through additional fish seed-producing resources (fry to fingerling), which can lead toward self-sufficiency. Effective utilization of seasonal water bodies in the district will be a milestone if the technology is scaled up.

5. INSTITUTIONAL LESSONS FOR SCALING UP TECHNOLOGIES THROUGH FARM SCIENCE CENTERS

Table 5.1 presents the institutional constraints identified during the adaptive field trials of the technologies studied in the previous section. Addressing these institutional constraints will require integrated solutions that bring together various actors and players in the value chain to support successful adoption by many farmers. Such scaling up also requires harmonization of the goals of the agencies involved in the research-extension-farmer continuum, although these linkages tend to be highly nonlinear. A key part of this study was to document the lessons learned about conducting these adaptive trials and demonstrations. The first key lessons were about the process of conducting the trials and demonstrations with fish farmers, because the farmers' preconceived opinion about new technologies was low, and convincing them to participate was a tough task for organizers.

Farmers agreed to try out the new technologies because the KVK has a presence and footing in the district. Managing the trials and demonstrations was complicated by slow budget releases and late-arriving inputs from the donor side. Another major lesson learned was that the budget was inadequate, providing supplies for only a few farmers to participate in each trial. The participation of KVK scientists in the adaptive research trials has made them familiar with the technologies they are expected to promote and helps to ensure that the sociological dimensions of farming are not neglected.

One of the striking lessons learned from the activities performed is that these results will be incorporated into mainstream extension messages that promote these technologies, perhaps prompting a large number of farmers to adopt them.

Aquaculture in India is a state subject, and large extension machinery is necessary to incorporate new technologies into the state schemes. Therefore the KVK conducted a workshop to share these technologies with state actors. One lesson learned at the workshop was that state extension workers are aware of these technologies but have not worked to disseminate them or pushed for wider adoption. The KVK needs to learn the proper pathway for including these technologies in the state schemes.

Table 5.1 Institutional constraints on scaling up aquaculture technologies after adaptive research trials

Technology or innovation for adaptive research and scaling up	Institutional constraints	Possible interventions to remove the constraints	Action plan and integration of extension services at the district level	If scaled up, what will change in the district
<p>Technology 1 Replacement of normal rohu with Jayanti rohu in composite fish culture</p>	<p>No availability of Jayanti brooder fish to meet demand Lack of multiplier units Lack of brood bank to distribute brood stock Lack of support for obtaining a higher price for Jayanti rohu</p>	<p>Strengthening the nucleus unit of Jayanti rohu at ICAR-CIFA Developing multiplier units Providing brooders of Jayanti rohu on a subsidized basis Proactively providing more demonstrations and other extension methods to promote large-scale adoption Contract farming for spawn rearing to remove the constraint on the supply of seeds to communities Assigning a higher (premium) price for improved fish seed Linking development schemes to adoption of Jayanti rohu</p>	<p>Government hatcheries should take initiative toward producing Jayanti rohu seeds Public-private partnership in production of Jayanti seeds by opening specialized outlets Development schemes for aquaculture in the district need a special emphasis on promoting the improved strain for larger adoption Adoption of Jayanti rohu in all schemes of aquaculture development</p>	<p>Replacement of normal rohu with improved strain Increased incomes of farmers in the district due to adoption of an improved strain Reduced time to harvest, enabling avoidance of water-scarce period Quicker return on investment</p>
<p>Technology 2 Incorporation of medium carps and minor carps in polyculture system</p>	<p>Non availability of quality brooders No availability of local market for diversified species Lack of awareness about the practice and the market for these species (regional demand) Lack of encouragement from government</p>	<p>Interstate marketing should be promoted for better reach of these species because they are highly region specific Public-sector hatcheries should maintain brood stock for seed production Brood stock from brood bank should be made available to other hatcheries Seasonal water bodies should be encouraged to stock minor carps</p>	<p>Awareness of the dietary value of the minor carps Private entrepreneurs should be encouraged to culture minor carps Community ponds can be a target for minor carps as a common-property resource and for income rather than local consumption Seasonal water bodies should be targeted</p>	<p>Interstate export of minor carps can add to the economy of the district Adoption of this technology will enhance the productivity of the ponds, and midterm income can be generated by harvesting the minor carps Ensures early harvest and quick return on investment</p>

Table 5.1 Continued

Technology or innovation for adaptive research and scaling up	Institutional constraints	Possible interventions to remove the constraints	Action plan and integration of extension services at the district level	If scaled up, what will change in the district
<p>Technology 3 Use of CIFABROODTM to increase spawning response in carps</p>	<p>High cost of the feed Access to and timely availability of the feed Cost is higher than conventional feed, but fish seed produced off-season should command a higher price The feed is produced in only one location in the country Cost of transportation is high</p>	<p>R&D efforts to reduce the cost of feed Marketing linkage between hatchery owners and the feed manufacturer Creation of more such feed producers Decentralized production of feed Making the feed widely available in the market</p>	<p>The feed should be included in the state scheme for supply to all hatcheries in the district The government should plan incentives for hatcheries producing yearly seeds The government should fix a premium price for fish seed produced in the off-season Feed industry should widely produce the feed</p>	<p>Year-round high-quality fish seeds will be available and the production cycle will increase Production of fish seeds can be achieved irrespective of the erratic monsoon, which makes CIFABROODTM likely to be a climate-resilient and sustainable technology Early production of seed will enable early stocking of seed The seed will be made available as soon as water is available in the pond</p>
<p>Technology4 Polyculture of Indian major carps (catla and rohu) with prawns(Macrobrachiumrosenbegii)</p>	<p>No availability of prawn seeds (juveniles) Limited hatcheries for prawns The investment required for a hatchery is high Availability of seawater is a major constraint High cost of seed</p>	<p>Private entrepreneurs should be encouraged to establish freshwater prawn hatcheries to produce juveniles Freshwater prawn juveniles should be made available to farmers through special outlets Farmers should be encouraged to produce quality juveniles from the post larvae stage produced by the hatcheries Government farms located near coastal areas should be leased out to establish prawn hatcheries A large amount of subsidy should be available for prawn hatcheries</p>	<p>The practice should be widely publicized through extension for wider adoption The technology should have a place in the state scheme Farmers should be given other incentives to reduce the cost of seed</p>	<p>Availability of prawns for consumption will increase Farmers can earn additional income from the same area Small-scale farmers will have an opportunity to consume prawns, a high-value species that is not only a product for the rich A special market will emerge for prawns in villages</p>

Table 5.1 Continued

Technology or innovation for adaptive research and scaling up	Institutional constraints	Possible interventions to remove the constraints	Action plan and integration of extension services at the district level	If scaled up, what will change in the district
<p>Technology5 Preparation of farm-made feed from locally available feed ingredients</p>	<p>Lack of awareness of cheap, locally available feed ingredients and their preparation Lack of complete information on composition Lack of guidelines for preparation of mixture based on local ingredients</p>	<p>Large-scale demonstration of the preparation of farm-made feed and its use/application Guidelines for preparation of feed</p>	<p>The government should map out the common cheap, locally available ingredients for farm-made feeds and subsidize the other critical inputs Farmers using farm-made feed should be provided with incentives because their production will be less than that of farmers using commercial feeds such as pelleted feeds The government could provide a small feed pelletizer machine as an incentive More demonstration of feed preparation is required</p>	<p>Investment in feeds can be reduced Cost of production will gradually decrease, and an increase in incomes can be realized Cost of the common ingredient used by farmers, groundnut oil cake, which can be replaced by adopting this practice, is increasing day by day Available agro-bio waste can be used for feed Availability of feed when needed Reduced financial burden on farmers</p>
<p>Technology6 Utilization of seasonal fallow ponds for carp fingerling production</p>	<p>Nonexistence of any development scheme toward promotion of fish seed production in seasonal ponds, as there is for community and small reservoirs Skill and knowledge for fingerling production is lacking</p>	<p>Mapping out the ownership/lease of these water bodies by the government Dedicated scheme by the government to encourage use of these resources Training and skill development</p>	<p>Extensive awareness campaigns for using these water bodies Large-scale training program</p>	<p>Additional fish seed-producing resources (fry to fingerling) can be enhanced in the district, leading toward self-sufficiency Effective utilization of seasonal water bodies of the district Utilization of underused water bodies</p>

Source: Authors

Note: ICAR-CIFA = Indian Council for Agricultural Research–Central Institute of Freshwater Aquaculture.

6. CONCLUDING REMARKS

Scaling up proven technological innovations in the farmer's field remains a development challenge for extension and rural advisory services. Scaling up innovations requires going beyond adaptive research trials on farmers' fields to identify the institutional challenges that may impede farmers' uptake of the technologies. This paper presents the results of adaptive research trials in farmers' ponds of six innovations in aquaculture technology, aimed at identifying institutional constraints on uptake and their possible solutions. Having technological solutions to farmers' problems alone will not boost the widespread adoption of innovations. The associated institutional constraints must be identified and removed through strategic approaches. This case study finds that six new aquaculture technologies subjected to adaptive trials were location specific and viable for promotion among fish farmers. However, the spread of these technologies depends upon the availability of critical inputs such as seeds, feed, and technical know-how. The mainstream extension system needs to address these constraints in order to promote more widespread adoption of new technologies among fish farmers.

REFERENCES

- Ananth, P.N., P. R. Sahoo, P. C. Das, S. S. Das, and P. Jayasankar. 2017. "Enhancing Benefits through incorporation of *Puntius gonionotus* in Polyculture System: Outputs from an Adaptive Trial in Rural Odisha." *International Journal of Fisheries and Aquatic Studies* 5(1): 324–327.
- Asopa, V.N., and G. Beye. 1997. *Management of Agricultural Research: A Training Manual*. Rome: Food and Agriculture Organization of the United Nations.
<http://www.fao.org/docrep/w7503e/w7503e00.htm#Contents>.
- Ayyappan, S., and J. K. Jena. 2006. "Inland Fisheries on a Fast Track of Development." In *The Hindu Survey of Indian Agriculture, 2006*, 143–146. Chennai: Kasturi & Sons.
- Belton, B., M. Karim, S. Thilsted, K. M. Jahan, W. Collis, and M. Phillips. 2011. *Review of Aquaculture and Fish Consumption in Bangladesh*. Studies and Reviews 2011-53. Penang, Malaysia: The WorldFish Center.
- Borah, B.C., R. Gogoi, and A. Rahman. 2014. "Performance of Orange-fin Labeo, *Labeocalbasu* (Hamilton 1822) as a Component of Polyculture System." *Journal of Fisheries* 2(1): 86–89.
- Box, L., and D. van Dusseldorp. 1992. *Sociologists in Agricultural Research: Findings of Two Research Projects in the Dominican Republic and the Philippines*. Wageningen Studies in Sociology 30. Wageningen, Netherlands: Agricultural University Wageningen.
- Das, P.C., and B. Mishra. 2016. "Multi-species Farming of gonionotus Major and Minor Carps for Enhancing Fish Production in Freshwater Aquaculture." *Indian Journal of Fisheries* 63(2): 55–61.
doi:10.21077/ijf.2016.63.2.5403808.
- Das Mahapatra, K., J. N. Saha, N. Sarangi, R. K. Jana, B. Gjerde, N. H. Nguyen, H. L. Khaw, and R. W. Ponzoni. 2007. "Genetic Improvement and Dissemination of Rohu (*Labeorohita*, Ham.) in India." *Proceedings of the Association for the Advancement of Animal Breeding and Genetics* 17:37–40.
- Dey, M.M., P. Kumar, F. J. Paraguas, C. O. Li, M. A. Khan, and N. Srichantuk. 2010. "Performance and Nature of Genetically Improved Carp Strains in Asian Countries." *Aquaculture Economics & Management* 14(1): 3–29.
- DFO (District Fisheries Officer). 2015. *Annual Report/Progress Report of District Fisheries Officer*. Khordha, Odisha.
- FAO (Food and Agriculture Organization of the United Nations). 2014. *The State of World Fisheries and Aquaculture: Opportunities and Challenges*. Rome.
- Fliert, E.V., B. Christiana, R. Hendayana, and R. Murray-Prior. 2010. "Pilot Roll-Out: Adaptive Research in Farmers' Worlds." *Extension Farming Systems Journal* 6 (1): 63–71.
- Gupta, M. V. and A. Rab. 1994. *Adoption and Economics of Silver Barb (Puntius gonionotus) Culture in Seasonal Waters in Bangladesh*. ICLARM Technical Reports 41. Manila, Philippines: International Center for Living Aquatic Resources Management.
- Handbook on Fisheries Statistics*. 2014. New Delhi: Department of Animal Husbandry, Dairying and Fisheries; India Ministry of Agriculture and Farmers Welfare..
- Haque, M.M. 2007. "Decentralized Fish Seed Network in Northwest Bangladesh: Impacts on Rural Livelihoods." PhD thesis, Institute of Aquaculture, University of Stirling, UK.
- Harohau, D., R. J. Sulu, J. M. Phillips, M. Sukulu, T. Pickering, and A.M. Schwarz . 2016. "Improving Household Tilapia (*Oreochromis mossambicus*) Aquaculture through Participatory Action Research." *Aquaculture* 465:272–286.
- Karim, M., D. C. Little, M. S. Kabir, M. J. C. Verdegem, T. Telfer, and M. A. Wahab. 2011. "Enhancing Benefits from gonionotus Polycultures including Tilapia (*Oreochromis niloticus*) within Integrated Pond-Dike Systems: A Participatory Trial with Households of Varying Socio-economic Level in Rural and Peri-urban Areas of Bangladesh." *Aquaculture* 314:225–235.

- Kohl, R., C. Foy, and G. Zodrow. 2017. *Synthesis Report: Review of Successful Scaling of Agricultural Technologies*. Washington, DC: United States Agency for International Development.
- Kumar, P., M. M. Dey, and N.K. Barik. 2008. "Farm-Economics of Genetically Improved Carp Strains in Major Asian Countries and Carp Seed Price Policy Model." *Agricultural Economics Research Review* 21:395–406.
- Lado, G. 1998. "The Transfer of Agricultural Technology and the Development of Small-Scale Farming in Rural Africa: Case Studies from Ghana, Sudan, Uganda, Zambia and South Africa." *Geojournal* 45(3): 165–176.
- Little, D.C., B. K. Barman, B. Belton, M. C. Beveridge, S. J. Bush, L. Dabaddie, H. Demaine, P. Edwards, M. M. Haque, G. Kibria, E. Morales, F. J. Murray, W. A. Leschen, M. C. Nandeeshha, and F. Sukadi. 2012. "Alleviating Poverty through Aquaculture: Progress, Opportunities and Improvements." In *Farming the Waters for People and Food: Proceedings of the Global Conference on Aquaculture 2010*, edited by R. P. Subasinghe, J. R. Arthur, D. M. Bartley, S. S. De Silva, M. Halwart, N. Hishamunda, C. V. Mohan, and P. Sorgeloos, 719–783. Rome: Food and Agriculture Organization of the United Nations; Bangkok: Network of Aquaculture Centres in Asia-Pacific.
- Nandeeshha, M.C. 1993. Aquafeeds and feeding strategies in India, In *Proceedings of the FAO/AADCP Regional Expert Consultation on Farm-Made Aquafeeds*, edited by M.B. New, A.G.J. Tacon and I. Csavas Farm-made aquafeeds. 14-18 December 1992, Bangkok, Thailand. FAO-RAPA/AADCP, Bangkok, Thailand, 434 p.
- Pankaj, P., and M. Jagdish. 2012. "Early Breeding of Carps as an Alternative to Increase the Income of Fish Farmers." *Trends in Biosciences* 5(4): 326–328.
- Rogers, E. M. 1995. *Diffusion of Innovations*, 4th ed. New York: Free Press.
- Rouse, D.B., and R.R. Stickney. 1982. "Evaluation of the Production Potential of *Macrobrachium rosenbergii* in Monoculture and polyculture with *Tilapia aurera*." *Journal of the World Mariculture Society* 13:73–87.
- Sahoo, P.R., B. K. Pati, P. N. Ananth, A. K. Dash, and P. Jayasankar. 2015. "A Study on Potentials of Utilizing Seasonal Fallow Ponds for Carp Fingerling Production in Khordha District, Odisha." *Ecology, Environment and Conservation* 21(1): 273–276.
- Sahoo, P.R., P.N. Ananth, S. Nandi, J.K. Sundaray and P. Jayasankar. 2017. "Early breeding and seed production of Indian Major Carps. Attributes of Innovations from an adaptive trial." *Current Agriculture Research Journal* 5(1): 58-65
- Sinha, V.R.P., R. D. Chakraborty, S. D. Tripathi, P. Das, and M. Sinha. 1985. *Carp Culture: Package of Practices for Increasing Production*. Aquaculture Extension Manual New Series No. 2. Barrackpore, West Bengal, India: Central Inland Fisheries Research Institute.
- Sutherland, A. 1987. *Sociology in Farming Systems Research*. Agricultural Administration Unit Occasional Paper 6. London: Overseas Development Institute.
- Tripp, R. 1992. "Expectations and Realities in On-Farm Research." *Farming System Bulletin Eastern and Southern Africa* 11:1–13.
- Venkatasubramanian, V., M. V. Sajeev, and A.K. Singha. 2009. *Concepts, Approaches and Methodologies for Technology Application and Transfer: A Resource Book for KVKs*. New Delhi: Indian Council for Agricultural Research.

For earlier Discussion Papers

please click [here](#)

**All discussion papers can be downloaded
free of charge**

**INTERNATIONAL FOOD POLICY
RESEARCH INSTITUTE**

www.ifpri.org

IFPRI HEADQUARTERS

1201 Eye Street, NW
Washington, DC 20005 USA
Tel.: +1-202-862-5600
Fax: +1-202-862-5606
Email: ifpri@cgiar.org