# Why should I bother to break the norm?: Exploring the Prospects of Adopting Technology-Driven Solutions by Indian Shrimp Farmers

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India produces a large amount of shrimp every year and exports them globally. Yet, concerns have been raised about shrimps produced in India not qualifying the global safety standards. In this paper, we took an ethnographic approach to understand the traditional farming practices followed by shrimp farmers in India. We interviewed 29 shrimp farmers from Andhra Pradesh in India for eight months. We learned that most experienced and large-scale shrimp farmers in India prefer to follow traditional practices in their shrimp farms. They prefer to adopt technology-driven solutions in their farming only if absolutely needed. However, we observed that young, small-scale farmers are more open to trying new technologies in their farming. We discussed several areas where initiatives can be taken to encourage more Indian shrimp farmers to adopt new technology-driven solutions in their farming.

CCS Concepts: • **Human-centered computing → HCI theory, concepts and models**.

Additional Key Words and Phrases: ICTD, shrimp farming, rural community, technology adoption, traditional norms, infrastructure, traditional occupations, first generation farmers

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## 1 INTRODUCTION

Individuals worldwide are accessing intelligent and more advanced technologies in many forms. These technologies bring more efficiency, improved accuracy, and reliability to our daily activities. Researchers in the CHI, CSCW, DIS, and visualization community have analyzed existing applications in terms of their usability, accessibility, and applicability for a wide range of user groups. They have suggested many critical design elements that either need to be revised or modified completely

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to make these applications usable by the target audience. Many of these research studies primarily focused on North American and Western European populations, whereas global south populations often received less attention.

Studies found that there are many barriers such as technical, organizational, and environmental to adopt technologies by global south communities [30, 60]. Previous work have shown them for essential services such as healthcare [22, 6], businesses [30], and education [76]. We extend this body of work and address the concerns of adopting technologies in the global south in the context of rural Indian Shrimp Farmers. Shrimp farming in Asian countries (such as China, Thailand, India, Vietnam, and Bangladesh) gained popularity in the 1980s. In the beginning, shrimp farming was considered as a desired profession as it provided immediate economic benefits, poverty reduction, food security, and generated employment from seed collectors to exporters. India has become the world's second-largest shrimp producer and the largest shrimp exporter in the USA [41]. Shrimp farmers make 5-7 times more profit than crop farmers in India.

Despite of these benefits, shrimp farming received criticism from various communities because of its effect on the environment and socio-economic condition of the neighboring communities. For instance, a number of research studies discussed how coastal shrimp farms in Bangladesh, India, and Vietnam became the primary source of mangrove destruction, water pollution, and land-quality degradation [50]. One of the primary sources of water pollution is the extensive use of antibiotics, pesticides, and disinfectants that leave toxic residues in the soil [25, 26, 36]. In addition to environmental unsustainability, shrimp farming was also blamed for the grave socio-economic impacts including traditional livelihood displacement, loss of land security, food insecurity, marginalization, rural unemployment, social unrest, political bullying, and conflicts [27].

Understanding the gravity of various challenges posed by shrimp farming, researchers proposed to introduce global guidelines for shrimp farming so that farmers can generate a reasonable and relatively stable net income/benefit on a long-term basis without degrading the environment [59]. For instance, previous studies discussed various organic and biotechnology-based measures that can provide economically feasible options for reducing water pollution and nutrient release from shrimp aquaculture [9, 7]. Moreover, to ensure the long-term sustainability of shrimp farming within existing communities, researchers proposed solutions such as farm management, integrated coastal zone management, and regulatory mechanisms and policy instruments [52]. Such initiatives perform the best when local communities and governments get involved as regulators [71].

The efforts show the extensive work done to identify the opportunities and measures that can make shrimp farming a sustainable procession. However, not much work has been done from the perspective of shrimp farmers. 90% farmed shrimp in India do not qualify the global standards and are rated as "Avoid". The primary challenge of shrimp farming is the frequent occurrence of diseases that significantly impact the productivity and sustainability of this profession. Moreover, as the production quality depends on several environmental factors, shrimp farmers in India struggle to produce good quality products with a high survival rate. One possible remedy to many of these challenges is to use production technologies that can assist farmers in maintaining diseases below the acceptable threshold and help boost the industry [68]. In shrimp farming, production technologies include, but not limited to, a combination of hardware devices, sensors, software, smartphone-based application interfaces, and standalone smartphone-based applications. However, before the mass introduction and promotion of these technologies, it is critical to understand shrimp farmers' opinions and mental models about adopting advanced solutions in their farms that can not only bring benefits for farmers but also can potentially make shrimp farming more sustainable for the environment. In this paper, we aimed to investigate the perspectives of shrimp farmers about technologies and the challenges that they face in adopting them on their farms.

We took an ethnographic approach to understand the general practices and common challenges of the shrimp farmers of Andhra Pradesh in India, the largest shrimp-producing state in India. Our work explores the existing perception of adopting new production technologies by shrimp farmers. We conducted an eight-month-long user study involving individual interviews and focus groups with 29 shrimp farmers. Throughout this study, we asked two research questions:

- **RQ1** What are their perceptions toward adopting production technologies in their profession? What are the roles of different stakeholders in the Indian shrimp farmers' community? How do they influence farmers' perception of technology-driven solutions?
- **RQ2** What initiatives can be taken to facilitate Indian shrimp farmers in adopting advanced technology-driven solutions in their professional practices without disrupting their current lifestyle and professional harmony? How will other stakeholders contribute to these initiatives?

We observed that shrimp farmers in India primarily follow a traditional approach on their farms. Large and medium-scale experienced farmers prefer to continue the same methods and products in their farms that worked for them in the past for many years. They often hesitate to try new technology-driven solutions because of the risk involved with those products. They value their family farming traditions and believe that following that tradition is critical to maintaining profitability in their profession. On the contrary, new, small-scale farmers are open to trying new technology-driven solutions. They prefer to take risks and believe that trying new technologies are critical to achieving the world standard in shrimp farming. We identified several approaches to help experienced farmers overcome mental barriers to adopting new technology-driven solutions. We also discussed initiatives that could provide more opportunities for collaboration between new and experienced farmers.

Our work show the social hierarchy and positive social interdependency among the shrimp farmers' community. We contribute knowledge to HCI about how the adoption of new technology does not entirely depend on the buying capacity, age, education level, or willingness of the global south population. Instead, system designers need to consider the uncertainties involved in different contexts and the interdependencies among stakeholders to introduce new technologies for a community. Building on our learnings, we discuss the potential of several context-aware design approaches that can encourage shrimp farmers in the global south to receive the benefits of advanced technologies without sacrificing their traditional practices. We note that these findings' impacts are best understood by acknowledging the benefits of existing traditional and intuitive farming practices of Indian shrimp farmers that helped India become one of the top shrimp production hubs in the world.

We have organized the rest of the paper in the following manner. In section 2, we presented previous work in the context of technology adoption by rural communities along with the opportunities and challenges related to shrimp farming. In section 3, we briefly discussed the main steps followed by our participants for shrimp production which is critical to understand our findings. In section 4, we described the procedure we followed to recruit participants for the user study. We addressed RQ1 in section 5. We discussed the challenges our participants face in adopting technology-driven solutions in their existing farming practice. We also discussed the promises we observed in adopting technologies in current practices. Finally, in section 6, we addressed RQ2. We discussed areas where initiatives can be taken to encourage farmers to adopt technology-driven solutions in their farming.

## 2 RELATED WORK

### 2.1 Adoption of Technologies by Rural Communities of Farmers

Technologies are often seemed to have a close association with urban communities. People and communities in rural areas face several challenges in seamlessly adopting these technologies in their personal and professional lives. The pandemic of COVID-19 had shown us how communication technologies could trigger a broad sense of reliance globally when millions of people were forced to stay at home, and regular communication channels were hard to access [56]. Yet, rural communities face many difficulties in adopting technologies as reliable and essential tools in their professions.

Researchers have extensively studied the role of technologies and intelligent solutions in improving professional practices among rural farmers. Interactive technologies were found to be beneficial in urban farming networks. However, these benefits could not be directly converted into practices in rural areas. For instance, an investigation in Hamisi, Kenya, revealed that although agro-diversity was critical for sustainable ways of living [46], it jeopardized diet quality and food security in rural areas [14]. Similar challenges were faced by mobile phones, which are reported to improve the income and efficiency of markets for farmers [5]. Yet, it required heavy infrastructure upfront to be used to its full potential in rural setup [19, 49, 51, 64].

In the context of Sub-Saharan Africa, several contrasting pieces of evidence were found where even after rolling out the mobile phone's network, the adoption of the technology did not have any positive impact on farmers' marketing decisions and prices received by farmers [5, 69]. To understand why the same technology cannot consistently and equally improve the livelihoods of all communities, researchers recognize the need for more in-depth knowledge about the influencing factors of technology adoption. A comprehensive review of the topic conducted by Mwangi and Kariuki [43] summarized a range of factors affecting the adoption of new technologies. The most commonly stated are technological, economic, institutional, and human factors. Technological factors refer to the technical aspects of the device itself. Economic factors usually include farm size, cost of adoption, and off-farm income. Institutional factors refer to being part of a social group that impacts access to specific information, including access to extension services and access to credit. Human capital refers to education, age, gender, and household size. For instance, when the adoption of mobile phones for farming activities was studied among Maasai farmers in rural Tanzania, it was found that hierarchical social structure became the key deciding factor as Maasai farmers trusted local leaders and well-respected community members more than standard technologies [8].

In addition to mobile phones, researchers studied the prospect of adopting video content developed in marginal settings on the latest farming practices [3, 24, 63, 12]. Such videos were created through a participatory process to share the knowledge of agricultural experts with farmers. These videos were also broadcasted by TV channels to demonstrate practical agricultural solutions to farmers via visits to farms around the country which positively influenced 36% of respondents to reconsider their current farming methods [73]. However, adopting technologies to support farming activities requires explicit mental models. Creating such a mental model becomes more challenging in rural setups where socio-cultural structures often hinder the adoption of new technological solutions. For example, studies have shown that in the African community, the use of ICT in farming went against the movement of gender [20, 35, 47] and economic disparity [11, 44]. In Taiwan, small agricultural firms could not access E-commerce facilities for their improvement because of the shortage of manpower and capital and discomfort in using digital medium [37]. Similar concerns were raised along with the lack of trust when Indian and Malaysian farmers were interviewed regarding their daily practices of using digital solutions in their profession [18].

To overcome such challenges, researchers proposed participatory socio-technical design approaches that take into consideration the problems around agriculture as seen from the perspective of local farmers [57, 58]. Several initiatives were taken where researchers closely observed and interviewed small-scale rural farmers and thus proposed design implications for presenting critical agricultural information in real-time considering the cultural, linguistic, and geographical diversity of the target group of farmers [53]. Rege et al. [54] built "Krishi-Mitra", a user-centered ICT solution that aimed to provide seamless access to vital agricultural information to rural farming communities in India. To promote community participation and better adoption, researchers proposed solutions such as local stewardship where instead of using external trainers, community members actively participated in the training process [72, 2]. Although there remains a wide gap in access between rural and urban areas, the spread of mobile phones in rural areas has led to essential changes in the agricultural sector. Studies found that farmers slowly started storing market information in their phone calendars, took and shared photos of farming demonstrations, and even used the speakerphone for group conversation when consulting with agricultural experts [44, 48]. These studies show that additional initiatives taken to promote technologies and intelligent solutions significantly improved adoption rates for technologies among farmers more than traditional methods.

In the context of adopting technologies, previous work primarily focused on land farmers and their socio-economic challenges. However, comparatively fewer studies have focused on fish farmers or aquaculture and their challenges in adopting technologies in their profession. The next section will discuss studies analyzing technology adoption among fish farmers.

### 2.2 Adoption of Technologies and Intelligent Systems by Fish Farmers

Fish farmers need to keep track of several parameters (such as oxygen level and ph factor of their farms' water) to maintain the growth of their produce. Technologies were introduced in fish farming for building tools and applications that can automate a manual process. For instance, Choi et al. [13] proposed a fish feeding model that can predict the amount of feed required by a fish pond/tank based on external parameters to eliminate the risk of overfeeding and underfeeding. Other than feeding, technologies are also being developed for monitoring the chemical properties of fish farms' water [4, 32, 75] which allows farmers to take immediate action, if required. In parallel to components directly assisting fish farmers, supporting modules such as automatic fish detectors and freshwater model simulators have been been developed with long-term goals of joining them as part of complete comprehensive systems [39, 62].

Even though intelligent systems are being developed for fish farming, it is critical to understand how motivated rural farmers feel about adopting these technologies. One way to promote technologies among farmers is through advisory and extension officers. However, Awuor et al. [23] have shown that in rural areas, extension officers face hardship because of the lack of manpower and the lack of mutual understanding between the extension officers and local fish farmers. Similar concerns were reported by Ifejika et al. [28]. Because of the lack of mutual trust among extension agents and fish farmers, farmers expressed doubt about the reliability and accuracy of information provided by extension agents. The authors proposed several training strategies for extension officers and fish farmers to overcome such challenges. Adoption of technologies also largely relied on the age and level of education of fish farmers [45]. Young, educated farmers preferred ICTs for gathering the latest information on aquaculture, whereas older and less educated farmers were more comfortable communicating with extension agents for the latest information.

The findings of the previous work indicate that the advancement of technologies alone is not sufficient to convince farmers to adopt these technologies in their profession. Instead, we need to investigate the farmers' communities more closely to understand their mental model of technologies. It is also critical to consider the social factors that heavily influence the choices of the farmers in adopting advanced, intelligent solutions. In this paper, we focused on shrimp farmers in India. We aimed to understand how these farmers perceive the importance of advanced and intelligent technologies in their farms to improve productivity, sustainability, and easiness of performing regular farming tasks. Before going into the details of our study, we briefly explained the existing work explicitly focusing on shrimp farming.

## 3 BACKGROUND: SHRIMP AQUACULTURE IN INDIA

India is one of the largest producers and exporters of shrimp in the World. The primary shrimp varieties in India are the native giant tiger prawn, modern and exotic white-leg shrimp, and L. Vannamei. Seven major states (West Bengal, Andhra Pradesh, Kerala, Karnataka, Orissa, Maharashtra) produce more than 95% of the total shrimp in India [66]. In this paper, we focused on shrimp farmers of Andhra Pradesh, the largest shrimp-producing state in India (including all three types of shrimps). We provide a brief background of the following five factors that are critical to shrimp farming: 1) pond preparation and maintenance, 2) starting the production cycle, 3) feeding, 4) diseases, and 5) selling the produce. This description will provide the necessary context to explain the findings from our qualitative analysis.

### 3.1 Pond Preparation and Maintenance

Each production cycle starts with the process of pond preparation. To minimize the chances of bacterial infection from previous productions, farmers first remove scrap soil from their ponds' beds. To add nourishment to the water, farmers add fertilizer. The fertilizer helps planktons bloom at the top layer, providing shade to shrimp larvae and preventing the growth of harmful algae in the pond. They also add probiotic solutions to the water to prevent bacterial and viral infection.

Although pond preparation is critical for the survival and growth of shrimp larvae, most of the workload is invested in maintaining the quality of the pond water throughout the production. For the healthy and optimum growth of their shrimp production, farmers need to monitor several factors related to water quality on a daily basis (such as Ph level, Oxygen level, Calcium, Nitrates etc). For instance, ph level is crucial for shrimps' growth which can often go down below the acceptable range. Such irregularity can be corrected by adding lime (organic) or other chemicals (inorganic).

### 3.2 Starting Production Cycle

Once the pond is prepared, farmers collect their seeds (shrimp larvae) from hatcheries. Hatcheries take newly hatched shrimps and take care of them until they reach the post-larvae stage in a very controlled condition (increases the chance of survival of the baby shrimps). Farmers collect post-larvae (PL) shrimps at the beginning of their production cycle. Farmers need to acclimate their PL shrimps in a semi-controlled tub or tank to test the strength of the batch before they are released or stocked in the pond. If the PL shrimps pass the acclimation process (survival rate is more than 80%), they are released to the pond. Once the ponds are stocked, routine checking of pond conditions needs to be done every morning to monitor physio-chemical parameters.

### 3.3 Feeding

The feeding of PL shrimps starts immediately after the PL larvae are stocked in the pond. The feeding cycle varies from two to five times a day during the first month(shown in Fig 1). It changes two more times during the entire life cycle of the produce. The quality of the feed varies significantly

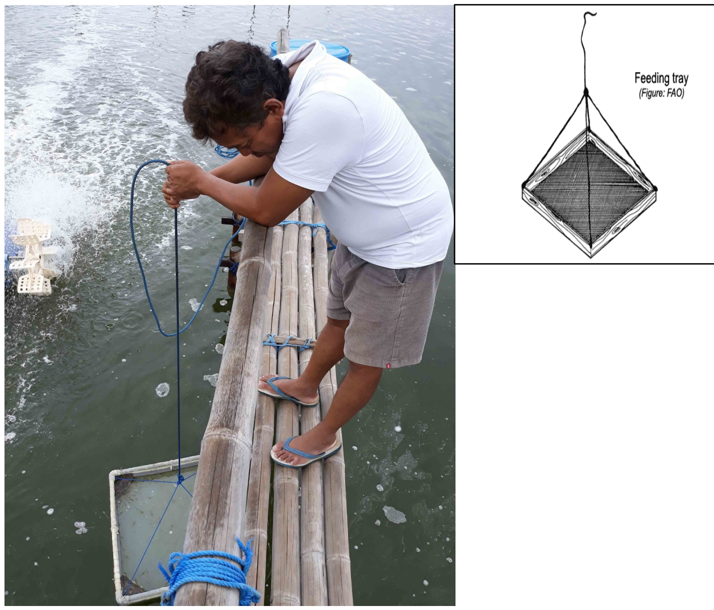


Fig. 1. A farmer is adding feed for shrimps using a traditional feeding tray. The feeding tray helps farmers ensure that the right amount of feed is served every time. Left-over feed in the tray indicates that more feed was served than was required. On the contrary, no left-over feed indicates that, most likely, not enough feed was served. The farmers try to adjust the feed amount based on these two signals.

from vendor to vendor. Farmers generally try various brands to buy their feed and continue with the one that works best for their production. Another criterion for choosing the brand is the availability of technicians provided by these feeding brands. These technicians offer a free consultation about the feeding strategy when farmers buy feed from the affiliated company. The quantity of the feed is decided based on several trials and the growth rate of the produce.

### 3.4 Common Diseases

Apart from feeding, preventing various diseases is critical for shrimp farmers. Three types of diseases are primarily observed in India: 1) white fecal (as shown in Fig 2), 2) slow growth and 3) bacterial infections. Among them, white fecal was reported most frequently. Some significant factors that might cause white fecal are the change in Ph level and the change in temperature of the pond water (as reported by participants). On the other hand, the primary cause of bacterial infection was the unused feed getting deposited on the ponds' soil which can cause rapid growth of bacteria and hence, the infection. Finally, slow growth can be caused for many reasons. It is often observed as an aftereffect of some other infections. Apart from other infections, slow growth can also occur because of the lower quality of the PL larvae, excess stocking of PL larvae, and poor water quality management in the pond.

### 3.5 Selling the Produce

The final step of this farming is to sell the produce to the market. Medium and small-scale farmers usually sell their produce to local distributors whom they know in person and trust with their produce. Distributors collect a large amount of produce from local farmers and sell them to national

Fig. 2. A shrimp infected by white fecal/white dots disease.

exporters. Large farmers, on the other hand, often sell their produce directly to exporters, avoiding distributors. Large farmers risk receiving their payments late by selling their products directly to distributors. However, due to their financial stability, they prefer this option because it allows them to avoid paying commissions altogether and gain more profit.

## 4 METHOD

To answer our research questions, we conducted a user study. This study was a combination of individual interviews and focus groups. We explained the details of the user study in this section.

### 4.1 Participants

All participants were male, as this is a predominantly male-dominated profession in India. They were between the age of 24 and 62. Participants were recruited from the following six cities of Andhra Pradesh state in India: Nellore, Koduru, Bhimavaram, Palakollu, Repalli, and Baptla. All had high school degrees, four had college degrees, and one did an MBA. We recruited the first set of participants from the personal connections of the first author. The first author who conducted the interviews and focus groups has a long-term (15 years) familiarity with the neighborhood as he was born and raised in Nellore. His extended family owns a dealership for shrimp's feed at Nellore. This positionality helped him initially contact 11 shrimp farmers whom he knew from his family's business connections.

Out of these 11 contacts, eight farmers agreed to participate in the study. Subsequently, we used a snowball sampling approach and asked participants to recommend anyone they thought might be a good fit for our research study. This strategy allowed us to recruit participants from six different cities. Since we recruited participants from personal contacts, we did not use any standard advertisements or flyers for recruitment. Instead, first author personally contacted each participant and asked them if they would like to discuss standard routines, practices, and challenges about their shrimp farms once every month through a whatsapp call for the next eight months.

In total, we recruited 29 participants. In addition, we recruited farmers of three different categories: five large farmers (farming in more than 50 acres of ponds), 2) 18 medium farmers (farming in 10-50

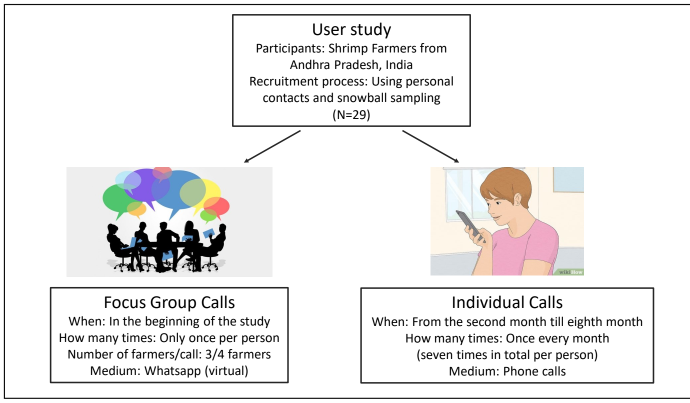


Fig. 3. The flowchart shows the steps taken to conduct the user study. Each participant attended one focus group call and seven individual calls (one call every month) as part of this user study.

acres of ponds), and 3) six small farmers (farming in 4-9 acres of ponds). The participants' eligibility criteria were that they had to produce or attempted to produce at least one crop in 2020. Table 2 in appendix section lists all participants along with their age, location, and the size of their shrimp farm. Participants did not receive any remuneration for their participation and were allowed to discontinue participating in the study at any point.

### 4.2 Procedure

A complete cycle of shrimp farming takes approximately four months (from introducing the shrimp larvae into the pond till the time they become ready to be sold). We started in May 2021 and continued our study for a little more than eight months to ensure that we could go through two complete farming cycles. Each participant began with a focus group session. After that, each participant was contacted once every month for a brief update call. All but three participants attended all (seven) update calls. Three participants missed one or two update calls because of personal issues. The first author coordinated all focus group calls and individual update calls in Telegu, the native language of the Andhra Pradesh state, that all participants and the first author speak fluently. All these calls were recorded for transcription purposes. The first author first transcribed all calls and later translated them into English. Figure 3 shows the steps taken to conduct the user study.

*4.2.1 Focus Group Calls.* Since there were COVID-19 restrictions during the study, we could not bring participants to any physical location for a focus group session. Instead, they virtually gathered through WhatsApp group calls. We invited three to four participants in each focus group session because of the upper limit of number of callers in a WhatsApp group call and low internet speed. A user study conducted over phone was new to participants. Thus, the focus group sessions were designed so that the participating farmers could gain a sense of trust about the authenticity of the study. Seeing other farmers in the focus group calls from the same community made them confident about their decision to participate in the study and encouraged them to recommend names of other farmers who would be interested to participate in the study.

Each focus group session lasted almost an hour. At the beginning of each focus group call, the first author explained the purpose of the study to the group. Next, all participants were read an oral consent form, and all provided verbal consent. We obtained verbal consent from the participants since many participants would have had trouble reading and understanding a written informed consent form, and none of them was comfortable signing a digital document. We used the initial focus group sessions to become familiar with the study participants. Each participant explained how and why they chose shrimp farming as their primary occupation. As a group, they briefly discussed their opinion on introducing technology-driven solutions to shrimp farming in India.

*4.2.2 Monthly Individual Calls.* The individual calls were all individual phone calls which were on average 22 minutes long. Each call was roughly divided into two parts. In the first part, the interviewer asked participants about the status of their current production. Our questions, in particular, addressed the general procedures they conducted during the last month on their farm and whether they experienced anything specifically challenging. If so, what actions they took to overcome those challenges, and the process they followed to find solutions to their problems.

In the second part, the interviewer discussed one/two significant topics related to shrimp farming, such as collecting larvae, farming seasons, shrimp's feed, common diseases, tracking growth, maintaining water quality, finding buyers, selling their products, and monitoring market price for their production. During these discussions, we explained the current technologies that might be helpful for that specific task (Table 1 shows the list of technology-driven solution designed for shrimp farmers that we discussed about during monthly individual calls). We asked participants whether they had heard about that technology and considered incorporating it into their farms. For instance, when we discussed feeding process, we introduced the automatic feeder and asked participants about that device. Every month, all research team members discussed the status and key findings of the study to finalize the following month's discussion topics. These open-ended discussions let us know the minute details of the farming practices adopted by our participants and thus, made specific plans for our next month's call. Participants who were not currently working on a production cycle skipped the first part and started with the second part of the interview. Screenshots of smartphone applications created for shrimp farmers are shown in Fig 4.

Here it is important to note that our goal was not to introduce an exhaustive list of technologies available for shrimp farming. Instead, we focused on presenting a wide range of technologies available for shrimp farming and asked our participants' opinions on them. Since our goal was to observe farmers' perception toward new production technologies over traditional, intuitive farming practices, we used "technology" and "technology-driven solutions" as blanket terms during our interviews and used examples to clarify the confusion. Although it was out of the scope of our work, we note that the term "technology" can be interpreted differently in different contexts, and in the future, researchers may consider exploring those distinctions to develop a deeper understanding of aquaculture farmers from the global south. We examined their overall attitude toward technology-driven solutions in comparison to traditional approaches. Our interviews included hardware, software, smartphone apps, and sensors under the same umbrella of technology-driven solutions without differentiating among them.

### 4.3 Analysis

The interviews were analyzed using open-coding approach from grounded theory [16]. After the completion of the study, the first author transcribed all recordings and translated them into English. Next, two researchers conducted a preliminary round of open coding of all interviews and focus group discussions using MAXQDA [38], a qualitative data analysis program. The researchers met once every week to discuss emergent codes. During this initial coding round, several codes pointed to themes of adopting and integrating technology-driven solutions into participants' daily tasks.

Table 1. List of technology-driven solutions that we discussed with interview participants to know their opinion on adopting similar products or services in their shrimp farms.

| Title of the Topics | Brief Description |
|---|---|
| Jala | Sensor for measuring water quality and analytics using algorithms |
| AquaEasy | Sensor for measuring water quality and analytics using algorithms. |
| Royye Raju | Smartphone application to digitalize aquaculture and make holistic information on shrimp farming |
| Aqua Brahma | Smartphone application to provide access to information to all related to shrimp farming |
| Nanrong Auto feeder | A remotely operated automatic feeder for shrimp farms |
| Dissolved Oxygen Meter | Instant oxygen meter for measuring oxygen level of shrimp ponds |
| Multiparameter Monitor | A smart monitor to measure multiple parameters related to water quality of shrimp ponds |
| Umitron Eagle | An AI based customizable health and growth monitoring system for shrimps |

We continued this process for several iterations until we categorized our themes. We identified several social, cultural, and economic aspects that contributed participants' regular practices and their opinions toward new and innovative technology-driven solutions.

### 4.4 Ethical Concerns and Approval

During the study, we learned the standard practices followed by shrimp farmers in India. We learned the opinions of the farmers toward technology-driven solutions. However, we put sincere effort not to demean their views and values. We refrained from showing a preference for technology-driven solutions over traditional techniques. To show respect for participants' perceptions and knowledge, we designed a longitudinal study. This design allowed us to avoid asking a list of questions on technology adoption in a single interview. Instead, we talked about participants' perceptions of technology-driven solutions in a more relaxed manner. We did not perform any intervention to respect the existing professional harmony among the farmers in the community. During the study, we individually collected permission from all farmers to invite them to one focus group call and seven monthly calls. Two participants, who refused to join the initial focus group sessions, were not invited to any group call. Instead, the first author called them privately and followed the same procedure they did in other focus group sessions. We took care to schedule the monthly update calls for each farmer so that those calls did not heavily interfere with their professional and social commitments. We also respected participants' (three farmers) wishes when they did not want to continue with the monthly calls. We explained our position — a group of HCI researchers — where only the interviewer could speak in Telegu, the native language of the farmers who participated in the study. No other authors of this paper could speak, read, or write in Telegu. The IRB office approved the study to ensure that no interview questions were sensitive or disrespectful to a specific community.

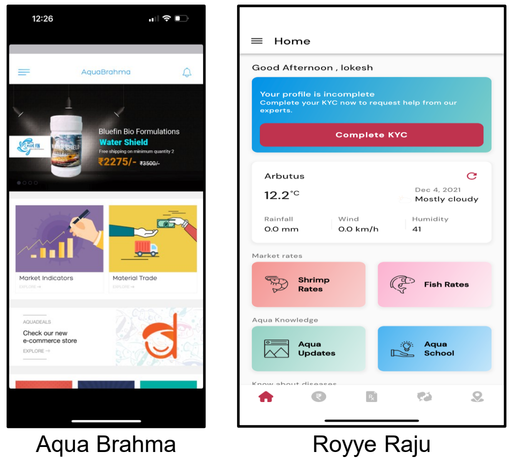


Fig. 4. Screenshots of the smartphone applications created for shrimp farmers for providing necessary information and expert advise.

### 4.5 Positionality

In qualitative research, it is important to embrace reflexivity where we acknowledge how our position might have influenced the types of information collected and the ways it is interpreted [67]. All authors of this paper are of Indian origin, and the first author is from Andhra Pradesh, India. This work is an outcome of 1.5 years of active collaboration of researchers, Indian shrimp farmers, and other stakeholders. We recruited participants from six cities in Andhra Pradesh. During this study period, the first author visited all six cities at least twice to visit the shrimp farms of the participants. In each city, the first author spent three to five days observing the farming process reported in the paper. No interviews were contacted during these in-person visits due to COVID-19 restrictions. The first author used Telegu (the native language of Andhra Pradesh) for all communication during these visits and did not require an interpreter.

All members of our team are trained HCI researchers who are familiar with qualitative research and working towards designing services and technologies for marginalized groups and communities. Our data interpretation is likely to be biased by our desire to discover the opinion of the Indian shrimp farmers towards adopting technology-driven solutions in their farms. We acknowledge that by choosing to publish this work at a specific academic venue on HCI that requires us to write in English, we might have unintentionally lost some subtle cultural and linguistic nuances. However, we also hope that by publishing this work at such a venue, our research will spark discussions around challenges experienced by farmers engaged in aquaculture in the global south.

## 5 CHALLENGES AND OPPORTUNITIES OF ADOPTING TECHNOLOGY-DRIVEN SOLUTIONS IN SHRIMP FARMING

### 5.1 Uncertainty Involved at Every Step

The shrimp farmers need to deal with many factors that involve uncertainty. In some scenarios, farmers have little to no control over the factors determining their profit. All of our participants mentioned the change of weather in this context. Rapid temperature change at the early stage of their production can cause unrecoverable damage to young PL larvae. Participants experienced similar uncertainties with a sudden outbreak of viral infections. Farmers often could not find any reliable reason for such outbreaks. Thus, they just tried to be more vigilant and careful about their products without knowing what they needed to be vigilant about.

Some of our participants (N = 6) (mostly experienced farmers) discussed the intuitions that saved them from severe loss of production on their farms. For instance, P6 described an incident when he included some natural ingredients (he did not disclose the elements as it was his business secret) into his store-bought feed. He learned about that ingredient from one of his friends and wanted to try it experimentally. That year, the growth of shrimp in his produce was much more impressive than other farmers in his area. He mentioned that it was those secret ingredients that he believed helped him gain more profit than other farmers. However, he also said that someone needs to be careful about mixing unconventional ingredients into their feed because too many such components can also cause harm to shrimp production.

Such a high level of uncertainties and decisions that require more intuition made our participants believe that technology-driven solutions such as automatic feeders and mechanical sensors would not perform well on their farms. Instead, they believed they needed to be personally invested in this process to achieve maximum benefits from their farms.

Another participant explained his experience when he was first introduced to an automatic feeder by a local distributor. He found that he could not clearly understand many features of the automatic feeder. He was not sure how well he would be able to control the feeder, especially if any specific changes needed to be made based on the growth of the produce. At P9 explained:

> I always change something in my feeding schedule. I monitor the growth of my shrimp every other day. If I see a sign of under-growth, I increase the feeding amount. After two days, I bring it back to the recommended amount. Sometimes I add some extra ingredients such as Jaggery (traditional non-centrifugal cane sugar). It helps balance the Ph level (scale used to specify acidity) of the water. I was not sure whether the feeder would be able to handle all these changes. It (shrimp farming) is a continuously changing process, and not everyone can do it. It takes patience, experience, and hard work. You cannot just create an automatic feeder and expect that it will be as good as an experienced farmer.

### 5.2 Hard to Break Regular Practices

The profession of shrimp farming takes some background knowledge to start with. Most of our participants (N = 23) were introduced to this business by their family members or some close acquaintances. They learned the details of farming from their predecessors and diligently continued that tradition to maintain a good profit margin. They hardly raised questions on existing procedures unless there was something that they could not resolve with their known remedies. As P3 mentioned:

> I acquired this profession from my dad. I take many small steps every day; I know I need to do them. I will not be able to explain them to you. But I know how to do them. My dad did them the same way, and I am just following his path. It has worked for me so far. Why break the norm?

Some participants (N = 4) also discussed how tasks related to farming had become part of their daily routine. For instance, P2 described how farmers traditionally take extra care of their ponds during the first month of stocking the pond as PL larvae remain most vulnerable to diseases and other related symptoms during that time period. This early stage of farming is also known as the blind feeding stage when farmers mostly focus on the feeding amount and make sure that the growth rate of the larvae is maintained as per the standard. P2 mentioned:

> During the blind feeding stage, I always wake up early in the morning and check the pond's status. I spend time checking every tiny detail. I talk to people in the same neighborhood. This is my life. This is what I am good at. I cannot imagine how my life would be if a machine could do all of these for me, and I am left to do nothing.

Other participants (N = 7) discussed their long-held beliefs that contradicted suggestions provided by technology-driven solutions. P15, for example, used a water quality monitoring device as part of a trial program but later decided not to continue. The app linked to the device suggested him to use several chemicals to maintain the pond water quality. P4 found those suggestions unacceptable because he believed that using too much chemical in the pond would have long-term effects on the produce:

> I am not a champion of using chemicals in the pond. Of course, it might give you a quick remedy for your current problems, which is attractive to new farmers. However, in the long run, they might permanently damage your pond. I always relied on natural ingredients such as turmeric, garlic, and yogurt. These organic ingredients will never have any long-term, hard-to-remove residue.

Since P15 found the suggestions the smart monitoring device provided unacceptable, he had no motivation to continue with the device.

### 5.3 Changes are Expensive and Not Trustworthy

Normative restrictions are not the only reasons for resisting technology-driven solutions to shrimp farming. All participants in our study described modern smart technologies as expensive for their businesses. They explained how they take every precaution to not lose their production because of an infection or because of a low growth rate. However, despite all precautions, it is not uncommon for them to lose their entire produce because of some bacterial infection. Investing in expensive devices seemed like a risky decision for many of our participants (N = 17) as they could not predict when they would have to deal with a big loss in their farm which would follow with an inevitably expensive process of extensively treating the pond to avoid any harmful effect on the next produce. As P11 explained:

> We always need to be ready for the worst time. Investing in expensive gadgets seems like an exciting idea, but economically it is too risky. If I spend all my savings on smart devices, I might lose my business altogether. I have seen people who had to leave this profession after a few years because they could not manage their finance. I do not want to be one of them. It is a profitable business if one can play safe. Otherwise, you might lose it all.

Some participants (N = 4) with more financial stability decided not to go for technology-driven solutions because they could not trust the sensors and automatic devices as reliable resources. P3, one of the most experienced (26 years of experience, farming in 160 acres of the pond) farmers in our subject pool attended a few demonstrations of automatic sensors for tracking pond water quality. These demonstrations helped him understand the utilities of the sensors. He admitted that installing similar sensors would reduce his workload to a great extent. However, he had not seen the device working in a real farm for a considerable duration. As he explained:

> ...I have never seen anyone using those sensors in their ponds. I saw the device when the company representatives gave the demo. But you know the demos always look good. What if it breaks within three months? Will it withstand the hot and humid summer of AP (Andhra Pradesh state)? You never know. I would rather wait for someone to try it first and then decide.

Some participants (N = 5) described a few incidents of failure of technology-driven solutions that made them doubt the trustworthiness of such devices. For example, P14 explained that he decided not to consider installing automatic size monitoring (size of the shrimp) device in his ponds because he recently heard of an incident where a size monitoring device broke after using it only for six months.

The decision to install an expensive technology (such as an automatic feeder or a water-quality measuring sensor) requires a long-term commitment which many of our participants (N = 11) were not ready to make. As P11 explained:

> It is not the same as hiring a worker. If you are unhappy with a worker, you can fire him and hire a new person. But you cannot change these devices easily. Once you buy one, you will have to stay with it. What if I am not happy with the machine? What if I do not find it that useful? Of course, I can stop using the device, but that seems wasteful.

Most of our participants (N = 24) primarily employed local workers (villagers) to monitor and take care of their ponds. These workers have been employed in this profession for many years. That experience gave our participants the confidence to continue with these workers rather than taking the risk of using new technologies and intelligent solutions. It also involves the cost factor, which we describe in the next section.

### 5.4 Availability of Low-Cost Labor

Employing local workers for monitoring ponds, feeding shrimps, and continuously checking the growth of the shrimp is the most popular practice among shrimp farmers in Andhra Pradesh. We have already discussed the availability of experienced workers for such jobs. Another critical factor that made it a common practice is the low cost of employing these workers compared to investing a large amount of money for technology-driven solutions. Our participants described that it was comfortable for them to communicate with these workers because they spoke the same native language. It gave them the flexibility to provide detailed instructions to their workers. Many of our participants (N = 18) were skeptical about introducing technology-driven devices on their farms because they did not know how precisely they would be able to control those devices. They were unsure about losing control of some parameters, which might negatively impact the life cycle of their produce. Our participants could afford to hire their workers at a much lower cost instead of investing in such automated devices.

Some participants also highlighted how they created a strong bond with their workers by employing them for years. P6 described:

> I know my workers well. I have been working with them for years, and they know what I expect. I can call them at 2 am in the morning. They would pick up my call, take my instructions carefully, and complete the job with utmost care. They would not complain about it. That level of dedication can only be expected from local workers because they understand the delicate nature of shrimp farming. Even out-of-state workers (workers from other states in India) can never be as efficient as our local workers because our workers grew up seeing shrimp farming around them.

Another critical challenge to adopting new technologies is local workers' lack of interest in using technology-driven solutions in farming. Many large-scale farmers own several ponds where they produce shrimp. It is impossible for one farmer to visit all his ponds every day and monitor their status. So these farmers rely on their employed workers. Often, workers mostly use old-generation (such as Nokia 225) phones in which they cannot access smart applications. A few workers who switched to smartphones still did not feel comfortable to use smart apps. As P19 explained:

> You need to examine this problem in the Indian context. For example, if I learn about a new smartphone-based app for monitoring the water quality of my ponds, I cannot immediately decide to use it. I need to talk to my workers if they are confident in using such apps because it is not all about me. The workers are the ones to check the ponds every day and monitor the growth rate. If they do not want to use apps, I cannot force them for that. It is hard to find good, sincere workers. I would rather sacrifice new technologies instead of losing a trusted worker.

Since there was no program to help local workers become familiar with technology-driven solutions, they have become the bottleneck in adopting such solutions on a large scale.

### 5.5 Promises of Using Technology-Driven Solutions by Farmers

*5.5.1 Technology Compensated the Lack of Family Connections.* In contrast to the attitude to avoid technology-driven solutions, we observed a natural interest in such solutions among participants who were new to this profession and did not acquire this profession from their families. We interviewed five participants who regularly monitored the fluctuation of feed prices using smartphone apps like Aqua Brahma and Royye Raju. Since these farmers did not acquire their business from their families, they initially did not know people involved with feed distribution agencies. They also did not know other shrimp farmers in the neighborhood personally. More experienced farmers usually shared information such as feed prices through WhatsApp group chat. The most common practice for them was to contact other farmers directly through WhatsApp or to create a small group (3-5 members) of fellow farmers on WhatsApp for regular communication. Experienced farmers maintained the social norm of communicating only with other farmers of the same social-status. This means that large-scale farmers only communicated with other large-scale farmers and vise-versa. New, primarily small-scale farmers were not included in any of these groups. Naturally, they relied on information provided by the apps and made their decision based on that information.

*5.5.2 Familiarity of Using Smart Technologies in Daily Life.* Another reason for using smartphone apps by new farmers is their natural inclination to use apps for various activities. These apps, like Aqua Brahma and Royye Raju were not much different from any other apps. They quickly figured out how to access information from these apps and use them as required in their farming. Some of these participants (N = 3) mentioned the unintuitive and not-so-user-friendly design of the app, which made it a little complex for them to explore all functionalities of the apps. Yet, that was not a significant bottleneck. All of these participants learned from these apps that shrimp prices and demand in the global market change daily, similar to the stock market. They also observed several trends in these smart-apps that they could predict those trends with a certain probability after following the app for almost a year. Instead of relying on the information provided by local distributors, whose primary goal is to pay less to farmers and make more profit on their own, they found it more convenient to follow the market price through the apps. They could apply their best judgment to decide when there was the maximum demand for shrimp in the market, and that is when they decided to sell their produce. As P27 mentioned:

> I admit that I may not have the best judgment of the price in the market. Sometimes I did predict a rise in demand, but it did not happen exactly like that. But following the app allowed me to sell my produce for at least a few hundred rupees (Indian currency) more per 10 kilograms. This profit margin is not insignificant when you are talking about the entire

> shrimp production from all of my ponds. That small decision can decide whether I would have a good or an outstanding farming season.

Moreover, all these participants (N = 5) at least completed their graduate degrees, and during their academic education, they were familiar with learning new skills and technologies from online platforms such as YouTube. When they found tutorials and informative videos about shrimp farming on YouTube, they were not hesitant to consume these videos with an open mind. YouTube videos helped them learn small details about shrimp farming that were hard to learn from other sources. They did not know many local farmers in person from whom they could ask for suggestions and recommendations. So they relied on technology-driven solutions as much as possible. They mentioned that they were not afraid to try new techniques recommended on YouTube. They admitted that sometimes online recommendations did not work for the benefit of their production, probably because of the variation in soil and water quality. Yet, they kept trying new suggestions as they found that online videos are often the only source to know about improved shrimp farming techniques, which takes a long time to learn from local technicians and other community resources.

*5.5.3 Opportunity to Expand in Newer Locations.* New farmers who did not inherit land from their families were keen to use technologies like automatic feeders in their ponds. They often could not purchase their ponds in one geographic location. To minimize the purchase cost, they preferred to buy ponds in different areas. However, sometimes they had to decline some good deals because of the long distance of the location of the new pond from their existing ponds. As they had to visit all their ponds everyday, they could not buy new ponds far from their existing ponds. These farmers wanted to introduce technologies such as automatic feeders in their ponds. This is because such technologies would not require them visit all their ponds everyday; thus, would allow them to purchase ponds in further locations in lower prices. Young, new farmers considered technology-driven solutions as essential elements for expanding their business.

In summary, we found two common factors among farmers who were more willing to adopt technology-driven solutions: 1) higher level of literacy and 2) lack of background and inherited property (no expert shrimp farmers among family members or close acquaintances). These two factors primarily motivated farmers to go beyond the traditional shrimp farming techniques and try new technology-driven solutions. Despite their willingness to adopt new technologies, we observed that these groups of farmers were still hesitant to try any expensive solutions that required more long-term commitment. In the next section, we discussed areas where initiatives can be taken to make technology-driven solutions more acceptable to farmers.

## 6 DISCUSSION AND DESIGN IMPLICATIONS

The goal of our study was to understand the perspectives of shrimp farmers on applying advanced and intelligent technologies in their routine farming activities. Our analysis found many challenges that made it difficult for farmers to adopt technology-driven solutions in their profession. At the same time, we also understood when technology was used and the reasons for this usage. In this section, we illustrate areas that designers and community leaders need to explore further when creating or deploying technologies that support shrimp farming in rural parts of India.

### 6.1 Creating Virtual Network for Farmers

Our interviews revealed that there was no community organization for shrimp farmers at the city or neighborhood level. For instance, experienced farmers (farming for more than 15 years) primarily relied on their intuition to make decisions on their farms. They were able to make those decisions because they had experienced similar problems many times in the past, and over the years, they learned which solution would work best in their context. Yet, they hardly ever shared their knowledge with less experienced farmers in the community as they did not have any common place to meet and talk to each other. Similar concerns were expressed by less experienced farmers (less than five years of experience in shrimp farming). They learned the latest developments in shrimp farming by following social media [21] and other apps. Yet, they never got an opportunity to discuss that information with any experienced farmers in the community. One possible solution would be to create a community-based WhatsApp group for all farmers. The aquaculture office (operated by the state government) may create the group initially and can ask local farmers to join the group. Such a group can also be helpful for the state authority at the time of emergency (such as a sudden outbreak of bacterial infection) to inform farmers to take precautions against the disease. Most importantly, a virtual network like this can provide a platform for sharing information among farmers of all experience levels. Free exchange of information through this shared medium can also help farmers to overcome their mental restrictions of using technology-driven solutions.

In the past, we observed several initiatives for using Interactive Voice Response (IVR) based community media platforms to empower the rural population in India. Because of their simplicity in design and accessibility, platforms such as Mobile Vaani (MV) [40], CGNet Swara [42], and Awaaj Otalo [49] were successfully used for the benefit of education, health, government, and other social ends. However, the usage pattern of mobile phones has changed significantly in the last five years in India. Recent studies showed that the availability of budget smartphones and affordable mobile data plans, along with the Indian government's efforts to strengthen the existing digital infrastructure, rapidly increased active users for messaging applications such as WhatsApp and Telegram [1, 65]. This is in contrast with past observations on internet use on mobile phones, which was more expensive even for smaller data plans [33]. WhatsApp was also the primary communication channel for our participants. We argue that future community platforms should leverage the popularity of these messaging apps to build their platforms to reach a wide range of users in rural India.

## 6.2 Discuss Technology-Driven Solutions in Common Gathering Locations

*6.2.1 Feed Distributors' Offices During Quarterly Meetings.* One event for which shrimp farmers meet regularly is the quarterly meeting arranged by feed distributor companies in their local offices. These meetings are hosted by the field technicians appointed by the distributor companies. Field technicians present their company's new products in these meetings, such as shrimp feed and probiotic ingredients. These quarterly meetings can be ideal venues for introducing technology-driven solutions such as auto-feeders and water quality measurement sensors to a large group of farmers.

Field technicians are the group of people who maintain direct contact with shrimp farmers. Farmers frequently communicate with these technicians for their feed and other technical issues related to their farming, such as shrimp's growth rate, chances of infections, and possible remedies for bacterial infection. Farmers often found that the suggestions provided by field technicians were more effective than regional experts as field technicians consider the local constraints. Thus, farmers trust these technicians and feel more comfortable adopting their suggested solutions. These technicians can be trained to present technology-driven solutions to the farmers. They can show demos of the new sensors and products to increase familiarity with those devices among the farmers. The technicians would be ideal for this job as they would know how new technology can be explained to farmers in their native language without using a lot of technical jargons. Moreover, farmers would also feel confident in adopting these devices introduced by the technicians because they would be able to reach the technicians at any time if they encounter any difficulty in operating those devices.

One critical side of this approach is the accountability of the field technicians toward shrimp farmers over their employer companies. Field technicians may possess either intentional or unintentional bias toward their employer companies. It will be critical to establishing a trustworthy relationship between technicians and shrimp farmer communities. To this end, farmers may choose their representatives to work closely with field technicians and evaluate new technologies from farmers' perspectives before presenting them to the broader community.

*6.2.2 Feed Distributors' Shops.* Another place where farmers meet each other frequently is the shop of the local feed distributors. Feed manufacturers (such as Avanti and CP) generally provide distribution rights to local dealers at the national level. Local dealers set up retail shops where farmers can visit and purchase their feed when required. Since these shops are conveniently located near the shrimp farms, farmers usually prefer to buy their feed as needed rather than storing a large amount of feed. Thus, they visit these feed distribution shops frequently where they regularly meet other farmers.

Introducing new technology-driven solutions through these shops can be preferable to introducing them in a new office. This is because, in these feed distributors' shops, farmers feel more comfortable to learn about a new products because they usually know about new feed variations in these shops. If a new technology-driven product is introduced in these shops, the farmers would probably have the same confidence to learn about that product. Moreover, since many farmers visit these shops as a group, they would be able to discuss the product with each other, weighing the pros and cons of the product more logically. This will also be an opportunity for young farmers, who are favorable to adopting technology-driven solutions, to express their opinions to experienced farmers, potentially convincing experienced farmers to reconsider their options. In these known environments, experienced farmers would feel more comfortable asking questions about new products, which might help clear out their confusion and indecision about the product.

### 6.3 Arranging Demos by Installing in Ponds

In our interviews, many participants discussed the unknown factors regarding technology-driven solutions. One possible approach to overcome these concerns is to introduce these products through trial ponds. Trial ponds are comparatively smaller ponds used by hatcheries for trying new types of shrimp larvae. They maintain a condition in these ponds similar to other natural ponds in the same town and try to produce fully-grown shrimps using a new type of larvae. When they become successful, farmers feel more confident trying that new variety of larvae. Such trials can also be used for new technology-driven solutions. Farmers will get more opportunities to examine how frequently those devices might encounter technical issues and how quickly a technician can address the problem and fix it. A trial run for the entire season might also help farmers to estimate how much they would have to spend to maintain those devices if they install them in their ponds. These trials would help large-scale farmers who were primarily concerned about the longevity and sturdiness of new devices in natural ponds.

### 6.4 Recruiting Volunteer Farmers

The concept of trial ponds can be extended to real farms with young farmers keen to adopt new technology-driven solutions but are hesitant because of the price of those products. Companies producing these new products can recruit volunteer farmers who agree to install these devices in their ponds for the entire farming season. The volunteer farmers can receive these products for free initially, and later if they decide to continue with the product, they might receive a discount on the actual price. This model might be acceptable for young farmers as the price of the new technology-driven products was their primary concern.

This approach would also allow farmers to observe the pros and cons of such devices for the entire farming season in a natural setting. Experienced farmers who expressed concerns about the longevity of these devices would get to talk with the volunteer farmers to learn about their first-hand experience using the product. This setup might help other farmers in the neighborhood to observe how much the new technology-driven products could increase their yearly production which can be the key motivation for them to decide to adopt those devices in their own farms.

### 6.5 Training the Human Workforce

The final bottleneck in this process is the lack of trained human laborers who can operate new devices without much intervention from the owner of these farms. Many of our participants were not willing to adopt new technologies because their existing human laborers were not trained to incorporate these devices into their daily activities. To encourage farmers to adopt new technology-driven solutions, we need to focus on training human laborers for these products and devices. Manufacturing companies can incentivize human laborers to take training sessions in their trial ponds. The training sessions need to be designed so that laborers with low and poor literacy skills can learn the essential skills of operating those devices even without knowing the technical jargon. Farmers could easily hire these trained laborers for their farms, which would encourage them to include new technology-driven products and sensors in their ponds. Adequately trained laborers should receive training for regular maintenance of these devices so that the farmers would not have to call the maintenance team for minor repairs.

### 6.6 Summary

In the broader sense, our findings are consistent with previous work. Adopting technology-driven solutions and precision farming practices among the global south population experienced several challenges. Government subsidies and promotional activities showed some early promising signs of adopting technologies among farmers in India [29, 70]. Yet, researchers only observed little progress in large-scale adoption without such subsidies and promotional activities [29], which is consistent with our observations. Here, it is critical to note that previous work frequently found experienced, wealthy, and male farmers were more willing to adopt technology-driven solutions compared to new, less experienced, and young farmers [74, 61]. In our work, we observed the opposite trend where experienced, wealthy farmers were more cautious about adopting new technologies. In contrast, new farmers without any family background in shrimp farming were keener to adopt them. One possible explanation might be the higher uncertainties involved in shrimp farming than in rice and dairy farming. Authorities and stakeholders need to take such context-specific factors into consideration before launching and promoting new technologies among Shrimp farmers in India.

We caution that our findings and overall understandings are not yet at a point where we can provide complete design guidelines. In the HCI4D domain, building a trustworthy relationship with end users has always been a struggle for technology providers [34, 55]. To provide more concrete design suggestions, we need to actually start designing in an iterative, participatory fashion, including members from all social categories, which is our next step. At this stage, our observations serve to steer design directions, anticipate social and cultural issues and challenges, and guide design in a way that should cause technology to fit the shrimp farmers' cultural practices the best. Thus, we have proposed enhanced collaboration, additional training, and better organizations for appointing volunteers as a set of design areas that researchers should explore further. As well, we highlight cultural factors such as the availability of low-cost labor and the natural inclination to avoid changes as challenges that will affect design work in this space.

In summary, we argue that technology-driven solutions should be introduced as complements of existing practices; rather than replacement solutions. Such an approach might provide farmers enough time to overcome their mental barriers and to evaluate the utility of the new technology with an objective mindset. In this context, it is crucial to consider that technology-driven precision farming techniques can become an easy target for privacy-related attacks and cyberattacks [31]. Organizations building these technologies sometimes pay less priority to managing farmers' and farming data securely. Thus, farming information becomes even more vulnerable compared to other sectors that engage technologies and digital solutions [17]. To mitigate the threat of such attacks, it is not sufficient to make individual-level efforts. Instead, long-term plans and actions, including all stakeholders, should be incorporated into the design of such solutions to better prepare against future attacks and use these technologies and solutions more responsibly.

### 6.7 Limitations

Our work has several limitations that might influence how our implications and broader considerations should be interpreted. First, our work is not free from participation bias and selection bias. We had the opportunity to engage with 29 farmers from six cities through a snowball sampling process. While we can assume that opinions and arguments represent the collective view of the residents of the whole geographic area, this may not be the case. In India, at least five other states produce exportable quality shrimps. Yet, because of the language barrier, we could only interview farmers from the state of Andhra Pradesh. We acknowledge that single-solution-fits-it-all approach might not be a good fit for the entire shrimp farmer community [10, 57, 58]. Designing one solution for a group of users might inadvertently empower the elites of the community and can potentially lead to the neglect of non-empowered participants [15]. In our work, although we interviewed farmers from three categories (large, medium, and small), majority of them (18 out of 29) belonged to the medium group. Some of our observations might be biased as we could not interview more large and small farmers. Future researchers may consider participatory design approach where farmers from all categories will have equal number of representatives during the design process to avoid sampling bias. Second, our interaction with the participants could also have suffered from experimental and methodological flaws. Question-order bias, self-presentation maintenance, and power imbalances might influence the kinds of things we observe.

## 7 CONCLUSION

The interview study allowed us to observe the regular practices followed by shrimp farmers in India. We learned their perceptions toward technology-driven solutions. Our qualitative analysis helped us identify the complex interdependencies between different stakeholders related to shrimp farming. We identified the impact of family tradition and belief on shrimp farmers when they were asked to judge the efficacy of technology-driven solutions. We proposed several initiatives that can encourage farmers to adopt new technologies. Here, it is worth mentioning that as researchers, we do not have any preference between traditional farming practices and technology-driven farming solutions. We believe both of these approaches have their benefits. We need technologies inspired by conventional farming practices to get the best of both approaches. Experienced farmers can be consulted before developing new technology-driven solutions. The new technologies must consider the environmental constraints and ecosystem of the surrounding infrastructures. Thus, new solutions will be more suitable for Indian shrimp farmers.

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# A APPENDICES

Table 2. Participants' overview

| | Age | Location | Size of the Shrimp Farm |
|---|---|---|---|
| Participant 1 | 46 | Nellore | Large |
| Participant 2 | 51 | Nellore | Large |
| Participant 3 | 57 | Koduru | Large |
| Participant 4 | 39 | Nellore | Large |
| Participant 5 | 60 | Nellore | Large |
| Participant 6 | 45 | Palakollu | Medium |
| Participant 7 | 41 | Koduru | Medium |
| Participant 8 | 55 | Baptla | Medium |
| Participant 9 | 62 | Koduru | Medium |
| Participant 10 | 50 | Nellore | Medium |
| Participant 11 | 48 | Koduru | Medium |
| Participant 12 | 44 | Palakollu | Medium |
| Participant 13 | 52 | Palakollu | Medium |
| Participant 14 | 49 | Nellore | Medium |
| Participant 15 | 59 | Nellore | Medium |
| Participant 16 | 34 | Nellore | Medium |
| Participant 17 | 36 | Nellore | Medium |
| Participant 18 | 51 | Koduru | Medium |
| Particpant 19 | 24 | Bhimavaram | Medium |
| Participant 20 | 37 | Baptla | Medium |
| Participant 21 | 34 | Repalli | Medium |
| Participant 22 | 30 | Nellore | Medium |
| Participant 23 | 37 | Bhimavaram | Medium |
| Participant 24 | 31 | Nellore | Small |
| Participant 25 | 41 | Baptla | Small |
| Participant 26 | 35 | Palakollu | Small |
| Participant 27 | 29 | Nellore | Small |
| Participant 28 | 27 | Bhimavaram | Small |
| Participant 29 | 39 | Repalli | Small |

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