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Digital Extension Services and Mobile Applications in Indian Freshwater Aquaculture: A Comprehensive Review of Productivity Enhancement and Youth Engagement

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Abstract

Freshwater aquaculture has emerged as one of the fastest-growing agricultural subsectors in India, contributing significantly to food security, nutritional improvement, employment generation, women improvement and rural economic development. The rapid advancement of Information and Communication Technologies (ICTs), digital extension services, and mobile-based applications has transformed the dissemination of aquaculture-related information, enabling fish farmers and fisherman to access real-time advisory services, market intelligence, weather forecasts, disease diagnostics, input management guidance, and financial services. Digital platforms such as the National Fisheries Digital Platform, mKisan, Matsya Setu, Fish Farmer Producer Organization (FFPO) portals, and various state-level fisheries applications have improved farmers' decision-making capabilities, which results in enhanced productivity, reduced production risks, and increased profitability. Furthermore, the integration of mobile applications and digital tools has attracted rural youth to freshwater aquaculture by creating opportunities for aquaentrepreneurship, skill development, e-commerce, and technology-driven freshwater fish farming enterprises. The present study examines the role of digital extension services and mobile applications in Indian freshwater aquaculture, highlighting their contribution to productivity enhancement, knowledge dissemination, disease management, market access, and youth engagement.

The present study also focusses on major challenges, including digital literacy gaps, inadequate internet connectivity in rural areas, language barriers, and limited adoption among small-scale farmers. Finally, it proposes strategic interventions to strengthen digital ecosystems, promote inclusive technology adoption, and foster sustainable growth in India's freshwater aquaculture sector. The study concludes that digital extension services and mobile applications are becoming indispensable tools for improving freshwater aquaculture productivity and encouraging youth participation, thereby supporting the long-term sustainability and competitiveness of Indian freshwater aquaculture.

Keywords: Freshwater Aquaculture, Digital Extension Services, Mobile Applications, Productivity Enhancement, Youth Engagement, Aquaentrepreneurship, Rural Development.

1. Introduction

Aquaculture has emerged as one of the fastest-growing food production sectors globally and plays a crucial role in ensuring food security, nutritional sustainability, employment generation, and economic growth. According to the Food and Agriculture Organization (FAO, 2024), aquaculture contributes more than half of the aquatic foods consumed worldwide and is expected to play an increasingly important role in meeting the growing demand for animal protein. India is the second-largest aquaculture producer and the third-largest fish-producing country in the world, with freshwater aquaculture accounting for nearly 70% of the nation's total aquaculture production. Indian freshwater aquaculture is primarily dominated by carp culture, although the cultivation of species such as catfishes *Tilapia*, *Pangasius*, freshwater prawns, and ornamental fishes has expanded significantly in recent years (Department of Fisheries, 2024). Despite remarkable growth, the freshwater aquaculture sector faces several challenges, including limited access to scientific information, disease outbreaks, poor water quality management, rising input costs, climate variability, and inefficient market linkages. Traditionally, fisheries extension services have relied on face-to-face interactions, field demonstrations, training programs, and printed advisory materials. However, these conventional approaches often fail to effectively reach a large number of fish farmers due to constraints such as inadequate extension personnel, geographical dispersion of farming communities, and limited institutional resources (Mohanty et al., 2021). Consequently, there is an increasing need for innovative and scalable approaches that can facilitate timely dissemination of technical information and support evidence-based decision-making among fish farmers.

The rapid advancement of Information and Communication Technologies (ICTs), coupled with increased smartphone penetration and internet connectivity in rural areas, has opened new avenues for transforming fisheries extension systems. Digital extension services and mobile applications have emerged as effective tools for providing real-time advisory services related to pond management, water quality monitoring, feed optimization, disease diagnosis, weather forecasting, market intelligence, and government support programs. These technologies enable farmers to

access location-specific and timely information, thereby reducing information asymmetry and improving farm productivity and profitability (Kumar et al., 2022).

Recognizing the potential of digital technologies, several initiatives have been introduced in India to strengthen fisheries extension and aquaculture development. Prominent examples include the Matsya Setu mobile application developed by ICAR-Central Institute of Freshwater Aquaculture (ICAR-CIFA), the mKisan portal, the National Fisheries Digital Platform (NFDP), and digital interventions under the Pradhan Mantri Matsya Sampada Yojana (PMMSY). These platforms provide multilingual advisory services, online training modules, disease management guidelines, market information, and access to government schemes, thereby enhancing farmers' knowledge and technological adoption (ICAR-CIFA, 2024). Such initiatives align with broader national programs such as Digital India and the Blue Economy Vision, which emphasize the integration of technology into rural development and resource management. Globally, the adoption of digital technologies in aquaculture has accelerated in countries such as China, Norway, Vietnam, Bangladesh, and Indonesia. Advanced technologies, including Artificial Intelligence (AI), Internet of Things (IoT)-based monitoring systems, cloud computing, remote sensing, and precision aquaculture tools, have demonstrated significant potential in improving production efficiency, disease management, environmental sustainability, and traceability within aquaculture value chains (Li et al., 2023; Misimi et al., 2022). Lessons from these countries provide valuable insights for enhancing the effectiveness of digital aquaculture initiatives in India.

In addition to improving productivity, digital technologies are increasingly influencing youth participation in the aquaculture sector. The availability of mobile-based learning platforms, online certification programs, digital marketplaces, and technology-driven farming systems has transformed aquaculture into a more knowledge-intensive and entrepreneurial profession. This transition is particularly relevant in India, where rural youth face challenges related to unemployment and limited livelihood opportunities. Digital extension services can facilitate skill development, innovation, start-up creation, and self-employment opportunities, thereby contributing to rural economic development and sustainable fisheries growth (CIFE, 2023).

Although several studies have explored the adoption of ICTs in fisheries and agriculture, a comprehensive review focusing on the combined role of digital extension services and mobile applications in Indian freshwater aquaculture remains limited. Furthermore, there is a need to synthesize existing evidence regarding their impact on productivity enhancement, technology adoption, market integration, and youth engagement. Therefore, the present study aims to critically examine the status, applications, opportunities, and challenges of digital extension services and mobile applications in Indian freshwater aquaculture. The study also highlights international experiences, identifies existing research gaps, and proposes strategic recommendations for strengthening digital aquaculture ecosystems to achieve sustainable and inclusive growth in the freshwater aquaculture sector.

1.1 Objectives of the Study

The present study was undertaken with the following specific objectives:

- To examine the growth and current status of digital extension services in Indian freshwater aquaculture.
- To analyse the contribution of mobile applications and ICT tools to aquaculture productivity and farm management.
- To assess the effectiveness of digital technologies in water quality monitoring, feed management, disease detection, and fish health management.
- To evaluate the role of digital platforms in enhancing market access, value-chain linkages, and profitability of fish farming.
- To study the impact of digital technologies on youth participation, entrepreneurship development, skill enhancement, and employment opportunities in the aquaculture sector.

2. Methodology

Present study adopted a systematic review to examine the role of digital extension services and mobile applications in enhancing productivity and youth engagement in Indian freshwater aquaculture. Relevant literature published between 2022 and 2026 was collected from reputable databases, including Scopus, Web of Science, Google Scholar, and along with reports from FAO, ICAR-CIFA, ICAR-CIFE, NFDB, World Fish, and the Department of Fisheries, Government of India.

A comprehensive search was conducted using keywords such as digital extension services, mobile applications, ICT in aquaculture, digital fisheries, smart aquaculture, productivity enhancement, and youth engagement. Peer-reviewed journal articles, conference proceedings, policy documents, and institutional reports relevant to freshwater aquaculture were selected for analysis.

The collected literature was screened and categorized into key areas, including mobile-based aquaculture management, water quality monitoring, disease management, market access, productivity improvement, and youth entrepreneurship. Data were synthesized using a qualitative content analysis approach to identify major trends, opportunities, challenges, and best practices. Comparative insights from Indian and international studies were incorporated to provide a comprehensive understanding of the contribution of digital technologies to sustainable freshwater aquaculture development.

3. Results and Discussion

3.1 Evolution of Digital Extension Services in Indian Freshwater Aquaculture:

The present study indicates that digital extension services have significantly transformed information dissemination and knowledge transfer mechanisms within Indian freshwater aquaculture. Traditional fisheries extension systems, often constrained by limited manpower and geographical barriers, have increasingly been supplemented by Information and Communication Technology (ICT) enabled platforms. Initiatives such as Matsya Setu, mKisan, National Fisheries

Digital Platform (NFDP), Pradhan Mantri Matsya Sampada Yojana (PMMSY) digital services, and state-level fisheries applications have facilitated real-time communication between researchers, extension personnel, and fish farmers. ICAR-CIFA's Matsya Setu mobile application has emerged as a notable innovation by providing multilingual training modules, technical advisories, and disease management information. According to ICAR-CIFA (2024), the application has enhanced farmers' access to scientific aquaculture practices, particularly in remote regions where conventional extension services are inadequate. Similar findings were reported by Mohanty et al. (2021), who observed that ICT-based extension approaches increased the adoption of improved aquaculture practices among small-scale fish farmers in eastern India.

Internationally, digital extension services have demonstrated comparable benefits. In Bangladesh, World Fish-supported mobile advisory services improved farmers' technical knowledge and decision-making capabilities, resulting in increased fish productivity and profitability (World Fish, 2022). Similarly, in Vietnam, mobile-based extension systems enhanced farmers' access to water quality and disease management information, thereby improving farm performance (Nguyen et al., 2021).

The findings suggest that digital extension platforms reduce information asymmetry, accelerate technology dissemination, and improve farmers' responsiveness to production challenges. These outcomes are consistent with the Agricultural Innovation Systems (AIS) framework, which emphasizes knowledge exchange as a critical driver of agricultural productivity (FAO, 2024).

3.2 Contribution of Mobile Applications in Productivity Enhancement:

In present study a major finding is that mobile applications significantly contribute to productivity enhancement through improved fish farm management practices. Productivity gains are primarily observed in water quality monitoring, feed management, disease surveillance, and production planning.

3.3 Water Quality Monitoring

Water quality parameters are one of the most critical determinants of fish growth and survival. Mobile applications integrated with sensor technologies enable real-time monitoring of key parameters such as Dissolved oxygen, Concentration of CO₂, water temperature, pH, ammonia, turbidity etc. Studies conducted in Andhra Pradesh and West Bengal reported that farmers utilizing digital water quality monitoring systems experienced production increases ranging from 15% to 25% compared to traditional management approaches (Kumar et al., 2022). In China, Li et al. (2023) reported that Internet of Things (IoT) enabled monitoring systems improved resource-use efficiency while reducing fish mortality. Similar findings were observed in Norway, where precision aquaculture technologies facilitated continuous environmental monitoring and enhanced production efficiency (Misimi et al., 2022). These findings indicate that digital monitoring technologies contribute directly to productivity by enabling timely corrective actions and reducing environmental stress on cultured fish.

3.4 Feed Management and Resource Optimization:

Feed costs account for approximately 60–70% of total aquaculture production expenses. Digital feeding applications provide recommendations based on fish biomass, growth stage, water temperature, and feeding behavior. Such systems improve feed conversion efficiency and reduce wastage. Studies from India indicate that digital feed management can reduce feed costs by 10–15% while increasing growth performance (Mohanty et al., 2021). International evidence from Norway and China similarly demonstrates that automated feeding systems increase feed utilization efficiency and lower operational costs (Misimi et al., 2022; Li et al., 2023). The adoption of precision feeding technologies aligns with sustainable intensification principles by improving economic returns while minimizing environmental impacts associated with excess feed inputs.

3.5 Disease and Health Management:

Disease outbreaks remain a major in freshwater aquaculture. Mobile applications equipped with image-recognition tools, telemedicine facilities, and diagnostic support systems enable early disease detection and rapid intervention. In India, disease advisory services available through Matsya Setu and related platforms have improved fish farmers' awareness regarding fish health management. ICAR-CIFA reports indicate that digital disease advisory systems have enhanced farmers' capacity to identify and manage bacterial, parasitic, and fungal diseases at an early stage (ICAR-CIFA, 2024).

Internationally, Joffre et al. (2023) reported that digital disease surveillance systems in Southeast Asia reduced fish mortality by 20–30% through timely diagnosis and intervention. Similar outcomes were observed in Bangladesh and Vietnam, where mobile-based advisory services significantly reduced production losses associated with disease outbreaks (World Fish, 2022).

3.6 Digital Platforms and Market Access Enhancement:

Market access is a critical determinant of aquaculture profitability. Digital platforms facilitate direct interactions between producers, traders, processors, and consumers, thereby reducing transaction costs and improving price realization. In India, digital marketing initiatives under PMMSY and NFDIP have enhanced market transparency and enabled fish farmers to access broader markets. Mobile applications providing real-time price information have reduced farmers' dependence on intermediaries and strengthened their bargaining power (Department of Fisheries, 2024). International studies similarly highlight the benefits of digital marketplaces. In Bangladesh, mobile-based market information systems increased farmers' net incomes through improved marketing efficiency (World Fish, 2022). In Indonesia and Vietnam, e-commerce platforms facilitated better integration of small-scale aquaculture producers into national and international value chains (Tran et al., 2022). These findings suggest that digital marketing tools contribute not only to increased profitability but also to greater resilience of aquaculture value chains.

3.7 Digital Technologies and Youth Engagement in Aquaculture:

One of the most significant outcomes identified in this review is the growing role of digital technologies in attracting youth to aquaculture. Traditionally perceived as a labor-intensive occupation, aquaculture is increasingly being transformed into a technology-driven enterprise.

3.8 Aquaentrepreneurship Development

Digital technologies have created opportunities for youth-led entrepreneurship in areas such as:

- Biofloc aquaculture systems
- Hatchery management
- Ornamental fish keeping
- Aquaculture consultancy
- Digital marketing of fish products
- Input supply and logistics services

The PMMSY framework specifically emphasizes entrepreneurship promotion among youth and women. Government reports indicate increasing participation of educated rural youth in aquaculture start-ups supported through digital training and financial assistance programs (Department of Fisheries, 2024). A study by CIFE (2023) found that digital literacy and access to online training significantly influenced young entrepreneurs' willingness to adopt aquaculture as a livelihood option.

3.9 Skill Development and Capacity Building:

Digital learning platforms provide continuous access to educational resources, webinars, virtual demonstrations, and certification courses. Such platforms reduce geographical barriers and facilitate lifelong learning. Matsya Setu's e-learning modules have enhanced technical competency among fish farmers and fisheries graduates. Similar capacity-building initiatives implemented by World Fish in Bangladesh and FAO-supported programs in Southeast Asia have demonstrated positive impacts on knowledge acquisition and technology adoption (FAO, 2024). The increasing availability of online fisheries education is expected to play a critical role in developing a digitally skilled aquaculture workforce.

4. Conclusion

The present study focused on the digital extension services and mobile applications have emerged as powerful instruments for transforming Indian freshwater aquaculture by improving information access, technology dissemination, farm management, and market integration. Digital platforms such as Matsya Setu, mKisan, National Fisheries Digital Platform (NFDP), and PMMSY-supported digital initiatives have strengthened the delivery of real-time technical advisories, enabling fish farmers to make informed decisions regarding water quality management, feed optimization, disease control, and marketing strategies. The findings in this study indicate that the adoption of mobile-based advisory services and ICT-enabled tools contributes significantly to productivity enhancement through improved resource-use efficiency, reduced production risks,

and better fish health management. Technologies such as IoT-based monitoring systems, digital feeding applications, and disease surveillance platforms have shown considerable potential in increasing production efficiency while promoting environmentally sustainable aquaculture practices. Evidence from India and leading aquaculture-producing countries, including China, Norway, Bangladesh, and Vietnam, further highlights the growing importance of digital innovations in modern aquaculture development. The study also reveals that digital transformation is creating new opportunities for aquaentrepreneurship, skill development, and youth engagement. Access to online training, digital learning platforms, e-commerce networks, and technology-driven farming systems is attracting educated rural youth to aquaculture and supporting the emergence of innovative aquaculture enterprises. These developments are particularly important in the context of rural employment generation, livelihood diversification, and the promotion of a sustainable blue economy. Despite these positive developments, several challenges continue to hinder the widespread adoption of digital technologies, including inadequate digital literacy, poor internet connectivity in rural areas, language barriers, affordability constraints, and limited institutional coordination. Addressing these challenges through targeted policy interventions, infrastructure development, multilingual digital content, capacity-building programs, and stronger public–private partnerships will be essential for ensuring inclusive and equitable access to digital aquaculture services. Overall, the present study concludes that digital extension services and mobile applications are becoming indispensable components of contemporary freshwater aquaculture systems. Their effective integration into aquaculture extension frameworks can significantly enhance productivity, profitability, sustainability, and youth participation. Future efforts should focus on leveraging emerging technologies such as Artificial Intelligence (AI), Internet of Things (IoT), Big Data Analytics, Blockchain, and Precision Aquaculture Systems to accelerate the digital transformation of Indian freshwater aquaculture and strengthen its contribution to national food security, rural development, and economic growth.

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