

Baseline Assessment of Freshwater Aquaculture Practices and Yield Constraints in Telangana

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Abstract

Freshwater aquaculture plays a crucial role in ensuring food security, rural employment, and economic growth in the state of Telangana, India. Despite significant expansion in pond-based aquaculture, particularly carp farming, fish yields across the region remain inconsistent and often below their potential. This study aims to assess existing aquaculture practices in Telangana and identify the key factors responsible for yield variability and productivity constraints. A field-based survey was conducted across selected aquaculture farms located in major fish-producing districts of Telangana. Primary data were collected through structured questionnaires, farmer interviews, and on-site observations, focusing on parameters such as pond characteristics, stocking density, feeding practices, water quality management, disease incidence, and harvest yield. Descriptive and correlation analyses were employed to evaluate relationships between management practices and production outcomes. The findings reveal that sub-optimal water quality management, inefficient feeding strategies, improper stocking densities, and limited adoption of scientific monitoring practices are the major constraints affecting yield performance. Additionally, the lack of region-specific technical guidance and limited awareness of sustainable aquaculture technologies contribute to productivity gaps. The study highlights the urgent need for an integrated, region-specific aquaculture management framework to enhance yield and sustainability. The baseline insights generated through this assessment provide a strong foundation for the development and implementation of advanced intervention models aimed at improving aquaculture productivity in Telangana.

Keywords: *Aquaculture, Freshwater ponds, Yield constraints, Water quality, Carp farming*

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Introduction

Aquaculture has emerged as one of the fastest-growing food production sectors in India, playing a significant role in ensuring food security, nutritional availability, employment generation, and rural economic development. India is the second-largest producer of fish globally, with inland aquaculture contributing a major share of total fish production [1]. The sector supports the livelihoods of millions of small and marginal farmers and contributes substantially to the national Gross Value Added (GVA) through fisheries and allied activities [2]. In recent years, aquaculture has gained increased policy attention due to its potential to provide affordable animal protein while promoting inclusive rural growth.

The demand for fish protein in India has increased steadily due to population growth, rising incomes, urbanization, and increased awareness of the nutritional benefits of fish consumption. Fish is recognized as a rich source of high-quality protein, essential fatty acids, vitamins, and minerals, making it a vital component of a balanced diet [3]. Simultaneously, aquaculture has become an important source of income for rural households, offering higher returns compared to traditional agriculture when managed efficiently. Government initiatives such as the Pradhan Mantri Matsya Sampada Yojana (PMMSY) have further accelerated investment in inland aquaculture by promoting infrastructure development, productivity enhancement, and technological adoption [4].

Among Indian states, Telangana has emerged as a prominent inland fish-producing region, primarily due to the availability of freshwater resources through tanks, reservoirs, canals, and farm ponds. Since its formation, the state has witnessed rapid expansion in freshwater aquaculture, particularly carp farming, supported by favorable policies, institutional support, and increasing farmer participation [5]. Districts such as Karimnagar, Nalgonda, Warangal, and Khammam have become major aquaculture hubs, contributing significantly to the state's fish production. The growth of freshwater aquaculture in Telangana has not only enhanced fish availability but has also strengthened rural livelihoods and allied economic activities.

Despite this growth, aquaculture practices in Telangana remain largely dependent on traditional pond management systems. Many farmers continue to rely on conventional methods characterized by limited water quality monitoring, unscientific feeding practices, inappropriate stocking densities, and reactive disease management [6]. Such practices often result in poor feed conversion efficiency, frequent disease outbreaks, and inconsistent yields. The lack of technical awareness, limited access to real-time water quality data, and insufficient adoption of scientific management tools further exacerbate productivity challenges (Boyd, 2020).

In this context, there is a critical need for a systematic and scientific assessment of yield constraints in freshwater

aquaculture systems in Telangana. Identifying the key factors influencing productivity—such as water quality parameters, feeding strategies, stocking density, and farm management practices—is essential for developing region-specific, sustainable aquaculture models. A comprehensive baseline assessment can provide valuable insights into existing gaps and guide the design of effective intervention strategies aimed at improving yield, profitability, and environmental sustainability. Therefore, the present study focuses on assessing current aquaculture practices in Telangana and identifying the major constraints limiting optimal fish production.

2. Review of Literature

2.1 Freshwater Aquaculture Practices in India

Freshwater aquaculture constitutes the backbone of India's aquaculture sector, accounting for a major share of total fish production. The dominant production systems in India are pond-based polyculture practices, primarily involving Indian Major Carps such as Rohu (*Labeo rohita*), Catla (*Catla catla*), and Mrigal (*Cirrhinus mrigala*) [1], [6]. These systems are widely adopted due to their relatively low capital requirements and adaptability to diverse agro-climatic conditions. Traditional management practices typically involve seasonal stocking, semi-intensive feeding regimes, and periodic water exchange. While such systems have contributed significantly to increased fish production over the past decades, their productivity often remains constrained due to limited scientific intervention and inadequate monitoring [7].

Recent studies emphasize the gradual shift from extensive and semi-intensive systems towards more intensive and technology-driven approaches to improve yield and resource efficiency [8]. However, adoption rates vary significantly across regions, with small and medium-scale farmers often constrained by lack of technical knowledge, financial resources, and institutional support. This has resulted in uneven productivity levels across states and farming clusters.

2.2 Yield Determinants in Freshwater Aquaculture

Fish yield in freshwater aquaculture is influenced by a complex interaction of biological, environmental, and managerial factors. Among these, water quality parameters such as dissolved oxygen, temperature, pH, ammonia, and nitrate levels play a critical role in fish growth, survival, and feed utilization [11]. Poor water quality has been consistently identified as a major limiting factor affecting productivity in pond-based systems.

Feeding practices are another key determinant of yield, accounting for nearly 60–70% of total operational costs in aquaculture [3]. Studies indicate that unbalanced feed formulations, improper feeding frequency, and overfeeding lead to poor Feed Conversion Ratios (FCR) and water quality deterioration, thereby negatively impacting growth performance [9]. Stocking density also significantly influences yield, as both under-stocking and over-stocking can result in inefficient resource utilization, stress, and increased disease susceptibility (Rahman et al., 2017).

2.3 Disease and Environmental Stress Factors

Disease outbreaks represent one of the most serious challenges in freshwater aquaculture, often leading to substantial economic losses. Bacterial, parasitic, and viral

infections are commonly reported in carp culture systems, particularly under conditions of poor water quality and high stocking density [14]. Environmental stressors such as temperature fluctuations, dissolved oxygen depletion, and accumulation of toxic metabolites further weaken fish immune responses, making them more susceptible to infections [12].

Climate variability has also emerged as a significant stress factor affecting aquaculture sustainability. Changes in rainfall patterns, increased water temperatures, and prolonged dry spells can alter pond water quality dynamics, thereby affecting fish growth and survival (FAO, 2020). These challenges highlight the need for proactive health management and adaptive farming strategies.

2.4 Limitations of Previous Studies and Research Gap

Although numerous studies have examined individual factors influencing aquaculture productivity, most of them focus on isolated parameters or controlled experimental conditions. Many existing yield enhancement models are generic in nature and do not adequately account for region-specific climatic, socio-economic, and management variations [13]. Furthermore, limited research has been conducted on comprehensive field-based assessments that integrate water quality, feeding practices, stocking density, and disease management in a single framework, particularly in semi-arid regions like Telangana.

The lack of region-specific baseline data and integrated analytical approaches restricts the practical applicability of existing recommendations. Consequently, there is a clear need for localized studies that assess real-world farming practices and identify context-specific constraints. Addressing these gaps can facilitate the development of sustainable, scalable aquaculture models tailored to the unique environmental and socio-economic conditions of Telangana.

3. Study Area Description

3.1 Geographic and Climatic Characteristics of Telangana

Telangana is located in the south-central region of India and lies on the Deccan Plateau, characterized by undulating terrain and predominantly semi-arid climatic conditions. The state extends between latitudes 15°46' N and 19°47' N and longitudes 77°16' E and 81°43' E. The climate of Telangana is marked by hot summers, moderate winters, and a monsoon-dependent rainfall pattern, with an average annual rainfall ranging between 700 mm and 1,100 mm (IMD, 2022). A significant portion of the rainfall is received during the southwest monsoon season (June–September), leading to seasonal variability in surface water availability. Temperature extremes, particularly during summer months, often influence water quality dynamics in aquaculture ponds, affecting dissolved oxygen levels and metabolic rates of cultured fish species (Boyd, 2020).

3.2 Selection of Key Aquaculture Districts

The study focuses on major aquaculture-producing districts in Telangana that have witnessed rapid expansion of freshwater pond aquaculture in recent years. Districts such as Karimnagar, Warangal, were selected based on criteria including aquaculture intensity, availability of freshwater resources, and farmer participation. These districts

collectively represent diverse agro-climatic zones and management practices, enabling a comprehensive assessment of aquaculture systems across the state. According to reports from the Department of Fisheries, Government of Telangana, these districts contribute a substantial share of the state's inland fish production and serve as important hubs for carp culture and emerging tilapia farming activities [5].

4. Water Availability and Seasonal Variability

Freshwater availability in Telangana is largely dependent on surface water bodies such as tanks, reservoirs, canals, and farm ponds, supplemented by groundwater sources. Major river basins, including the Godavari and Krishna, play a crucial role in supporting inland aquaculture through irrigation canals and reservoir-based fisheries [21]. However, water availability is highly seasonal, with peak availability during the monsoon and post-monsoon periods, followed by significant reductions during summer months. Seasonal water scarcity often leads to increased concentration of nutrients and organic matter in ponds, resulting in deteriorated water quality conditions such as elevated ammonia levels and reduced dissolved oxygen (FAO, 2020). Such fluctuations pose challenges to maintaining stable culture environments and consistent fish growth throughout the production cycle.

5. Species Commonly Cultured

Freshwater aquaculture in Telangana is predominantly based on carp polyculture systems. Indian Major Carps—Rohu (*Labeo rohita*), Catla (*Catla catla*), and Mrigal (*Cirrhinus mrigala*)—are the most commonly cultured species due to their fast growth rates, compatibility in polyculture, and strong market demand [6]. In recent years, Tilapia (*Oreochromis niloticus*) has gained popularity owing to its high tolerance to environmental stress, efficient feed conversion, and adaptability to diverse culture conditions [15]. The combination of these species allows farmers to optimize pond resource utilization by exploiting different ecological niches within the water column, thereby enhancing overall productivity. However, improper species composition and management practices can lead to competition, stress, and reduced yield, underscoring the need for scientific assessment and management interventions.

6. Parameters Studied

The present study examines key biological, environmental, and management parameters that significantly influence productivity in freshwater aquaculture systems. The selection of these parameters is based on their established role in determining fish growth, survival, and overall yield in pond-based culture systems [11][6].

6.1 Pond Size and Water Source

Pond size is a critical physical parameter affecting water quality stability, management efficiency, and fish growth. In the study area, pond sizes typically range from small-scale (<0.2 ha) to medium-scale (0.2–1.0 ha) systems. Larger ponds generally exhibit greater thermal and chemical stability, whereas smaller ponds are more susceptible to rapid fluctuations in temperature and dissolved oxygen levels [11]. Water sources for aquaculture ponds in Telangana include irrigation canals, tanks, reservoirs, bore wells, and rainwater harvesting systems. The quality and reliability of the water source significantly influence pond productivity. Surface water sources are often nutrient-rich but may introduce

contaminants and pathogens, while groundwater sources provide stable water supply but may have issues related to hardness and salinity [16].

6.2 Stocking Density

Stocking density plays a crucial role in determining growth rate, feed utilization efficiency, and fish health. Both under-stocking and over-stocking can lead to sub-optimal production outcomes. High stocking densities often result in competition for space and dissolved oxygen, increased stress, and higher susceptibility to diseases [10]. Conversely, low stocking densities may lead to inefficient utilization of available pond resources. Therefore, stocking density was assessed in relation to species composition and pond size to evaluate its influence on survival rate and yield performance [6].

6.3 Feeding Practices and Feed Type

Feeding practices constitute the largest operational cost in freshwater aquaculture and significantly influence growth performance and feed conversion efficiency. The study examined feed type (commercial pelleted feed or farm-made feed), protein content, feeding frequency, and feeding methods adopted by farmers. Improper feeding practices, such as overfeeding or the use of nutritionally imbalanced feed, can lead to poor Feed Conversion Ratio (FCR) and accumulation of organic waste, thereby deteriorating water quality [3][9]. Efficient feeding strategies are essential for achieving higher productivity and economic sustainability.

6.4 Water Quality Parameters

Water quality is a fundamental determinant of fish health and growth in aquaculture systems. Key physicochemical parameters monitored in the study include temperature, pH, dissolved oxygen (DO), ammonia, nitrite, and nitrate concentrations. Variations beyond optimal ranges can cause physiological stress, reduce feed intake, and increase disease susceptibility [11]. Regular monitoring of water quality parameters is essential for maintaining stable culture conditions and maximizing yield potential.

6.5 Disease Incidence

Disease incidence was assessed through farmer-reported data and field observations, focusing on the occurrence of bacterial, parasitic, and fungal infections. Poor water quality, high stocking density, and inadequate biosecurity measures are known to increase disease outbreaks in freshwater aquaculture systems [13]. Disease-related mortality leads to significant production losses and affects economic viability. Understanding disease prevalence and management practices is therefore crucial for identifying yield constraints.

6.6 Harvest Yield

Harvest yield, expressed as total biomass produced per unit area (kg/ha/crop), serves as the primary indicator of aquaculture productivity. Yield data were collected at the end of the culture cycle and analysed in relation to management practices and environmental parameters. Previous studies have demonstrated strong correlations between yield and factors such as feed efficiency, stocking density, and water quality management [7]. Yield assessment provides a comprehensive measure of system performance and forms the basis for identifying productivity gaps.

7. Data Analysis

The data collected from field surveys and on-site observations were systematically organized and analysed to examine existing aquaculture practices and identify key factors influencing productivity in freshwater pond systems of Telangana. Both descriptive and inferential statistical techniques were employed to ensure comprehensive interpretation of the data [18][19].

7.1 Descriptive Statistical Analysis

Descriptive statistics were used to summarize and present the basic characteristics of the collected data. Parameters such as pond size, stocking density, feed input, water quality variables, disease incidence, and harvest yield were analyzed using measures of **mean, percentage, and standard deviation**. These measures provide insights into central tendencies, variability, and distribution patterns across different aquaculture farms [18].

The mean values helped in understanding the typical management practices adopted by farmers, while standard deviation was used to assess the extent of variation among farms. Percentage analysis was applied to categorize farmers based on management practices, disease occurrence, and adoption levels of water quality monitoring. Descriptive analysis is widely recognized as a fundamental approach for identifying baseline trends and disparities in aquaculture production systems [7].

7.2 Correlation Analysis Between Yield and Key Parameters

To evaluate the relationship between harvest yield and selected management and environmental parameters, **correlation analysis** was performed. Pearson's correlation coefficient was used to quantify the strength and direction of association between yield and variables such as stocking density, feed quantity, dissolved oxygen, ammonia concentration, and disease incident [19].

Correlation analysis enables the identification of parameters that have significant positive or negative influence on productivity. Previous studies have demonstrated strong correlations between fish yield and factors such as feed efficiency, water quality stability, and stocking density [11][10]. By identifying statistically significant relationships, this analysis provides empirical evidence to support the selection of critical intervention areas for yield improvement.

7.3 Identification of Major Constraints Affecting Productivity

Based on the combined outcomes of descriptive and correlation analyses, major constraints affecting aquaculture productivity were identified. Parameters showing high variability and significant negative correlations with yield were considered as primary limiting factors. These include inadequate water quality management, inefficient feeding practices, improper stocking density, and high disease incidence.

Constraint identification is an essential step in aquaculture systems analysis, as it helps in prioritizing management interventions and policy actions [16]. The analytical approach adopted in this study allows for a systematic diagnosis of productivity bottlenecks under real farm conditions, thereby providing a strong foundation for developing region-specific, sustainable aquaculture intervention models.

8. Results and Discussion

8.1 Current Status of Aquaculture Practices

The results indicate that freshwater aquaculture in Telangana is predominantly characterized by **traditional and semi-intensive farming practices**. Most farmers depend on earthen ponds with limited mechanization and minimal use of scientific management tools. Stocking density, feeding schedules, and water quality management are largely based on experience rather than standardized protocols. Similar observations have been reported in several Indian states where small and medium-scale farmers rely on conventional practices due to limited access to technical guidance and extension services [7][16]. Although some progressive farmers have adopted commercial pelleted feeds and aeration systems, widespread adoption of advanced technologies such as automated feeders, water quality sensors, and disease diagnostics remains low. This uneven adoption results in significant variability in productivity across regions.

8.2 Yield Levels Across Regions

The analysis revealed **considerable variation in fish yield across different aquaculture districts of Telangana**. Regions with relatively better water availability and access to feed inputs exhibited higher average yields, whereas districts experiencing seasonal water scarcity and poor pond management recorded lower production levels. The observed yield variations highlight the influence of local environmental conditions and management practices on aquaculture productivity. Comparable regional disparities have been documented in previous studies on freshwater aquaculture in India, where yield differences were attributed to variations in pond infrastructure, farmer skill levels, and resource availability [20][21]. The findings suggest that regional-specific strategies are necessary to address localized production constraints.

8.3 Major Limiting Factors Affecting Productivity

8.3.1 Poor Water Quality Management

Water quality parameters such as dissolved oxygen, pH, ammonia, and turbidity were found to be inadequately monitored in most farms. The absence of regular water quality assessment often resulted in suboptimal growing conditions, leading to stress, reduced growth rates, and increased susceptibility to diseases. Correlation analysis indicated a strong association between water quality fluctuations and yield reduction.

Previous research has established that poor water quality is one of the most critical constraints in freshwater aquaculture, directly affecting fish metabolism and survival [11][8]. The present findings reinforce the need for routine monitoring and scientific water management practices.

8.3.2 High Feed Cost and Inefficiency

Feed constitutes the largest operational cost in aquaculture, and the study revealed that many farmers rely on unbalanced or improperly formulated feeds to reduce expenses. Inefficient feeding practices, including overfeeding and inconsistent feeding schedules, were commonly observed, resulting in feed wastage and water quality deterioration.

These findings align with earlier studies that identified feed cost and feed conversion inefficiency as major constraints limiting profitability in Indian aquaculture systems[3][7].

Improving feed quality and feeding strategies could significantly enhance yield and economic returns.

8.3.3 Disease Outbreaks

Disease incidence was identified as a major factor contributing to yield losses. Farmers reported frequent outbreaks of bacterial and parasitic infections, particularly during seasonal transitions and periods of water quality stress. The lack of early diagnosis and preventive health management further exacerbated the impact of diseases.

Similar disease-related yield losses have been widely reported in Indian freshwater aquaculture, with poor biosecurity and limited veterinary support identified as major contributors [13][22] 2017). The study highlights the importance of proactive health management and disease surveillance systems.

8.3.4 Lack of Scientific Monitoring

The study revealed a significant gap in the adoption of scientific monitoring tools, including routine water testing, growth tracking, and record keeping. Most farmers lacked awareness of standard operating procedures and relied on visual assessment to make management decisions. This approach often leads to delayed responses to environmental stress and disease outbreaks.

The absence of scientific monitoring has been identified as a key limitation in traditional aquaculture systems, restricting productivity and sustainability [16] [[11]]. Integrating simple monitoring frameworks can enable farmers to make data-driven decisions and improve production outcomes.

8.4 Comparison with Findings from Previous Studies

The findings of the present study are largely consistent with earlier research conducted in different parts of India. Previous studies have reported similar challenges related to water quality management, feed efficiency, disease control, and limited technological adoption [20][23]. However, the present study adds **regional specificity** by highlighting district-level variations within Telangana, which are often overlooked in broader national assessments.

Unlike generic national-level studies, this research provides field-level evidence of localized constraints, thereby offering a more nuanced understanding of productivity gaps. Such region-specific insights are essential for designing targeted interventions and policy frameworks tailored to the socio-economic and environmental conditions of Telangana.

9. Key Findings

The present study provides critical insights into the status of freshwater aquaculture in Telangana and identifies key constraints responsible for suboptimal yield performance. The major findings are summarized and discussed below.

9.1 Summary of Critical Yield Constraints

The analysis clearly indicates that **water quality management, feeding practices, disease control, and scientific monitoring** are the primary determinants of productivity in Telangana's freshwater aquaculture systems. Inadequate monitoring of key water quality parameters such as dissolved oxygen, pH, and ammonia was found to significantly affect fish health and growth performance. Poor pond management practices resulted in stress conditions that increased disease susceptibility and mortality rates. Feed-related challenges, including high feed costs, poor feed quality, and inefficient feeding strategies, emerged as another

major constraint. Many farmers relied on substandard feeds or irregular feeding schedules to minimize operational costs, which adversely affected feed conversion efficiency and overall yield. Similar yield-limiting factors have been reported across Indian aquaculture systems, highlighting the systemic nature of these constraints [7][11]. Additionally, frequent disease outbreaks—exacerbated by inadequate biosecurity measures and delayed diagnosis—were found to contribute significantly to yield losses. The lack of access to aquatic animal health services and limited farmer awareness regarding preventive health management further intensified production risks, consistent with earlier findings in Indian freshwater aquaculture [13] [22].

9.2 Evidence of Productivity Gap

The study revealed a **substantial productivity gap** between actual farm-level yields and the potential yields achievable under scientifically managed semi-intensive aquaculture systems. While a small proportion of progressive farmers achieved higher productivity through improved feeding and partial water quality management, the majority of farms operated well below optimal production levels. Regional variations in yield further demonstrated that access to water resources, quality seed and feed, and farmer skill levels play a critical role in determining production outcomes. These findings align with earlier studies that reported wide yield gaps in Indian aquaculture due to uneven adoption of best management practices and technological inputs[20][21]. The persistence of such productivity gaps indicates that existing development efforts have not been sufficiently tailored to address region-specific challenges.

9.3 Need for Sustainable Intervention Models

The findings strongly emphasize the need for **sustainable, region-specific intervention models** that integrate scientific management practices with locally feasible technologies. Traditional approaches that focus solely on increasing input use without improving management efficiency are unlikely to deliver long-term productivity gains. Instead, integrated intervention models that combine water quality monitoring, optimized feeding strategies, disease surveillance, and farmer capacity building are essential.

Previous studies have demonstrated that the adoption of science-based management frameworks can significantly enhance productivity while reducing environmental impacts [16][23]. In the context of Telangana, sustainable intervention models should be designed to address water scarcity, seasonal variability, and the socio-economic conditions of small and medium-scale farmers. The insights generated from this study provide a strong empirical foundation for the development of such targeted intervention strategies, which can improve yield, profitability, and long-term sustainability of freshwater aquaculture in the region.

10. Research Gap and Future Scope

10.1 Absence of Region-Specific Yield Enhancement Models

Despite the substantial growth of freshwater aquaculture in India, most existing yield improvement strategies are **generic in nature** and lack sensitivity to regional environmental, climatic, and socio-economic conditions. National-level models often recommend uniform stocking densities, feeding regimes, and water management practices, which may not be

optimal for regions such as Telangana that experience **seasonal water scarcity, high temperature variability, and heterogeneous pond conditions**.

Previous studies have primarily focused on broad productivity assessments or species-specific performance without integrating local constraints such as water source reliability, input accessibility, and farmer capacity (Sahu et al., 2013; Jayanthi et al., 2018). As a result, there is a clear gap in the availability of **region-specific, empirically validated yield enhancement frameworks** tailored to Telangana's agro-climatic conditions. Addressing this gap is critical for developing sustainable and scalable aquaculture solutions that can be effectively adopted by local farmers.

10.2 Lack of Technology Integration at Farm Level

Another major research gap identified through this study is the **limited integration of modern technologies at the farm level**. Although technological advancements such as water quality sensors, automated feeding systems, and digital disease diagnostics are increasingly available, their adoption in small and medium-scale aquaculture farms remains minimal. The majority of farmers continue to rely on manual observation and experience-based decision-making, which restricts timely intervention and reduces production efficiency.

Several studies have highlighted that the absence of real-time monitoring and data-driven management leads to increased production risks, including water quality deterioration and disease outbreaks [23][16]. Furthermore, existing research on aquaculture technologies has largely focused on controlled or large-scale systems, with limited emphasis on **low-cost, farmer-friendly solutions suitable for resource-constrained settings**. This underscores the need for technology integration models that are economically viable, context-specific, and easy to implement at the grassroots level.

10.3 Justification for Stage-2 Intervention-Based Research

The findings of the present study provide a strong empirical justification for **Stage-2 intervention-based research** aimed at improving aquaculture productivity in Telangana. While Stage-1 research has identified key constraints and productivity gaps, addressing these challenges requires the design, implementation, and validation of **integrated intervention models** that combine scientific management practices with appropriate technological tools.

Stage-2 research should focus on developing and testing intervention frameworks that incorporate real-time water quality monitoring, optimized feeding strategies, early disease detection mechanisms, and farmer decision-support systems. Previous studies have demonstrated that intervention-based approaches can significantly enhance yield, reduce environmental impacts, and improve economic sustainability when adapted to local conditions [8][11].

By transitioning from diagnostic assessment to solution-oriented intervention research, Stage-2 studies can bridge the gap between research and practice. Such an approach will not only contribute to academic advancement but also support policy formulation and extension programs aimed at strengthening sustainable aquaculture development in Telangana and similar agro-climatic regions.

11. Conclusion

The present study underscores the importance of a **systematic and region-specific assessment** of freshwater aquaculture practices to understand the underlying factors influencing yield variability in Telangana. By integrating field-level observations, farmer surveys, and statistical analysis, the research provides empirical evidence on how pond management practices, water quality control, feeding strategies, and disease management collectively influence aquaculture productivity. Such a structured assessment approach is essential for identifying real-world constraints that are often overlooked in generalized or model-based studies [16].

The findings confirm that despite the rapid expansion of freshwater aquaculture in Telangana, **existing challenges persist across the sector**. Inadequate water quality monitoring, high feed costs coupled with inefficient feeding practices, frequent disease outbreaks, and limited adoption of scientific and technological interventions continue to restrict productivity. These constraints are consistent with challenges reported in earlier studies conducted across different regions of India, indicating that the problems observed are not isolated but systemic in nature (Jena et al., 2016; Boyd, 2020; Jayanthi et al., 2018). The persistence of these challenges highlights the limitations of traditional farming approaches in achieving sustainable yield improvements under changing environmental and resource conditions.

Importantly, the study establishes a strong foundation for **guiding the next phase of research** by clearly identifying priority areas for intervention. The empirical insights generated through this assessment provide a rationale for transitioning from diagnostic analysis to **intervention-based research frameworks** that integrate scientific management practices with appropriate technological tools. By addressing region-specific constraints and incorporating real-time monitoring, optimized feeding, and preventive health management strategies, future research can focus on developing sustainable and scalable aquaculture models tailored to Telangana's agro-climatic and socio-economic context. Such an approach aligns with global recommendations emphasizing evidence-based, technology-supported aquaculture development to enhance productivity, profitability, and environmental sustainability [16][23].

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