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Comparative effectiveness of public and private extension systems in the fisheries sector: An exploratory study in Uttar Pradesh, North India

Sanee Chauhan[1*], V. Geethalakshmi[2], K. Rejula[2], A. K. Mohanty[3], Shalumol Salas[1] and P. Dona[1]

[1]Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi, Kerala - 682 506, India
[2]ICAR- Central Institute of Fisheries Technology, Kochi, Kerala - 682 029, India
[3]ICAR-Agricultural Technology Application Research Institute, Umiam - 793 103, Meghalaya, India

Abstract

Extension services are crucial in the fisheries sector, helping to bridge knowledge gaps, facilitate access to essential resources and promote sustainable practices. While many studies focus on public extension systems, there is limited research comparing the effectiveness of both public and private extension systems. To address this knowledge gap, this research was conducted in Shravasti, Ayodhya and Azamgarh districts of Uttar Pradesh. A sample of 120 fish farmers were selected using stratified random sampling and effectiveness index (EI) was calculated using four indicators. The findings indicated that fish farmers' change in awareness was the most significant factor with an index value of 0.81 for the effectiveness of the public extension system, whereas the extent of delivery was identified as the least contributing factor to the perceived effectiveness, with an index value of 0.59. With an index score of 0.85, the fish farmers' change in yield and income has proven to be highly effective by private extension system. In terms of overall effectiveness, group means indicated that effectiveness of private extension systems (M=0.76) is significantly higher ($p<0.05$) than that of public extension systems (M=0.70). The study suggests public-private partnerships (PPPs) can significantly enhance support for fish farmers by combining the strengths of both sectors.

Introduction

India ranks third in fish production globally, contributing 7.96% to the world's total fish production (DoF, 2022). For the financial year 2022-23, India's fish production was estimated at 16.25 million t, with 12.12 million t from the inland sector and 4.13 million t from the marine sector. The country is also a leading aquaculture producer, second only to China. Fisheries and aquaculture are vital sources of food, nutrition, income, and livelihoods for millions of people in India (DoF, 2023).

Uttar Pradesh (UP) is the most populous state in India and is endowed with abundant aquatic bioresources, showcasing a rich genetic diversity of freshwater fish (Pathak *et al.,* 2019). The state ranks third in inland fish production, next only to Andhra Pradesh and West Bengal, with current production estimated at 8.09 lakh t (DoF, 2022).

Public and private extension systems have similar primary goals, centered on increasing food production, ensuring food and nutrition security, and securing the livelihoods of rural communities (Christoplos, 2003). Public extension systems can introduce new initiatives and enforce agricultural policies, while private extension offers specialised services to farmers based on their unique needs. Farmers then make decisions based on what they believe will benefit them the most, with private sector extension systems focusing primarily on cash crops or input sales (Chiru *et al.,* 2021).

As the fisheries sector becomes more commercialised, there is a growing need for new knowledge and continuous support. The existing public extension system alone cannot meet the increasing demand, leading

*Correspondence e-mail:
sunny94.chauhan@gmail.com

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to a gap in extension services. This gap presents an opportunity for the introduction and development of privatised extension services (Singh and Narain, 2016). The emergence of private extension services may have been a result of the public extension's limitations in effectively reaching all farmers at all times and addressing all their concerns. Private extension system has gradually filled this gap by providing additional support such as input supply, information support, market assistance and processing, which are not fully provided by the public extension system (Shekara, 2001).

Achieving a satisfactory level of performance in extension system has proven to be difficult because of the ever-changing nature of agricultural challenges and the traditional setup of public extension services (Swanson, 1984; Benson and Jafey, 2013). It is noteworthy that the public extension system still holds great importance, particularly in scenarios where there is a high demand for information and public goods. Moreover, it serves as a means of integrating disadvantaged groups, such as women who significantly contribute to agricultural production (Farrington *et al.,* 2003; Quave *et al.,* 2017).

The effectiveness of an extension system can be described as its ability to successfully carry out its tasks in order to achieve the predetermined goals. To effectively reach a large number of farmers in India, it is crucial for extension system to transfer technologies quickly, efficiently and effectively. Given the current scenario where numerous organisations are operating in India, it is imperative to prioritise the effectiveness of extension system working at the grassroot level to fulfill their objectives (Mukherjee and Maity, 2015). In practice, the assessment of agricultural extension system performance tends to prioritise the impact it has on various aspects, such as production, yield, and the financial gains of farmers (Mofya and Kabisa, 2016).

The disparities between public and private extension systems are evident in various aspects, including their fundamental nature, approaches to extension services, operational mechanisms, organisational configurations and the outcomes they produce for farmers. It is essential to assess the efficiency of extension services that meet the needs of the farming community and effectively serve farmers. As a result, a comprehensive investigation was conducted to analyse the effectiveness of public and private extension systems and identify the factors that affect their effectiveness.

Materials and methods

The study was conducted during 2022-2023 in Uttar Pradesh (23°52'N; 31°28'N; 77°3'E; 84°39'E), employing an exploratory research design. The three administrative divisions of Uttar Pradesh, Faizabad, Azamgarh and Devipatan were selected based on simple random sampling. One district from each division *i.e.,* Ayodhya, Azamgarh and Shravasti was purposively chosen based on high, medium and low availability of area under tanks and ponds, as well as the presence of extension organisations. Two public and two private extension organisations were selected from each district based on their involvement in the fisheries sector, making a total of twelve organisations. The selected public extension organisations included the Fisheries Department and Krishi Vigyan Kendra (KVK) in Shravasti, the College of Fisheries and Saryu Matsya Beej Utpadan Kendra (Hatchery) in Ayodhya and the Fish Farmers Development Agency (FFDA) and Rural Self Employment Training Institute (RSETI) in Azamgarh. The private extension organisations selected were Arham Matsya Beej Hatchery Private Limited (Hatchery) and Virbac Animal Health Private Limited (Medicine) in Shravasti, Tamsa Matsya Beej Utpadan Kendra Private Limited (Hatchery) and Biomed Techno Ventures Private Limited (Medicine) in Ayodhya, and ABIS Exports Private Limited (Feed) and Neospark Drugs and Chemicals Private Limited (Medicine) in Azamgarh.

Based on data from the extension organisations, a comprehensive list of public and private beneficiaries was compiled district-wise. The population was deliberately divided into homogeneous groups (strata), "Public beneficiaries" and "Private beneficiaries." Utilising stratified random sampling techniques, 60 respondents were randomly selected from each stratum. Equal allocation across strata was adopted to ensure balanced representation for comparative analysis. Primary data were collected through a pre-tested structured interview schedule, enabling detailed responses. Effectiveness of extension system was measured by four different indicators namely *change in awareness* of technologies or package of practices, *change in adoption* of technologies or package of practices, the *extent of delivery* and the *change in yield and income* of fish farmers. A three-point rating scale was employed for each indicator. The collected data was thoroughly analysed and scores for each indicator was calculated using the index followed by Chiru *et al.* (2021) using the following equation:

$$EI = \frac{\text{Total obtained scores of all items-Minimum score}}{\text{Total maximum possible scores on all items-Minimum score}}$$

To compare the mean effectiveness scores of different indicators between public and private extension systems, independent-samples t-tests were employed. To identify determinants of the perceived effectiveness of extension systems, multiple regression analysis was performed, with effectiveness index (EI) as the dependent variable and socio-economic characteristics as independent variables. To enhance the clarity and comprehensibility, a broad range of data was condensed and classified. The data was analysed using the Statistical Package for Social Sciences (SPSS) tool.

Results and discussion

Socio-economic profile of fish farmers

Table 1 presents the socio-economic characteristics of fish farmers associated with public and private extension services. Among fish farmers availing public extension services, the majority fall in the middle age category with 58.3%, followed by the young age group at 23.3% and the old age group at 18.3%. In contrast, a larger proportion of fish farmers using private extension services are younger, with 50%, while 45% are in the middle age group, and only 5% were old. Male fish farmers dominate both groups, comprising 96.7% of those using public extension services and 100% using private services. Only 3.3% of the public extension users were females, with none in the private extension group.

Table 1 also reveals that education levels vary between the groups. For public extension users, 53.3% completed primary school, while only 6.7% had graduate or higher education. Private extension users showed a higher educational attainment, with 43.3% having completed primary school and 23.3% attaining graduate-level

Table 1. Socio-economic profile of fish farmers

Variable	Category	Fish farmers availing public extension services (n=60)	Fish farmers availing private extension services (n=60)
Age	Young (<35)	14 (23.3)	30 (50)
	Middle (35-50)	35 (58.3)	27 (45)
	Old (>50)	11 (18.3)	3 (5)
Gender	Male	58 (96.7)	60 (100)
	Female	2 (3.3)	0 (0)
Education	Illiterate	3 (5)	1 (1.7)
	Primary School	19 (31.7)	7 (11.7)
	Secondary School	34 (56.7)	38 (63.3)
	Graduate and above	4 (6.6)	14 (23.3)
Family size	Small (<5 members)	9 (15)	5 (8.3)
	Medium (5-8 members)	26 (43.3)	36 (60)
	Large (>8 members)	25 (41.7)	19 (31.7)
Occupation	Fish farming	15 (25)	27 (45)
	Fish farming+Agri.	38 (63.3)	28 (46.6)
	Fish farming+Service	6 (10)	1 (1.6)
	Fish farming+Business	1 (1.7)	4 (6.7)
Area of fish farm	Less than 1 ha	36 (60)	9 (15)
	1 to 4 ha	17 (28.3)	33 (55)
	More than 4 ha	7 (11.7)	18 (30)
Annual income	Less than 1 lakh	11 (18.3)	2 (3.3)
	1 to 5 lakhs	40 (66.7)	21 (35)
	More than 5 lakhs	9 (15)	37 (61.7)
Farming experience	Upto 4 years	9 (15)	12 (20)
	5 to 7 years	17 (28.3)	25 (41.7)
	More than 7 years	34 (56.7)	23 (38.3)
Extension contact	Regular	21 (35)	52 (86.7)
	Occasional	39 (65)	8 (13.3)

Figures in parentheses indicate percentage to total

education. Among fish farmers using public services, 43.3% had medium-sized families, 41.7% had large families and 15% had small families. In the private extension group, 60% had medium-sized families, 31.7% large families and only 8.3% had small families. Public extension users were primarily involved in fish farming combined with agriculture (63.3%), whereas private extension users had a higher proportion engaged solely in fish farming (45%). A small percentage in each group combines fish farming with other occupations such as service or business. A notable difference exists in farm sizes, 60% of public extension users operate farms smaller than 1 ha, while 55% of private extension users had farms between 1 to 4 ha. Additionally, 30% of private extension users own farms larger than 4 ha, compared to only 11.7% in the public group. Fish farmers using public services primarily fall within the income range of 1 to 5 lakhs (66.7%), whereas those using private services tended to have higher incomes, with 61.7% earning more than 5 lakhs annually. Only 3.3% of private extension users earn less than 1 lakh, compared to 18.3% of public service users. A larger proportion of public extension users had more than 7 years of experience (56.7%), compared to 38.3% of private extension users. Private extension users had a higher proportion of farmers with moderate experience at 41.7% as opposed to 28.3% in the public group. Regular extension contact is more common among private service users, with 86.7% reporting regular contact. In contrast, only 35% of public extension users had regular contact, with 65% relying on occasional support.

Effectiveness of public extension system

Table 2 indicates that majority of fish farmers perceived the effectiveness of public extension system to a notable change in awareness of technology or package of practices as 66.7% were classified to the high category, indicating their strong conviction of this factor. Public extension system often focuses on knowledge transfer, which is crucial in sectors like fisheries, where new technologies (*e.g.,* better fish feed, pond management, or disease control techniques) can directly enhance productivity. The high conviction among farmers reflects the success of extension programs in bridging the knowledge gap and promoting sustainable practices. Similar findings were reported by Umeh *et al.* (2018), that farmers possess a high level of knowledge in the role and information transfer through agricultural extension services. This reflects the effectiveness of extension organisations in delivering key information to farmers, particularly in areas related to agricultural innovation, technology dissemination and best farming practices.

The perceived effectiveness of public extension system was also impacted by two key factors: *change in yield and income*, as well as *change in adoption*. Table 2 also revealed that *change in yield and income* directly reflects the effectiveness of the technologies or package of practices promoted by public extension system. When farmers experience increased yields due to the adoption of new

Table 2. Fish farmer's perceived effectiveness of public extension system

Effectiveness	Perceived effectiveness of public extension system (n=60)			
	Change in awareness	Extent of delivery	Change in adoption	Change in yield and income
Mean	0.81	0.59	0.67	0.73
Standard deviation	0.20775	0.21772	0.31178	0.07178
Range (Min-Max)	0.19-1	0.09-1	0.06-1	0.50-1
Very low	3 (5)	14 (23.3)	11 (18.3)	1(1.7)
Low	8(13.3)	16(26.7)	16 (26.7)	29(48.3)
Medium	9 (15)	17(28.3)	8 (13.3)	30(50)
High	40(66.7)	13(21.7)	25(41.7)	0(0)

Figures in parentheses indicate percentage to total

technologies or practices suggested by extension organisations, it enhances their perception of the organisations' value. Tigabu and Gebeyehu (2018) in their study reported that farmers who adopt technologies are more likely to do, so again emphasises the profitability associated with agricultural technology adoption. Once farmers experience the benefits of modern inputs such as increased yields or reduced costs they are more inclined to continue utilising these technologies. This finding reflects the concept of path dependency, where past decisions and experiences shape future technology adoption behaviours. Interestingly, the *extent of delivery* was found to have the least impact on determining perceived effectiveness. This result presents a noteworthy perspective on how these extension services are evaluated by fish farmers. One interpretation of this result is that quality over quantity may be a decisive factor in how farmers assess the value of extension services. While having a wide reach and high delivery rates may seem beneficial, the relevance, accuracy, and practicality of the information provided are likely to be more influential. The finding aligns with the study conducted by Rivera and Qamar (2003), when extension system prioritises meaningful engagement over sheer volume, farmers may be more likely to view these services as effective, regardless of the extent of service delivery.

Fig. 1 indicates the dimension-wise mean level of effectiveness index scores. The score reveal that fish farmers perceive the highest effectiveness in the *change in awareness*, with an index value of 0.81. This suggests that public extension system successfully raise awareness of new technologies and practices. Following this, the perceived effectiveness regarding *changes in yield and income* is also high, with an index value of 0.73. These findings underscore the impact that improved awareness can have on increasing yield and income when fish farmers implement the knowledge gained through public extension services. However, the lower perceived effectiveness in *extent of delivery*, indicated by the lowest index value of 0.59, suggests room for improvement in the accessibility and timeliness of extension services. This gap highlights a critical need for public extension system to strengthen the delivery mechanisms to enhance outreach and support for fish farmers, ensuring they fully benefit from the available services. Improving service delivery could further enhance the positive outcomes in yield and income as well as overall adaptation to recommended practices.

Effectiveness of private extension system

The significance of private extension system in effectiveness is depicted in Table 3, where the most influential factor was the *change in yield and income* of fish farmers. This factor accounted for 78.3% of fish farmers being classified in the high category. Adopting private extension services can lead to significant

Fig.1. Effectiveness parameters of public extension system

Table 3. Fish farmer's perceived effectiveness of private extension system

Effectiveness	Perceived effectiveness of private extension system (n=60)			
	Extent of delivery	Change in awareness	Change in adoption	Change in yield and income
Mean	0.69	0.75	0.74	0.85
Standard deviation	0.17	0.24	0.25	0.128
Range (Min-Max)	0.33-1	0.19-1	0.10-1	0.50-1
Very low	3(5)	6 (10)	7(11.7)	1(1.7)
Low	15(25)	14(23.3)	8(13.3)	2(3.3)
Medium	31(51.7)	11(18.3)	10(16.7))	10(16.7)
High	11(18.3)	29(48.3)	35(58.3)	47(78.3)

Figures in parentheses indicate percentage to total

improvements in yield and income for fish farmers by providing tailored, timely advice and access to quality inputs. Baiyegunhi *et al.* (2019) concluded that farmers participating in private extension programs experienced a substantial increase in their net farm income, underscoring the critical role of these programs in improving financial outcomes. This boost reflects the effectiveness of private fisheries organisations in providing specialised guidance, resources and market access, which enable farmers to optimise productivity and profitability. The findings highlight how private extension initiatives support the economic advancement of fish farmers by equipping them with the tools and knowledge necessary for efficient, profitable aquaculture practices. *Change in awareness* and *change in adoption were* the next crucial factors in determining the effectiveness of private extension system, with fish farmers in this category attributing 58.3 and 48.3% of their success to these factors. Private extension system drives higher adoption rates and elevates awareness among fish farmers by offering targeted, relevant information and practical training on new technologies and practices. Sylla *et al.* (2019) demonstrated that the quality of services provided by private extension systems was rated more favourably by farmers compared to public extension services. In the context of private fisheries organisations, this finding underscores the superior service delivery in areas such as technical assistance, timely support and tailored resources like quality fish seed and feed. Private extension system typically offers a more responsive and adaptable approach, addressing the specific challenges fish farmers face with a focus on efficiency and effectiveness. This favourable rating highlights the trust and value fish farmers place in private services, as these organisations consistently provide the expertise and resources needed to enhance production and profitability in aquaculture. Swanson and Samy (2002) concluded that with access to superior technologies, private sector firms are able to equip farmers with the necessary information to effectively utilise these new technological products.

Fig. 2 indicates the dimension-wise mean level of effectiveness index scores. The score reveal that fish farmers perceive the highest effectiveness in the *change in yield and income* with the highest index score of 0.85, while the *change in awareness* obtained a score of 0.75. This suggests that fish farmers associated with private extension system were pleased with the improvements in their yield and income resulting from their utilisation of extension services provided. With advanced techniques, personalised support and improved resources like high-quality feed and seed, farmers often see higher productivity and reduced losses. Private extension system also frequently offers market linkages and price information, helping farmers to sell at premium prices and secure better profits. This combination of increased yield and strategic market access contributes to income growth and greater stability, making private extension a valuable tool for enhancing fish farming profitability.

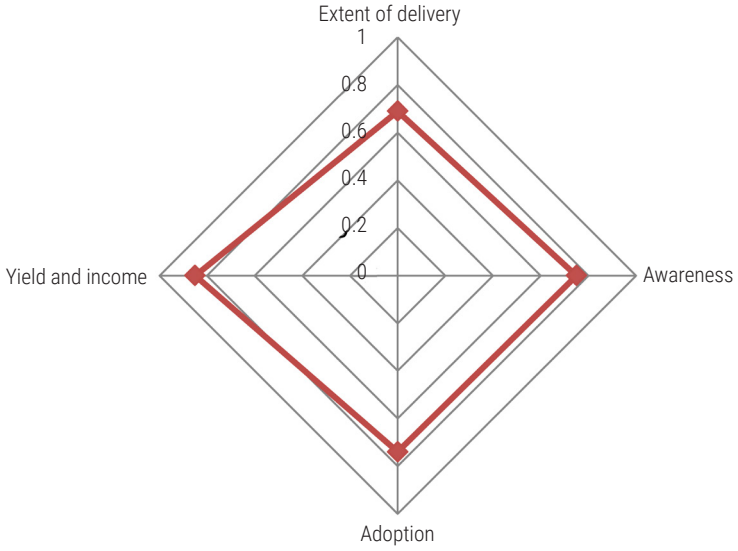

Fig.2. Effectiveness parameters of private extension system

According to Mukherjee and Maity (2015) private extension organisations provide services that are quick, timely, efficient and well-tailored to the farmers' needs. These qualities often highlight the limitations of traditional public extension systems, which may lack the resources or agility to respond rapidly to farmers' demands. Although private services are driven by profit motives, they play a crucial role in filling the gaps left by the public sector, thereby meeting the otherwise unmet needs of many farmers across India. This profit-driven approach, while sometimes critiqued, does not necessarily detract from the effectiveness of private services in supporting farmers, who benefit from their adaptability and responsiveness in delivering technological solutions. Thus, it can be concluded that high yield and income make them aware of latest technologies and practices which help them to avail more profit. When fish farmers make themselves aware about technologies and practices, it became easy for them to adopt the latest technology and services. Private extension system sees a decline in extent of delivery with an index value of 0.69. Even though the index value is low, their emphasis is on delivering high quality services rather than concentrating solely on quantity, distinguishing them from public extension organisations. Devkota *et al.* (2016) observed that private extension organisations, including agro-vets, equipment vendors, and dealers, have expanded swiftly in response to a supportive political climate and lucrative incentives for selling specialised inputs like fish seeds, feed and aquaculture equipment. Over time, these private organisations have developed strong networks within the farming community, establishing themselves as crucial influencers in promoting and supplying essential resources to fish farmers. Their rapid growth and direct market engagement have enabled them to shape farming practices, particularly by filling gaps left by public extension systems and offering farmers more accessible and customised support options.

Comparing the means of effectiveness of public and private extension systems

The t-test was performed to determine if there were any variations in the average scores of four parameters between public and private extension systems. Based on the findings presented in Table 4, it is clear that there was a significant difference in the mean values of perceived changes in terms of yield and income of the fish farmers between the public and private extension systems. The findings indicated a clear distinction between the private extension system and the public extension systems in terms of the yield and income of fish farmers. Examination of group means highlights that the yield and income of the private extension system (M=0.85) are significantly superior to those of the public extension system (M=0.73) ($p<0.001$).

Table 4 also revealed that the private extension system significantly differed from the public extension system with regard to extent of delivery. An examination of group means indicates that extent of delivery by private extension system (M=0.69) is significantly higher than that of public extension system (M=0.59). The result depicted in Table 5 revealed that the private extension system was significantly different from public extension system with regard to effectiveness. An examination of group means indicated that the effectiveness of extension delivery by private extension system (M=0.76) is significantly higher than that of public extension system (M=0.70). The results presented in Table 6 shows that the mean effectiveness index for public extension system is 0.70, whereas the mean effectiveness index for private extension system is 0.76. Within the public extension system, 21.7% of fish farmers were classified as having a high effectiveness index score, while in the private extension system, 45% of fish farmers fall into the high effectiveness index category. Based on the comprehensive effectiveness index value analysis, it can be inferred that the perceived efficiency of providing fisheries extension services by private extension system surpasses that of public extension system.

The better performance of the private extension system can be attributed to its personalised, timely and market-oriented approach. Frequent contact with extension agents, access to high-quality inputs such as fish seed and feed, targeted advisory services tailored to individual farm conditions, and practical training on improving yield and income collectively enhanced adoption and profitability among farmers. Private extension also provides market linkages and rapid problem-solving support, making it effective for farmers (Prabhakar *et al*., 2019; Chandra *et al*., 2022). In contrast, public extension primarily focuses on awareness generation, community-level training programs and broad-based outreach. Its effectiveness may exceed that of private extension under conditions such as supporting resource-poor or small-scale farmers, promoting sustainable practices across communities, building long-term capacity and leveraging local institutions to expand reach. Enhancing feedback mechanisms, adopting demand-driven approaches and tailoring technologies to local contexts could further improve public extension performance.

Table 4. Comparing the means of public and private extension system

Variables	Public mean	Private mean	Difference between means	t-value	p-value
Extent of delivery	0.59	0.69	-0.1	-2.739**	0.007
Awareness of services	0.81	0.75	0.06	1.483	0.141
Adoption of technologies and practices/services	0.67	0.74	-0.07	-1.235	0.219
Yield and income	0.73	0.85	-0.12	-6.684**	0.001

**p<0.01

Table 5. Overall effectiveness index of public and private extension systems

Overall effectiveness	Mean	Standard deviation	t-value	p-value
Public extension system	0.70	0.15	-1.996	0.048
Private extension system	0.76	0.15		

Regression analysis for factors affecting the effectiveness of private extension system

A comprehensive analysis utilising multiple regression was conducted to identify the factors influencing the effectiveness

Table 6. Comparison of overall effectiveness index of public and private extension systems

Effectiveness	Public extension system (n=60)	Private extension system (n=60)
Mean	0.70	0.76
Standard deviation	0.15	0.15
Categories		
Very low (<0.50)	10(16.7)	8(13.3)
Low (0.50 to 0.59)	20(33.3)	12(20)
Medium (0.60 to 0.74)	17(28.3)	13(21.7)
High (>0.74)	13(21.7)	27(45)

Figures in parentheses indicate percentage to total

of the private extension system in delivering extension services. A regression equation was formulated with perceived effectiveness index scores as the dependent variable and nine independent variables (age, education, experience, size of fish farm, extension contact, extension participation, economic motivation, innovative proneness, and scientific orientation). The results presented in Table 7 revealed that approximately 67% of the variance in the effectiveness of the private extension system could be explained by the included variables, as indicated by a statistically significant R^2 value of 0.67. Additionally, three variables were identified as significant contributors to the effectiveness of the private extension system in providing extension services.

Table 7 illustrates a statistically significant relationship between fish farmers' educational level and their propensity to engage with extension services offered by the private extension system. This finding underscores the positive influence of higher education on the perceived effectiveness of private extension system. Moreover, the data indicates that frequent contact with extension agents significantly enhances the effectiveness of extension system, as regular interactions enable fish farmers to receive timely solutions to various farm-related challenges. Additionally, the innovative proneness of fish farmers was found to be positively correlated with effectiveness of private extension systems. This suggests that a willingness to embrace innovation not only enriches the farming experience but also amplifies the perceived effectiveness of private extension support in the fisheries sector.

Table 7. Regression analysis of the perceived effectiveness of private extension system

Model	Unstandardised coefficients		Standardised coefficients	t-value	p-value
	B	Standard error	beta		
Constant	.005	.272		.020	.984
Age	-.001	.001	-.044	-.482	.632
Education	.010	.003	.307	3.448**	.001
Experience	.000	.003	.003	.035	.972
Size of fish farm	.000	.001	-.036	-.404	.688
Extension contact	.177	.036	.535	4.876**	.000
Extension participation	-.002	.012	-.015	-.151	.880
Economic motivation	-.006	.007	-.076	-.875	.386
Innovative proneness	.029	.008	.345	3.770**	.000
Scientific orientation	.004	.007	.047	.543	.589

R^2=0.67, F ratio=11.279, **p<0.01

Regression analysis for factors affecting the effectiveness of public extension system

The results displayed in Table 8 indicate that around 44% of the variance in the effectiveness of the public extension system can be explained by the variables included in the regression equation, as evidenced by a statistically significant R^2 value of 0.44. Furthermore, two variables were identified as significant contributors to the effectiveness of the public extension system in delivering extension services.

The education level of fish farmers plays a crucial role in their utilisation of extension services. Higher educational attainment often correlates with a greater understanding of practices and the benefits of extension system, leading to increased engagement with these resources. Lower levels of education may hinder farmers' willingness or ability to engage with public extension system, resulting in underutilisation of extension services. Active participation in extension programs empowers fish farmers to make informed decisions, adopt innovative practices, and improve the sustainability and profitability of their operations. Increased involvement in these programs is linked to better management practices, higher productivity, and ultimately enhanced livelihoods for fish farming communities. In contrast to private extension systems, the public extension system attracts a larger number of farmers primarily due to its provision of free services. This cost-free access makes it especially appealing to small-scale and resource-constrained farmers who may not afford private services.

Public extension system mainly focuses on developing the fisheries sector by running awareness camps, training programs and implementing development schemes. In contrast, private extension system prioritises supplying high-quality fisheries inputs and regularly monitoring fish farms to help increase their yield and income. They also have different ways of sharing information; Public extension system relies on group meetings and awareness programs, while private extension system prefers personal contact with farmers. The key factor influencing the effectiveness of public extension system is the change in awareness of fish farmers, while for private extension system; the crucial factor is the change in yield and income of farmers. The findings indicate that private

Table 8. Regression analysis of the perceived effectiveness of public extension services

Model	Unstandardised Coefficients		Standardised Coefficients	t-value	p value
	B	Standard error	beta		
Constant	.001	.326		.002	.999
Age	.002	.002	.138	1.139	.260
Education	.017	.005	.442	3.559**	.001
Experience	-.005	.003	-.182	-1.537	.131
Size of fish farm	.000	.000	.135	1.219	.229
Extension contact	.041	.039	.123	1.048	.300
Extension articipation	.024	.008	.346	3.107**	.003
Economic motivation	-.001	.008	-.022	-.171	.865
Innovative proneness	.013	.009	.169	1.487	.143
Scientific orientation	.003	.011	.030	.235	.815

R^2=0.44, F ratio=4.429, **Significant at 0.01 level of probability

extension performs better in improving yield and income due to its personalised advisory services, on-farm monitoring and access to high-quality inputs. To capitalise on this strength, it is recommended to integrate private sector expertise into public extension programs through public-private partnerships (PPPs), allowing for tailored guidance and direct farm-level support. Conversely, public extension excels in raising awareness but often lacks consistent follow-up and practical engagement. To enhance its impact, feedback loops, hands-on training and targeted interventions should be implemented to ensure that knowledge translates into effective adoption of practices. Adoption of technologies was strongly influenced by farmer education and innovative proneness, highlighting the need to incentivise innovation and leverage digital tools such as mobile advisories, monitoring dashboards and data-driven interventions to encourage early adoption and sustained practice of recommended technologies.

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