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Aquaculture-based production systems for the livelihood security of coastal farm families in the risk-prone agro-ecosystem of India: an appraisal

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Abstract
Sundarban area of West Bengal State in India is a complex-diverse-risk prone agro-ecosystem grappled with degraded soil, water logging, brackish ground water, and marginal farm holdings. South west monsoon rain-fed paddy crop is the major production system, and the farm families have to migrate to other areas for employment during the post-monsoon season. Farm pond-based rainwater harvesting and optimally utilizing it to cultivate vegetables and rearing fish in the pond would provide them employment, income, and self-reliance on a sustainable basis which is the solution. Rainwater harvesting-based production system models, namely, land shaping for aqua-agri integration, brackishwater pond-based polyculture, and paddy-cum-fish farming, were implemented to 370 beneficiary families to enhance the livelihood security at Kakdwip and Namkhana blocks of South 24 Parganas district of West Bengal. A set of 15 indicators were identified by the subject matter scientists to assess the outcome of the interventions in enhancing the livelihood security of farm families. Impact analysis was done using “before vs after” and "control vs treatment" research design. Primary data were collected from 120 proportionate random sample beneficiary farm families using a structured questionnaire and focus group meetings. The findings substantially indicated that all the three farming models have contributed for enhancing the livelihood security levels of the farm families in terms of creation of livelihood asset mainly the farm pond, conservation of natural water for multiple cropping and aquaculture, enhanced capabilities, employment generation, improved production from the land/pond, enhanced income from farming, access to better market price, access to development institutions, minimization of migration during off-season, enhanced self-reliant, and social status of the farm families. The analyses have confirmed that all the three farming models have significantly contributed for the livelihood security of the coastal farm families ($p < 0.01$). Therefore, the study suggested that the government may evolve a scheme with inbuilt subsidy in up-scaling these models in the entire Sundarban region for enhancing the livelihood security of farm families.

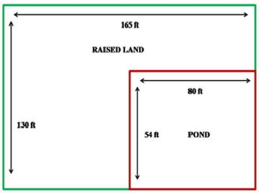
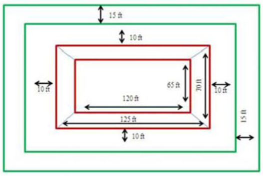
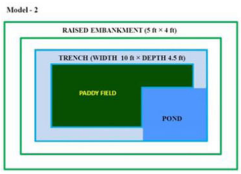
Keywords Rainwater harvesting · Aquaculture · Marginal families · Livelihood security · Agri-aqua integration · Farming systems research and extension

Introduction

Livelihood comprises possession of assets, capabilities and access to activities, and resources to earn a decent income continuously on a sustainable basis to secure the physical, biological, and social needs of a family. Time immemorial fisheries and aquaculture have been a livelihood activity mostly practiced by the disadvantaged marginal fisher/farm families in the coastal deltaic regions (FAO 2012). Aquaculture has been introduced in many parts of the world, especially in Africa and Asia, as a means to improve the standard of living and escape from poverty among the rural communities (Edwards 2000; Ahmed and Lorica 2002; FAO 2012; Mwaijande and Lugendo 2015) and even among the fishers to mitigate the population pressures, environmental degradation or loss of access, and the decline in catches from the wild fisheries (Halwart et al. 2007). Fish farming has been found to be an innovative and economic practice for transforming rural livelihoods (Shava and Gunhidzirai 2017). Sundarban region in West Bengal State of India is one of the vulnerable agro-ecosystems. It receives copious rainfall during the monsoon (June–September), but the ground water is saline due to numerous brackishwater creeks flowing in the region with higher tidal amplitudes and water logging. Monsoon rain-fed paddy is the only crop, and post-monsoon crop is not possible. About 90% of them are marginal farm families with an average land holding of 0.29 to 0.36 ha, and farming contributed around 56% to their income. Farmers are poor with limited resources, and their access to institutions was also limited. Hence, partial migration during post-monsoon in search of employment was prevalent (Mandal et al. 2013; 2015).

Participatory rural appraisal and consultations with researchers, development personnel, and farmers pointed out that rainwater harvesting and optimally utilizing it for irrigation and fish farming would provide employment in the post-monsoon period, income, and self-reliance on a sustainable basis which is the better fit solution to provide livelihood security and minimize migration. Subsequently farm ponds were dug for the following: (a) to utilize the harvested water for supplementary irrigation, fish farming, and cultivating vegetables in the bunds and raised area formed around the pond using the drugged soil; (2) farm ponds for brackishwater polyculture along the creeks; and (3) inland freshwater paddy-cum-fish farming suitable to the locations were taken up with 370 beneficiaries identified through wealth ranking exercise (Swathilekhsmi et al. 2008) in the selected six villages of Kakdwip and Namkhana blocks (Fig. 1). A brief description of the above three interventions is given in Table 1. Critical inputs such as fish seed and fish feed, vegetable seeds, training, linkage with agriculture, and allied institutions and market were done part of the National Agricultural Innovation Project with adequate handholding over a period of 3 years. In the first year, on-farm training and inputs were given from the project, and in the second year, the farmers linked with input suppliers and market with technical facilitation. From third year onwards, the farmers were motivated to operate independently, and the profit earned from the previous crop was used to meet out the operational cost. In this backdrop, the present study was undertaken to assess whether the interventions undertaken has any impact on the livelihood levels of the families sustainably. This appraisal could aid in planning and execution of similar programs elsewhere and render adequate information to convince the policy makers to plan suitable schemes to up-scale these activities in a wider geography as indicated by Anandajayasekeram et al. (2008).

Table 1 Brackishwater aquaculture based livelihood models of CIBA

<table>
<tr><th>Land shaping for Aqua-Agri integration</th><th>Brackishwater aquaculture (polyculture)</th><th>Paddy-cum-fish culture</th></tr>
<tr>
<td>➢ Unit area : 0. 2 ha
➢ Excavation of 1/5th area of the low land up to a depth of 9 feet (Pond size: 90 feet x 30 feet)
➢ Adjoining low land raised up to 1.5 feet. Pond embankment-5 feet wide and 4 feet height and embankment around the area-3 feet wide and 3 feet height.
➢ 6-9 acre inch of rain water can be harvested and stored in the pond.
➢ Alternation or modification of the surface of the land for harvesting rainwater for irrigation, reducing the effect of ground water salinity, reducing drainage congestion and growing multiple crops round the year.
➢The pond was used for rain water harvesting which was used for supplementary irrigation, taking up of additional crop and fish culture.
➢ Fish seeds, feed, vegetable seeds were provided.
➢ On-farm and institutional trainings were conducted.

</td>
<td>➢ Unit area - 0.2 ha
➢ Ponds were dug. The height of the embankment is determined by the tidal height occurring in the area, generally about 30 cm above the maximum flood level.
➢ Sluice gates are constructed in the deepest portion of the farm.
➢ Polyculture of shrimps and fishes were undertaken. Shrimp, Penaeus monodon/P.vannamei at a low stocking density of 3 ps/m^2 and finfish species, Mugil cephalus and Liza tade were stocked in1:3 ratio at a rate of 0.6 no./m^2 and farmers stocked other fishes available.
➢ Quality shrimp and fish seeds were supplied.
➢ On-farm and institutional trainings were conducted.

</td>
<td>➢ Unit area: 0.2 ha
➢ Excavation of 1/10th area of the low land up to a depth of 6-7 feet or peripheral canal with top-6ft*bottom-4ft*height-4ft.
➢ Pond embankment-5 feet wide and 4 feet height
➢ Land embankment around the area -5 feet wide and 4 feet height
➢ 2-3 acre inch of rain water can be harvested and stored in the pond/canal from an area of 1 acre.
➢ The pond was used for rain water harvesting which was used for supplementary irrigation, taking up of additional crop and fish culture.
➢ Fish seeds, feed, vegetable seeds were provided.
➢ On-farm and institutional trainings were conducted.

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Methodology

Framework

Present study adopted Sustainable Livelihoods (SL) Framework with modifications (Fig-2.) as it could provide scope to comprehend the multidimensional impact of extension programs on strengthening livelihoods in terms of enhancing their assets base, activities, and programs responsible and decrease in vulnerabilities (DFID 1999; Christoplos et al. 2001). An impact pathway is an explicit indication of the interrelationships among the activities and their effect on the asset development through which a project will achieve impact (Douthwaite et al. 2003). Using this framework, the major indicators to evaluate the livelihood development were identified.

Identification of indicators

The project team together with the beneficiaries and other stakeholders prepared an exhaustive list of indicators to capture the activities associated with the development of physical, natural, financial, human, and social assets and activities implemented, and utilization of these assets and intended outcomes was prepared. The indicators were grouped against the respective livelihood asset and indicators expressing similar connotations were clubbed and further pruned by a team of scientists. The indicators were further scrutinized for their relevancy, obscurity, and measurement by group subject matter experts. Subsequently, 15 indicators, which had a mean relevancy score of 2.7 and are important to measure the outcome of the interventions vis-à-vis the sustainable livelihood development, were selected. The identified indicators were scored as 3, 2, and 1 based on three-point perception, namely, major extent, moderate extent, and little extent. A mean score for each indicator was arrived by adding the scores of all the respondents and dividing the sum by number of respondents for each indicator for before-and-after situation individually as done by Pandey (2005).

Data collection

The study adopted before-after and control vs treatment research designs to give more authenticity to the results. A proportionate random sample of 120 beneficiaries was selected to collect primary data among the 370 total beneficiary families comprised of aqua-agri integration ($n1 = 60$), brackishwater aquaculture ($n2 = 30$), and paddy-cum-fish culture ($n3 = 30$) beneficiaries. The primary data were collected using a structured and pre-tested questionnaire. Case studies and focus group discussions were also conducted in the village clusters, and the data collected through them were used for data validation and triangulation of the data collected through the survey.

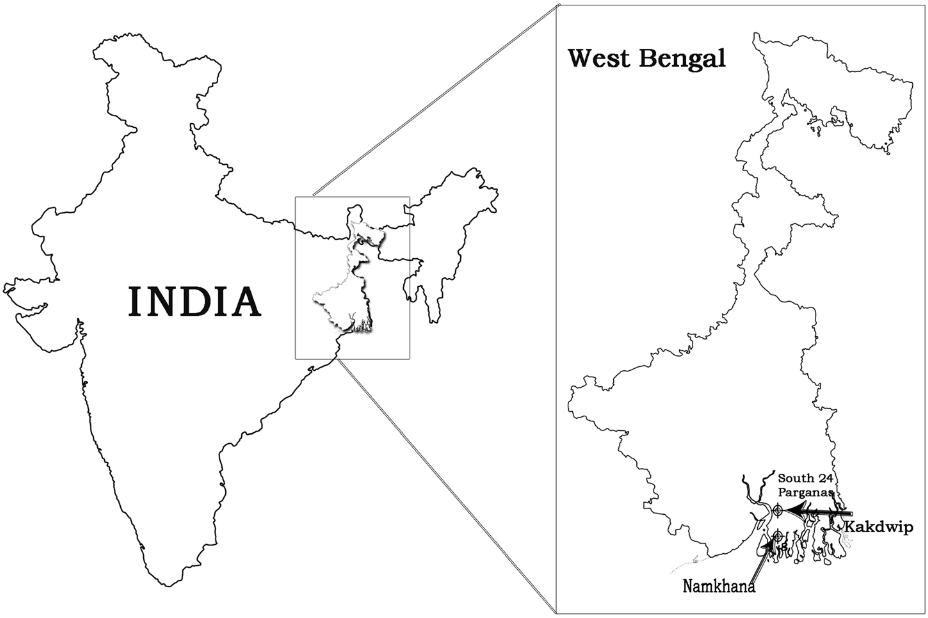

Fig. 1 The study area

Data analysis

The data were analyzed using statistical package SPSS 20.0. Descriptive statistics frequency, mean, and percentage analysis were used to covert the data for inferences. Parametric paired t-test was used to assess the before vs after effects of the interventions implemented for the respective interventions. The results were again corroborated with Wilcoxon test (also known as Wilcoxon signed-rank test) a nonparametric alternative to paired t-test. Similarly, Student's t-test was used to compare the data collected from the control vs treatment data, i.e., beneficiaries and non-beneficiaries.

Results and discussion

The results presented in Tables 2 and 3 indicate that all the interventions taken up have contributed significantly toward the enhanced livelihood security of the farm families. It is seen from Fig. 3 that farm pond-based aqua-agri integration had better economic returns followed by the paddy-cum-fish and brackishwater aquaculture interventions, respectively. It is based on the extent of improvement created by the interventions vis-à-vis prior to their introduction in a unit area taking in to account all the indicators. It was noted that average income per ha of farmland increased by 6–8 times, from Rs.11000–24,000 to Rs.70000–160,000 per annum. The cropping intensity increased from 114% to 240% with the possibility of additional crop cultivation, and the employment generation increased sharply from 85–100 days to 180–240 days in a year after the interventions which have reduced the post-monsoon migration phenomenon to a greater extent. The farm production enhanced with an increased production, post-monsoon vegetable cultivation using the conserved water, and culture of fishes in farm pond. These results corroborated the

Table 2 Summarized impact of livelihood development interventions

Sl.No	Livelihood security indicators	Perceived impact of livelihood interventions ($N = 120$)	
		Before	After
1.	Livelihood asset	Land + migratory labor	Land + farm pond
2.	On-farm conservation of rainwater	Not exist	Created
3.	Cropping intensity	Mono cropping of paddy	Multi-cropping + fish culture
4.	Employment generation in a year	85–80 days	190–240 days
5.	Farm production (0.2–0.3 ha)	Paddy 0.4–0.5 t	Paddy 0.7–1.0 t + .08–1.2 t of vegetables + 100–150 kg of fish (400–500 kg in BW)
6.	Annual income in Rs	11,000–24,000	70,000–160,000
7.	Problem of water logging during rainy season and salinization during the off-season	High	Relatively low
8.	Migratory labur – for employment	Prevalent	Reduced (up to 75–80%)
9.	Knowledge and skill capacity	Low	Relatively high
10.	Women participation in farming	Low moderate	Relatively high
11.	Access to institutions and market	Low	Relatively high
12.	Livelihood security and self-reliance	Low	Relatively high

findings of Mandal et al. (2013) who reported that the proposition of crop-fish integration has been found quite suitable for enhancing the income and employment in the coastal region of India. Sharmi et al. (2012) and Ahmed and Garnett (2011) reported that the Bangladesh farmers have received approximately US$125 increase in their average annual net income after integrating aquaculture in their rice farm. Ahmed and Garnett (2011) found that integrated rice-fish farming can play an important role in increasing food production, as the integrated farming system is better than rice monoculture in terms of resource utilization, diversity, productivity, and both the quality and quantity of the food produced. Importantly introduction of vegetable cultivation and fish culture increased the participation of women in farming operations. The pond water was rich in nutrients due to fish wastes which reduced the cost of production and enhanced the quality of vegetables. Several studies reported similar results elsewhere (Edwards 2000; Uddin and Takeya 2006; Ahmed and Lorica 2002; Noble and Ruaysoongnern 2002). The pond water was rich in nutrients due to fish wastes which reduced the cost of production and enhanced the quality of vegetables. The rainwater harvesting in the farm pond has minimized the water logging as the rainwater is channelized to the pond. The interventions are economically viable because all the three interventions provided an additional income source from the fish culture. The interventions are sustainable because they are economically remunerative, environment-friendly, and socially and culturally acceptable in the region. The farmers are practicing shrimp farming with minimum stocking (extensive culture) density in a polyculture system where fishes were also stocked and this farming has grown in the region considerably. Shrimp farming in polyculture system is sustainable with the adoption of good aquaculture practices. Brackishwater shrimp farming had led to improvement in livelihood security for a section of poor people who had cultivating land along the creeks (Roy 2013). The paddy-cum-fish integration has reduced the use of pesticides in paddy cultivation as the fish acted as predators of insects, enhanced the soil fertility, reduced production cost, and increased the profit and aided in environment conservation in the area. This system is unique in providing carbohydrate and protein products and by conserving biodiversity (Xie et al. 2011) Fig. 3.

On-farm training and interactions with researchers and development personnel during the implementation enhanced the knowledge and skill capacities of the farmers, and many farmers were found to become trainer farmers. Similarly, interactions conducted with development departments during the implementation of interventions at the villages increased their access to development institutions and market to a greater extent. Overall, it was reported that the livelihood assets created and activities undertaken have substantially enhanced the livelihood security levels of the farm families to a greater extent. This made them self-reliant and enhanced the socioeconomic status of the marginal farm families.

It was reported that creation of physical asset of the farm pond to conserve the precious natural water for both fish crop farming through supplementary irrigation was perceived to be major breakthrough in the modules implemented. It provided an additional production system fish farming which contributed to the enhanced per capita fish consumption and family nutritional security. This intervention prevented the water logging and salinization of lands to a possible extent which was a major problem in the area. On-farm water harvesting creates option for multiple cropping including growing fish and also reduces soil and water salinity (Burman et al. 2013). All the three modules contributed to the self-sufficiency in home consumption and family health. Cultivation of vegetables and cash crop like betel vine using the conserved rainwater provided access to better market and access to institutional

Table 3 Impact of aquaculture based modules in livelihood security of farm families

Sl.No	Livelihood security indicators	Aqua-agri integration ($n = 60$)		Brackishwater aquaculture (n = 30)		Paddy-cum-Fish farming ($n = 30$)		Mean value beneficiaries (n1 = 120)	Mean value non-beneficiaries (n2 = 120)
		Before	After	Before	After	Before	After		
1.	Physical asset the farm pond and an additional production system	1.78 ± 0.41	2.78 ± 0.42	1.00 ± 0.00	2.40 ± 0.49	1.67 ± 0.48	2.63 ± 0.56	3.00 ± 0.00	1.60 ± 0.49
2.	Prevention of soil problems through rainwater conservation	1.00 ± 0.01	3.00 ± 0.01	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	2.70 ± 0.46	3.00 ± 0.00	1.00 ± 0.00
3.	Efficient utilization of land through multi-cropping	1.00 ± 0.01	3.00 ± 0.12	1.47 ± 0.51	2.37 ± 0.49	1.00 ± 0.00	2.03 ± 0.46	3.00 ± 0.00	1.02 ± 0.13
4.	Enhanced knowledge and skill capacity	1.00 ± 0.01	2.40 ± 0.49	1.37 ± 0.49	2.47 ± 0.51	1.00 ± 0.00	2.00 ± 0.00	3.00 ± 0.00	1.62 ± 0.49
5.	Employment generation for the family	1.00 ± 0.01	3.00 ± 0.01	2.00 ± 0.00	2.53 ± 0.51	1.00 ± 0.00	2.57 ± 0.54	3.00 ± 0.00	1.33 ± 0.47
6.	Increased production from the land holding	1.00 ± 0.01	3.00 ± 0.01	1.60 ± 0.49	3.00 ± 0.00	1.00 ± 0.00	2.00 ± 0.0	3.00 ± 0.00	1.17 ± 0.38
7.	Balanced diet consumption and improved health status (cereals, vegetables, and fish)	1.82 ± 0.39	3.00 ± 0.01	2.00 ± 0.00	2.00 ± 0.00	2.00 ± 0.00	2.40 ± 0.49	3.00 ± 0.00	2.35 ± 0.48
8.	Increased family income	1.00 ± 0.01	3.00 ± 0.01	2.00 ± 0.00	3.00 ± 0.00	1.00 ± 0.00	2.27 ± 0.45	3.00 ± 0.00	1.13 ± 0.34
9.	Access to premium market	1.00 ± 0.01	2.00 ± 0.47	2.00 ± 0.00	2.30 ± 0.47	2.00 ± 0.00	2.00 ± 0.46	1.38 ± 0.49	1.17 ± 0.38
10.	Access to development institutions and institutional credit	1.00 ± 0.0	1.48 ± 0.50	1.00 ± 0.00	2.00 ± 0.00	1.00 ± 0.00	1.63 ± 0.49	2.23 ± 0.43	1.27 ± 0.45
11.	Prevention of migratory labor	1.00 ± 0.00	2.72 ± 0.45	2.00 ± 0.00	2.50 ± 0.51	1.00 ± 0.00	3.00 ± 0.00	3.00 ± 0.00	1.15 ± 0.36
12.	Enhanced social status with Improved living shelter, access to better health care, quality education for children, vehicle, and communication aids	1.00 ± 0.00	1.73 ± 0.46	2.00 ± 0.00	2.57 ± 0.54	1.00 ± 0.00	1.57 ± 0.50	2.65 ± 0.48	1.68 ± 0.47
13.	Enhanced risk coping ability through improved far infrastructure and savings in the form of gold	1.00 ± 0.00	2.00 ± 0.00	1.00 ± 0.00	2.17 ± 0.38	1.00 ± 0.00	1.67 ± 0.48	3.00 ± 0.00	1.73 ± 0.47
14.	Economic self-reliant and peace of mind	1.00 ± 0.00	2.40 ± 0.49	2.00 ± 0.00	2.57 ± 0.54	2.00 ± 0.00	2.97 ± 0.18	2.63 ± 0.49	1.38 ± 0.49
15.	Self-esteem improvement	1.00 ± 0.00	2.00 ± 0.00	2.00 ± 0.00	2.80 ± 0.41	2.00 ± 0.00	2.67 ± 0.48	3.00 ± 0.00	1.38 ± 0.49
	Overall mean	**1.11 ± 1.00**	**2.63. ±1.68**	**1.69 ± 0.86**	**2.52 ± 2.93**	**1.31 ± 0.66**	**2.57 ± 2.69**	**2.70 ± 0.58**	**1.49 ± 049**
Test of significance (Paired *t*- test for before vs after and students *t*-test for beneficiary vs non-beneficiary)		130.379**		42.871**		44.538**		8.013**	

** Significant at 1% level and confirmed with nonparametric statistic Wilcoxon signed rank test for related samples. ** Significant at 1% level

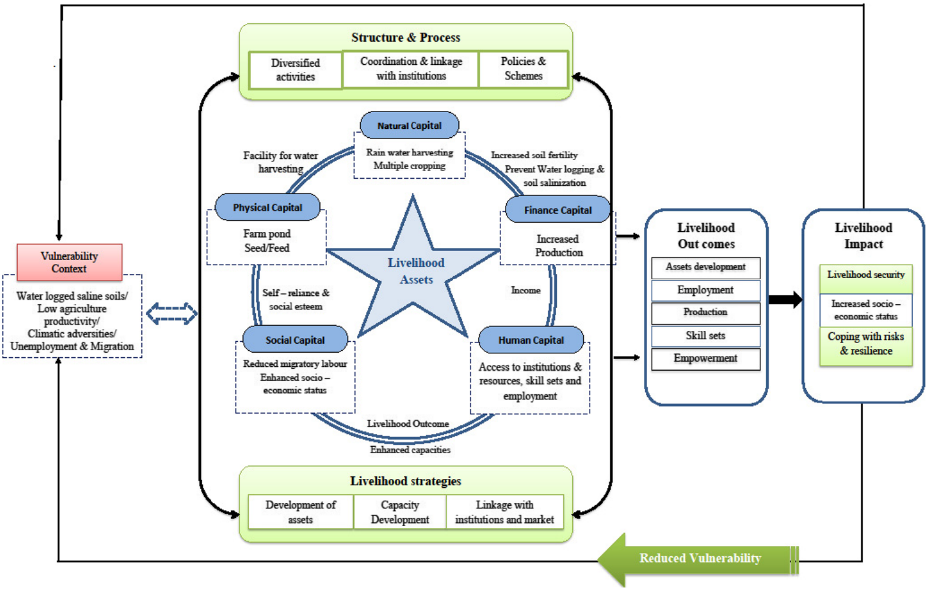

Fig. 2 Modified livelihood Development Framework (adopted from DFID)

credit. Enhanced income from farm ensured better health care by accessing good hospitals, access to quality education for children, own vehicle for mobility, possession of communication aids, improved living, shelter and ultimately investment in gold or land which altogether empowered the farm families and enhanced the risk coping ability. Ahmed and Garnett (2011) have reported that farmers' power has increased than before and had better access to the resources, which includes sanitary, transportation, housing, health services, and communication technologies, all are credited to integrated farming.

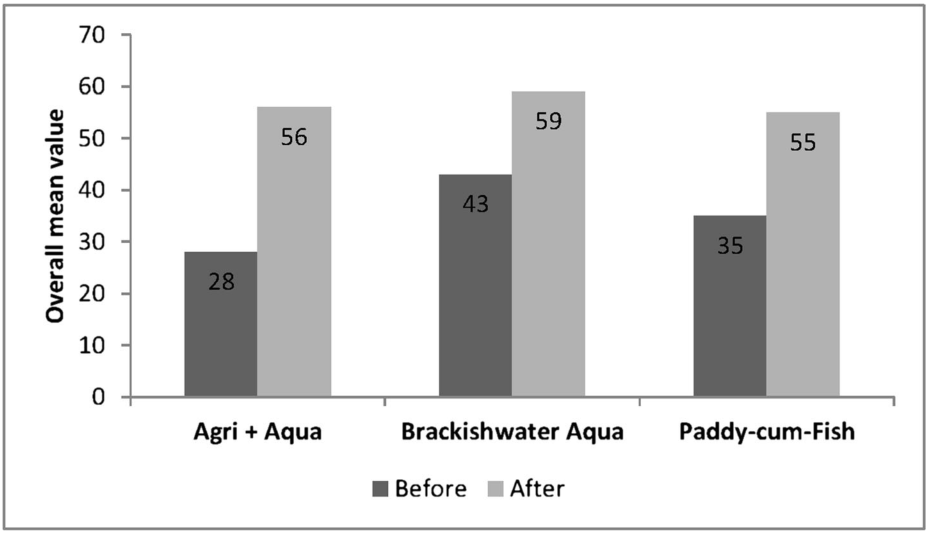

Fig. 3 Summarized impact of livelihood security interventions

Conclusion

The study concludes the following:

- The aquaculture-based livelihood development interventions were proved to be economically viable systems and sustainable. The interventions provided adequate employment and income to the families and reduced the migratory labor to the maximum extent. Further, these modules provided them viable livelihood assets and conservation of rainwater for productive purposes, increased productivity per unit area, assured income and continuous employment, enhanced women participation, and minimized their livelihood risk and vulnerability.
- The rapid expansion of aquaculture in the villages adopted in the recent years was attributed to a large extent to the interventions taken up. Similarly, manifold increase in the production of vegetables in the villages bear testimony to the impact of the livelihood modules implemented.
- These modules positively impacted the marginal farm families with viable livelihood assets, conservation of rainwater for productive purposes, increased productivity per unit area, assured income and continuous employment, enhanced women participation, and minimized their livelihood risk and vulnerability.
- Considering the economic viability of these models, the government may evolve a scheme with inbuilt subsidy in up-scaling these interventions in the entire region for enhancing the livelihood security of farm families in the coastal regions of the country.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with animals performed by any of the authors.

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