Indian J. Fish., 58(4) : 139-145, 2011

Constraint analysis and performance evaluation of participatory agri-aquaculture in watersheds

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ABSTRACT

The present study was undertaken at the watershed level to identify the major constraints in adopting/developing participatory agri-aquaculture and to make technological interventions with low input-based scientific aquaculture practices. The constraint analysis through preferential ranking technique delineated as many as nine constraints with Rank Based Quotient values ranging between 19.05 (priority to domestic use) to 100.0 (lack of awareness and technical knowledge) in all the three study locations. After problem identification, an attempt was made to improve the existing agri-aquaculture practices with community participation. Under the participatory intervention, fish yield was enhanced from 0.26-0.3 t ha^{-1} (before intervention) to 0.94-1.72 t ha^{-1} (after intervention), while the net water productivity of water harvesting structures ranged between Rs. 4.7-5.35 m^{-3}. The return from *rabi* crop was highly encouraging and farmers had additional income. Economic analysis of the interventions clearly showed that the fish culture along with agriculture activity (post-intervention) enhanced the annual income of the farming community by Rs. 3561 - Rs. 12533 per hectare. Further, utilisation of water from the water harvesting structures (WHSs) during *rabi* crop enhanced the cropping intensity from 100 to 137%. As in the present study, scientific approach with low input-based participatory aquaculture and multiple use of water would certainly enhance the overall crop productivity, cropping intensity, water productivity and income.

Keywords: Agri-aquaculture, Constraint analysis, Multiple use, Water productivity, Watershed

Introduction

Participatory watershed management and value addition of water through multiple uses has received special importance in the context of watershed development in recent years. Natural and man-made water bodies in watersheds are the ecological boon for economic development of rural communities. Majority of rural population in India depends on agriculture and allied activities for their livelihood. Despite several programmes/schemes, the expected outcomes of socio-economic development of rural poor have not been witnessed, mainly due to lack of awareness and community participation among the poor. As a result, they not only remain resource deficient but also unable to derive benefits from the public investments. This could be primarily due to lack of focus on livelihood component under the watershed development programmes (Samra and Sharma, 2009).

Therefore, in watersheds, common property resource management has become vital under various schemes. The traditional water bodies like tanks/ponds, wetlands, water harvesting structures (WHS) and the drainage lines are issues of conflicts due to clash of interest among the users (Nanda *et al.*, 2010a). The traditional management mechanism and property right issues got blurred as commercial interest linked to these resources (Nanda *et al.*, 2010b). The emerging scenario of participatory management in the watershed development programmes necessitated common property management and community action. Almost all watersheds possess vast potential for medium and short-duration aquaculture, which can give immediate return to the community. Aquaculture can be integrated into existing farming systems in watersheds to enhance rural employment and income because of additional and off-seasonal production activity, improved food security and reduced risk due to diversification (Mohanty and Ghosh, 2009). Aquaculture can also improve water availability and nutrient recycling and provide environmental benefits. A well-planned aquaculture development program thus has the potential to create new jobs, improve food security among poor households, remove variability in terms of household income flow, and increase farm level efficiency, and sustainability (Kaliba *et al.*, 2007).

However, the concept of participatory aquaculture has not reached the resource-poor farmers in the watershed regions due to lack of awareness, problems in water conservation and management, and conflict between users.

Hence, it is imperative to develop awareness towards low-input aquaculture on participatory basis and encourage multiple use of the available water for higher productivity and income. No programme, whatever be its technical excellence, will succeed unless the people are (a) convinced of its necessity, (b) participate in it willingly, and (c) assume responsibilities, including partial sharing of its cost in cash or kind (Samra and Sharma, 2009). In this backdrop, a study was undertaken at the watershed level under different agro-climatic conditions in Odisha state to identify the major constraints in adopting/developing participatory agri-aquaculture in watersheds and to undertake technological intervention with low input-based scientific aquaculture practices.

Materials and methods

Problem identification at three different watershed sites (mid-central table land: Dhenkanal district; east and south-eastern coastal plains: Ganjam district and north-central plateau: Keonjhar district) was carried out. Subsequently, an attempt was made to improve the existing aquaculture practices with community participation during the year 2006-07 and 2007-08. One WHS at each site was selected for this purpose and farmers were motivated to participate in this intervention as a group. Data on pre-intervention agri-aquaculture practice were collected for all the three sites prior to present intervention.

Strength Weakness Opportunity and Threat (SWOT) analysis

In most of the watersheds, it is observed that though there exists a potential for community aquaculture, most of the water resources (large, medium and small water bodies / WHSs) are unutilised or underutilised. To provide an overall picture of the potential strengths (S), weaknesses (W), opportunities (O) and threats (T) in watershed aquaculture, SWOT analysis with the participation of farmers/resource users was carried out for the three different watersheds.

Constraints prioritization

The SWOT analysis has helped in listing out the constraints that restrict aquaculture development in watersheds. The listed constraints were then quantified through Rank Based Quotient (RBQ) technique (Nirmala *et al*., 1998; Ghosh *et al*., 2003) following various steps such as identification of key informants, identification of farmers/users, quantification of data and calculation of magnitude value of the constraint and final ranking. A sample of 20 farmers and 5 key informants (watershed development team members, watershed committee office bearers) were selected as respondents to derive final RBQ value for each of the identified constraints under each of the watersheds studied. Thus, responses of a total sample of 60 farmers and 15 key informants were collected in the present study. Lower the mean rank value of the constraints, higher was the severity of the problem with higher RBQ value.

Rank Based Quotient (RBQ) was calculated for each constraint with the formula:

$$RBQ = [S\ Fi\ (n+1-i) / N\ n] \times 100$$

where, F_i is the frequency of farmers for the i^{th} rank of constraint; N and n denote the total number of respondents and total number of constraints identified, respectively.

Technological intervention

The long-duration (150 days) rice variety *Swarna* (MTU 7029) was transplanted in the 3^{rd} week of July in all the study sites for two years. Rice was cultivated by following the standard practices (ICAR, 2006) and three seedlings were transplanted with a spacing of 20 cm X 15 cm. The fertilizer application rate was 80 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1}, and 40 kg K_2O ha^{-1} through urea, single super phosphate (SSP), and muriate of potash (MOP), respectively. Fifty per cent of the N and the full dose of P and K were applied as basal dose at the time of transplanting. The remaining nitrogen was applied in two equal splits during tillering and panicle initiation stages, 30 and 60 days after transplanting (DAT). Grain yield and yield attributes of crops were recorded at the time of harvest. Crops in an area of 5 m^2 from each replication were harvested excluding the border effect for determination of yield per unit area and the test weight (1000-grain weight) at 14.5% seed moisture content. Yield components like number of panicles per unit area and number of filled grains per panicle for each replication were determined. Other than rice, standard agronomic practices were also followed (ICAR, 2006) for brinjal, ladies finger, potato and black gram, which were grown in the adjacent areas using water from the WHSs.

Pre-stocking preparation of WHSs for aquaculture included horizontal and longitudinal ploughing followed by the application of lime ($CaCO_3$) at 750 kg ha^{-1}, raw cattle dung (RCD) at 7000 kg ha^{-1} as a basal dose and fertilizer (Urea: Single Super Phosphate, 1:1) at 3 ppm rate. Seven days after pre-stocking preparation of WHSs (during 3^{rd} week of July), fish fingerlings (23.0 - 25.8 g mean body weight) were stocked at the rate of 5,000 per ha with the species composition, 25:35:40 (*Catla catla*: *Labeo rohita*: *Cirrhinus mrigala*) in all the three selected WHSs. Area (ha) of the WHSs were 1.39, 0.60 and 0.16 respectively for site-I, site-II and site-III. Supplemental feeding was provided at the ratio of 55:35:10 (rice bran: groundnut oil cake: fish meal) at 5%, 4%, 3% and 2.5% of mean body weight, twice a day, during 1st, 2nd, 3rd and 4th month to harvesting, respectively. Periodic manuring with raw cattle dung at the rate of 500 kg ha^{-1} and liming at 200 kg ha^{-1} was carried out in the WHSs at 15 days interval to maintain plankton population in the ecosystem. Fish rearing continued for 180-210 days depending upon the water availability. Fortnightly physico-chemical parameters of water were monitored *in-situ* using standard methods (APHA, 1995). Fortnightly growth study was carried out by sampling prior to feeding so that complete evacuation of gut was ensured. Mean body weight (MBW), per day increment (PDI), survival (SR%), biomass (kg), feed requirement, percentage of feed, feed requirement per day and apparent feed conversion ratio (AFCR) were estimated at fortnightly intervals as described by Mohanty (2004). Economic indices of water productivity (Rupees m^{-3}) was estimated as suggested by Boyd (2004).

Results and discussion

Strength Weakness Opportunity and Threat (SWOT) analysis

SWOT analysis for assessing the potentiality of watershed aquaculture is presented in Table 1. Availability

Table 1. SWOT analysis for assessing the potentiality of watershed aquaculture

Strength	• Availability of natural/ man-made water resources with potential for aquaculture
	• Availability of unutilized/ underutilized human resources
	• Availability of agricultural and livestock wastes and cheaper fish feed ingredients
	• Availability of location and resource specific aquaculture technologies
	• Accumulation of nutrient rich organic matter in the water bodies from catchments
Weakness	• Poor group organisation among users due to personal disputes
	• Lack of visionary/ capable community leader
	• Multiple-water rights for irrigation, domestic purposes and other uses
	• Unaware of 'common property resource management'
	• Lack of interest in 'participatory aquaculture' due to multiple-ownership
	• Conflict among user groups: agriculture *vs.* aquaculture
	• Weak research-extension linkage and poor cooperation among operational agencies
	• Lack of technical awareness and commitment of farmer/ users
	• Poor training facilities at the grass root level
	• Ambivalence towards the involvement of women
	• Lack of material input and credit facilities
	• Non-availability of fingerlings in time
	• High feed cost
	• Not one man's job: Group formation is required
	• Low water depth in summer
	• Poor marketing facilities
Opportunity	• Multiple use management of available nutrient-rich water bodies/ WHSs, utilization of underutilized human resources and waste materials for multi-commodity production at one place in order to enhance the land and water productivity
	• Landless and resource poor farmers will have the opportunity in involving participatory aquaculture, integrated farming, value addition and processing
	• Increased aquatic productivity, social equity, food and employment security, equity in income and environmental sustainability
	• Participatory learning and empowerment of users and women.
	• Minimal migration in search of job
Threat	• Unutilized water bodies will promote water quality deterioration and weed infestation which facilitate mosquito breeding that may cause health hazards
	• Unemployment, labour migration, food insecurity, reduced per capita income
	• Non-recycling of agricultural and livestock wastes
	• Less opportunity for participatory learning and empowerment of users and women
	• Scope for integrated farming and value addition will be lost.

of natural/ man-made water resources with nutrient rich organic matter suitable for aquaculture, availability of human resources for aquaculture practices, cheaper feed ingredients, location and resource specific scientific technologies are some of the strengths for aquaculture in the watersheds. Lack of leadership, group mobilization, conflict, multiple water-use disputes, poor forward and backward linkages are existing bottlenecks for watershed aquaculture. However, scientific multiple use management of existing water bodies and involvement of resource poor farmers in participatory aquaculture would provide enhanced income, diversified livelihood as well as provide employment opportunity which would aid in lowering migration and achieving social equity. Threats of water quality deterioration and weed infestation in existing water bodies, non-recycling of agricultural and livestock wastes and above mentioned unemployment and labour migration in the watersheds can be addressed through promotion of participatory watershed aquaculture integrated farming.

Peoples' involvement in watershed aquaculture through group approach ensures 'economic benefits' such as increase in land and water value, yield, enterprise development and demand of labour; 'social benefits' like greater self-confidence, fewer conflicts over resources, reduced out-migration, and a new rapport between local people and external professionals; 'environmental benefits' such as maintaining water quality, recycling of agricultural and livestock wastes, reduced weed infestation in water bodies and use of fertilizers and pesticides. Under the watershed development programmes, apart from natural resource management, policy focus is also on livelihood security, equity and institutional development. In this context, integrated farming, emphasizing aquaculture in the watershed would ensure diversified livelihood options and enhanced income. Positive impacts in the watersheds in terms of empowerment of the stakeholders including the womenfolk would be ensured through intervention of participatory aquaculture based integrated farming system. In the study an watershed, there are 39 water bodies available, of which 23 water bodies suitable for aquaculture are presently not being utilized by the beneficiaries. Therefore, the utilization of available water in the created and existing water bodies through aquaculture would provide the opportunity for enhancing water productivity fulfilling the goal of more yield and income per drop of water.

Constraints

The constraint analysis through preferential ranking technique delineated as many as nine constraints. They were: (1) lack of awareness and technical knowledge, (2) high feed cost, (3) low water depth in summer, (4) lack of interest, (5) not one man's job, (6) priority to domestic use, (7) non-availability of fingerlings in time, (8) agriculture *vs.* aquaculture and (9) No emergency assistance. The mean rankings given to these problems by different key informants and the farmers/ users are indicated in Table 2. Based on the ranks, given by the key informants and the farmers/ users, RBQ was calculated for each constraint. The calculated RBQ values ranged between 19.05 (priority to domestic use) to 100.0 (lack of awareness and technical knowledge). Lower the mean rank value of the constraints, higher was the severity of the problem (Table 2). Pooled response of farmers/ users in these three sites of Odisha pointed out the first five constraints in watershed aquaculture as (a) lack of technical knowledge and awareness towards participatory aquaculture, (b) it is a group job and not one man's activity, (c) non-availability of fingerlings in time for higher survival and return, (d) conflict between user groups: agriculture *vs.* aquaculture

Table 2. Constraint/problem identification in watershed aquaculture under three different agro-climatic zones of Orissa (n = 75)

Constraints	Site-I (Ganjam)		Site-II (Dhenkanal)		Site-III (Keonjhar)	
	Mean rank of the constraints	RBQ	Mean rank of the constraints	RBQ	Mean rank of the constraints	RBQ
Lack of awareness and technical knowledge	1.19 (1)	97.92	1.19 (1)	97.92	1.00 (1)	100.0
High feed cost	5.38 (6)	51.39	5.06 (6)	54.90	7.11 (7)	32.10
Low water depth in summer	5.25 (5)	52.78	6.24 (7)	41.83	2.33 (2)	85.19
Lack of interest	6.00 (7)	44.44	5.00 (5)	55.56	7.63 (8)	26.39
Not one man's job	2.67 (2)	76.39	2.29 (2)	85.62	3.11 (3)	76.54
Priority to domestic use of water	8.17 (9)	20.37	8.29 (9)	19.05	8.00 (9)	22.22
Non-availability of fingerlings in time	3.69 (3)	70.14	3.76 (3)	69.28	5.00 (5)	55.56
Agril. *vs.* Aquaculture	4.06 (4)	65.97	4.06 (4)	66.01	3.67 (4)	70.37
No emergency assistance	6.56 (8)	38.19	6.47 (8)	39.22	6.11 (6)	43.21

Figures in parenthesis indicate ranking of constraints/problem and (e) low water depth in summer: no idea of short-duration aquaculture.

Technological interventions

After problem identification at three different watershed sites, an attempt was made to improve the existing agri-aquaculture practices with community participation. In all the three sites, the existing agricultural cropping pattern in the *Kharif* was followed while, *Rabi* crop was introduced for the first time at Ganjam (site-I) and Keonjhar (site-III) utilizing water from the WHSs. Though *rabi* crop (paddy only) was already in practice at Dhenkanal, instead of paddy, vegetable crop was introduced during the intervention phase. Apart from fish culture, water of WHSs was judiciously utilized for *rabi* crop at all the three sites as life saving irrigation. Under this community participation-based intervention, fish yield (Table 3) enhanced from 0.26-0.3 t ha^{-1} (before intervention) to 0.94-1.72 t ha^{-1} (after intervention), while the gross and net water productivity of WHSs ranged between Rs. 9.46-10.33 and Rs. 4.7-5.35 respectively. The operational cost includes the cost of feed at Rs. 24.00 per kg; fish seed at Rs.500.00 per 1000 advanced fingerlings; raw cow dung at Rs. 500.00 per 1000 kg; labour at Rs. 100.00 per man day; lime at Rs. 9.50 per kg and other costs (plant material, fertilizer *etc*.) while the farm gate selling prices of rice, brinjal, ladies finger, potato, black gram and marketable fish were 7.00, 7.50, 8.00, 3.50, 35.00 and 60.00 rupees Rs.kg^{-1} respectively. This water productivity reflects the objectives of producing more food, income, livelihood and ecological benefits at less social and environmental cost per unit of water consumed. Higher water productivity reduces the need for additional water and land resources in rain-fed systems (Kassam *et al*., 2007; Molden *et al*., 2009).

Factors influencing the intensification of fish farming technology

In this community based agri-aquaculture, it was mainly relative profitability and technical support that motivated the group to undertake low input-based scientific aquaculture. However, a study in Tanzania reveals that the factors that influence the intensification of fish farming technology are mainly age, religious faith, knowledge of fish farming, relative profitability, relative marketability, relative risk, relative palatability and relative easiness to obtain farmed fish (Wetengere, 2010). The return from *rabi* crop was highly encouraging and was an additional income for the farmers (Table 4). Economic analysis of the intervention clearly infers that growing vegetable in *rabi* is more profitable than growing paddy or pulses (Table 5). Fish culture along with agriculture activity (post-intervention) enhanced the annual income of the farming community by Rs. 3561 in site - I to Rs. 12533 in site - II per hectare (Table 5). Further, utilisation of water from the WHSs during *rabi* crop enhanced the cropping intensity from 100 to 133%, 100 to 137% and 100 to 129% at site - I, site - II and site-III respectively. In this intervention, the benefits of multiple use water (WHSs) go far beyond the benefits to individual households as evident from higher productivity and income of the groups. Systems that cater to multiple uses are also more likely to be sustainable, because users benefit more from them, have a greater stake in them, and are more willing and better able to pay for them (Senzanje *et al*., 2008). In Asia, a wide

Table 3. Aquaculture scenario in selected watersheds

Study site	Area of WHS (ha)	Status before intervention	Status after intervention	Apparent FCR
Site-I, Ganjam	1.39	Fish yield: 370 kg @ 0.26 t ha^{-1}	Fish yield: 1310 kg @ 0.94 t ha^{-1}	1.44
Site-II, Dhenkanal	0.603	Fish yield: 180 kg @ 0.3 t ha^{-1}	Fish yield: 1040 kg @ 1.72 t ha^{-1}	1.53
Site-III, Keonjhar	0.16	No aquaculture activity	No return due to heavy rain, overflow and structure damage	-

** Stocking density was 5000 fingerlings per ha*

Table 4. Agricultural crop scenario and comparative crop yield before and after intervention, utilizing water from the WHS

Site	Before intervention			After intervention		
	Crop productivity	Area coverage	Yield (t)	Crop productivity	Area coverage	Yield (t)
I	*Kharif* paddy @ 2.3 t ha^{-1} *Rabi* : No crop	40 ha	92	*Kharif* paddy @ 2.35 t ha^{-1} *Rabi* pulses @ 0.26 t ha^{-1}	40 ha 20 ha	94 5.2
II	*Kharif* paddy @ 2.7 t ha^{-1} *Rabi* paddy @ 1.6 t ha^{-1}	2.5 ha 1.0 ha	6.751.6	*Kharif* paddy @ 2.8 t ha^{-1} *Rabi*: Brinjal @ 5.2 t ha^{-1} L.Finger @ 4.4 t ha^{-1}	3.0 ha 0.6 ha 1.2 ha	8.4 3.12 5.28
III	*Kharif* paddy @ 2.2 t ha^{-1} *Rabi* : No crop	1.7 ha	3.74	*Kharif* paddy @ 2.9 t ha^{-1} *Rabi*: Potato @ 8.8 t ha^{-1}	1.7 ha 0.5 ha	4.93 4.4

Table 5. Economic output (Rs.ha^{-1}) of aquaculture and agriculture practices before and after the intervention

Site	Crop	Before intervention		After intervention		Intervention impact
		Gross Income	Net income	Gross Income	Net income	Net benefit (Rs.ha^{-1})
I	*Kharif*	16096	5432	17796	7434	2002
II		18728	8548	33600	17555	9007
III		15400	4086	20300	8172	4086
I	*Rabi*	-	-	9100	5120	5120
II		11200	3840	36466	18000	16060
III		-	-	30800	17600	17600
I						3, 561
II		Net enhancement in annual income per hectare (*Kharif* + *Rabi*)				12, 533
III						10, 843

range of integrated agriculture-aquaculture (IAA) systems are in use and are mainly practiced in Bangladesh, China, India, Indonesia, Malaysia, Thailand and Vietnam. IAA farming systems, with aquaculture as a major or minor component differ greatly from extensive or intensive fish farms that are stand-alone enterprises. As stand-alone fish farms are risky ventures and are not an option for resource-poor farmers (Prein, 2002), integrated agriculture-aquaculture seems to be a viable option in watershed development in developing countries.

A number of recommendations can be drawn from this study regarding the intensification of agri-aquaculture in watersheds. Firstly, there is a need to provide extension education to the practicing farmers on various aspects of agri-fish farming. Secondly, efforts should be made to improve the profits of fish farming through use of low cost inputs, integrating fish farming with other crop components, shortening production cycle, and rearing of advanced fingerlings that grow faster. Thirdly, efforts should be made to improve marketing of produce through providing information on prices and nutritional value among vulnerable groups, improving roads to access urban markets to get higher profits, formation of marketing groups, provide information on preservation and storage. Fourthly, efforts should also be made to reduce risk associated with fish farming and agriculture. As in the present intervention study, scientific approach with low input-based culture, community participation and multiple use of water would certainly enhance the overall crop productivity, cropping intensity, water productivity and income. In participatory agri-aquaculture management; socio-economic, cultural, political and environmental conditions of the community members should be considered for sustainable, profitable, equitable and compatible development of watershed agri-aquaculture. Their active and dedicated involvement in decision-making, planning, technology implementation, and management will not only promote aquaculture and agriculture in watersheds but also ensure employment, income and food security.

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Date of Receipt : 22.07.2011
Date of Acceptance : 22.10.2011