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Transformation of Multiple Use Water Bodies for Freshwater Aquaculture — Determinants of Technology Adoption and Collective Action: A Study in Odisha

Nagesh Kumar Barik

Central Institute of Freshwater Aquaculture, Kausalyaganga, Bhubaneswar-751 002, Odisha

Abstract

Expanding aquaculture to the non-conventional water resources like multiple use water bodies is a challenge. Involvement of multiple users and diverse stakeholders make access, negotiations, management a difficult task. Under this situation adoption of technologies governed by diverse factors operating at resource, community and household levels is a challenge. This paper has econometrically determined the factors contributing positively or negatively to the adoption process. The research conducted among multiple use water resources in the state of Odisha during 2010-2012, has shown that the factors like better physical environment, higher size of water bodies, government support, collective action, effective leadership, and higher dependence for livelihood contribute positively to the adoption of aquaculture. On the other hand, the factors like weed infestation and very old ponds contribute negatively. These findings may have implications for devising policies for integration of aquaculture in the non-conventional aquaculture resources like multiple use water bodies in the country.

Key words: Multiple use water bodies, aquaculture, adoption, community management, livelihood, Odisha

JEL Classification: Q16, Q22

Introduction

In India, the inland fisheries which included aquaculture, has grown at the rate of 5.1 per cent during the past 50-year period, 1961-2011. Despite such a growth, the price of the fishes has been increasing at the rate of 7 per cent per year in the recent times contributing to food inflation. During April 2010 to October 2011, eggs, fish, meat, milk and fruits have together contributed more than 40 per cent to food inflation (MoA, 2012). The changing pattern in consumers' demand as well as the need to use the available fisheries resources drive the transformation of fisheries sector in India. Since independence, the use of all available resources for fisheries development has been a prime objective of the national policy (Alikunhi, 1957); consequently, the production of the inland fisheries has grown from 0.75 million tonnes (Mt) in 1950 to 5.71 Mt in 2012-13 (DAHD&F, 2014). Freshwater aquaculture constitutes more than 85 per cent of the inland fisheries and hence, the growth of this sector holds the key for meeting the demand for fish in the country.

The large portions of the unused water bodies are in the form of ponds, tanks, traditional water bodies, water harvesting structures, minor irrigation structures, etc. which are mostly used for multiple purposes. There is competition for these water resources for uses like agricultural irrigation, drinking water supply, sanitary use, livestock watering, hydroelectric power generation and fisheries. From the fisheries perspective, all such water bodies together can be categorized as small multiple use water resources (MAR) which separate out the large water bodies like reservoirs and rivers

Email: nageshbarik@hotmail.com

used for the capture or culture based fisheries (Sugunan, 1995; Sugunan and Sinha, 1997) and private single-use water bodies. The integration of aquaculture use into the water bodies adds significant value per cubic metre of water use (Dugan *et al.,* 2007), even a low intensive fish culture has great potential benefits in terms of income, employment and quality protein consumption of poor households (Ahmed, 1999; Ahmed and Loria, 2002). Several social benefits are foregone due to low level of adoption of the aquaculture technology.

In the past, serious efforts have been put through training, motivation and demonstrations by the research institutes and development agencies to encourage aquaculture in the multiple use water bodies. The All India Coordinated project on composite fish culture during 1971-1984, IDRC- Rural Aquaculture project during 1975-1978, adopted village of Krishi Vigyan Kenda of CIFA, demonstration projects of FARTC of CIFRI and CIFA have demonstrated the fish production level of more than 3 t/ha/year in many of these ponds. All these cases presented the successful adoption of technology, high production level, community participation and high level of social benefits. Numerous studies have reported the success in terms of the physical, social, nutritional and livelihood improvement in these villages (CIFA, 1990; 1996; 1998; 2004; 2011; Radhesyam, 1998; Randhir, 1998). In these water bodies on an average , 38 - 64 families were benefited with fish production level of 2.8 - 4.4 t/ha up from 0.27 to 0.40 t/ha in the pre-adoption stage. The average size of the ponds varied from 0.3 ha to 3.5 ha.

Despite successful case of technological and social development and considerable capacity building of the villagers involved in aquaculture, most of them failed to sustain after withdrawal of support. Now most of these ponds have retuned back to the old stage of dereliction, weed chocked or wasteland scenario (CIFA, 2011; Radhesyam, 1989; Radhesyam *et al*, 2011). A survey conducted by CIFA during 2008-2010 found that most of these ponds were poorly managed without replication of past successes (CIFA, 2011). In the absence of outside support, most MAR are in dire state of degradation and dereliction, leading to wastage of vital resources which raised the question of sustainability of aquaculture in multiple use water bodies.

The supply of the technology is a necessary but not the sufficient condition for the adoption of technology in the complex socio-ecological system like MAR. The MAR held as common pool resources has great potential, but the issues like access, management, conflict resolution, etc., require negotiations and engagement with the diverse actors and stakeholders (Ostrom, 1990; Ostrom, *et al*., 1994) are the critical areas in the management of these resources. The adoption of technology is fundamental to the improvement of aquaculture productivity but is constrained by complex socio-ecological system settings. A large number of social and institutional factors play a role in the adoption of technology.

Limited studies have been conducted so far on the factors determining the adoption of aquaculture technologies in the multiple use water resources. Therefore, the present study was carried out to identify the reasons for adoption (non-adoption) of aquaculture technology in the small multiple use ponds. Understanding the dynamics of socio-ecological system will provide an insight into the large governance and policy issues that need to be tackled in future.

For study, the state of Odisha was selected because it is rich in water resources as around 11 per cent of the total water resources of the country are available through eleven river basins. The fresh water resources of the state are estimated to be 6.71 lakh ha with a break-up of 1.20 lakh ha of ponds/tanks, 2.00 lakh ha of reservoirs, 1.80 lakh ha of lakes, swamps and jheels and 1.71 lakh ha of rivers and canals. (DoF, 2009).

Despite richness in the water resources, the fisheries and aquaculture sector in Odisha has not realized its full potential. In 2010-11, the state produced about 0.38 Mt of fish (0. 25 Mt from inland and 0.13 Mt from marine sources). The inland production included 0.22 Mt from fresh waters and 0.03 Mt from brackish waters. The per capita consumption of fish has appreciably increased in the state from 7.3 kg in 1999-2000 to 9.3 kg in 2010-11, which is still less than the recommended level of 11 kg. To fill the gap, about 0.1 Mt of fresh fish water fishes are imported every year from the neighbouring states.

Beyond these aquaculture resources, there is a vast stretch of water resources which are not recognized as aquaculture resources because of their multiple-use in nature. These small multiple-use water resources

(MAR) consist of diverse category of resources like traditional water bodies, micro-irrigation, water harvesting structures, tanks, ponds etc. which are held as common pool resources. These have a total area of about 143 thousand ha, which is about 76.3 per cent of total multiple use water bodies (188 thousand ha) available in the state. The present paper deals with the adoption of aquaculture technologies in these water bodies. Scope of the study is confined to water bodies of less than 40 ha to differentiate with the capture and culture based fisheries resources.

Data and Methodology

The study is based on the survey conducted during 2010-2012 among these water bodies in two regions of Odisha, viz., Coastal (Puri and Khorda districts) and Interior (Nuapada and Bargarh districts). These two regions fall into two distinct agro-climatic zones of the East Coast Plain and Hills (EG) and Eastern Plateau and Hills (EHg,), respectively, as per Planning Commission of India (Anon, 1989). The study has used three levels of data collection, viz. village level, resource level and household level. A total of 83 water bodies from 62 villages were sampled and about 5-6 households depending on the resources, were also sampled. For development of statistical model, 62 villages with one resource from the village and one household were selected randomly.

To determine adoption of technology, two distinct variables taken as target variables were: stocking and feeding. In technology adoption studies, the dependent variable is the decision to adopt an improved aquaculture technique (Ahmed *et al.*, 1995). For empirical model, stocking and feeding were taken as two dependent variables for which two separate models were developed. In this case, the aquaculture adoption variables (stocking and feeding) were discrete-dichotomous variable (users of MAR are either adopters or non-adopters). For studying aquaculture adoption the logit models are widely used (Ahmed *et al.*, 1995; Adeogun *et al.*, 2008). In this study also, the logit model was fitted for both technology components, viz. stocking and feeding.

The specification of the logit model is as follows:

$$P_i = \text{Probability}\,(F_i = 1) = \frac{\exp(z)}{1+\exp(z)} \quad \ldots(1)$$

where, P_i denotes the probability that the *i* th MAR would adopt technology (Stocking/ feeding) (F_i = 1) and

$$Z = \beta_0 + \sum_i^m \beta_i X_i$$

where, β_0 is the intercept, β_i is a slope parameter in the model, and *Xi* is an independent variable.

Results

Determinants of Stocking in Multiple Use Water Bodies

A total of 62 samples were studied and a large number of variables across village, resources and household levels were screened to find the contributing factor to the model. Only six factors were found to be important in determining the adoption of stocking of seed in the water bodies (Table 1). In general, 54 out of 62 samples reported stocking and model was able to predict 95 per cent of the cases (Table 2).

Three community level variable, viz., history of collective action in the village, presence of specific leader in aquaculture and community management of the aquaculture were found to determine positively the adoption of stocking. The villages with greater cooperation and the presence of a leader provided conducive social environment for the people to come together in the community mode of management. The level of dependence on the fisheries for livelihood was also found to have a positive coefficient and people with higher dependence put efforts in stocking seeds. The area of the water bodies was also found to have a positive coefficient as large water bodies stocked more compared to smaller water bodies. The water resources under the study were small, but within it very small water bodies were not stocked (Table 3).

The weed infestation was measured through five-point scale in the order of infestation with clean (0.1), few weeds (0.2), half of the area covered (0.5), mostly covered (0.75) and fully covered (1.0). The variable was found to contribute negatively to the stocking. The high score of weed level was indicative of poor environmental conditions, whereas in the clear and few weeds, the possibility of stocking was more. In other words, stocking was adopted in the ponds with less weeds (Table 3).

Table 1. Variables in the model on determinants of stocking (Model 1)

Variables	Values	Unit	Non-adoption	Adoption	Total
History of collective action in village (dummy variable)	No (0)	N	6	31	37
	Yes (1)	N	2	23	25
Presence of specific leader in aquaculture (dummy variable)	No (0)	N	6	20	26
	Yes (1)	N	2	34	36
Level of weed infestation (ordinal variable)	Fully weed choked (0.1)	N	3	4	7
	Mostly weed choked (0.2)	N	3	14	17
	Half weed chocked (0.5)	N	0	14	14
	Few weeds (0.75)	N	2	15	17
	Clean (1)	N	0	7	7
Level of dependence of users on aquaculture for livelihoods	100% (5)	N	0	1	1
	75% (4)	N	0	2	2
	50% (3)	N	0	10	10
	25% (2)	N	1	8	9
	Marginal (1)	N	4	25	29
	No dependence (0)	N	3	8	11
Community based management (dummy variable)	Others (0)	N	4	20	24
	Community (1)	N	4	34	38
ln area of pond in acres (continuous variable)		Mean	0.29	0.73	0.67

Table 2. Prediction of logistic model of adoption of stocking in aquaculture (Model 1)

Variable	Observed	Predicted	Percentage of correct prediction
Stocking (no)	8	6	75.0
Stocking (yes)	54	53	98.1
Total	62	59	95.2

Table 3. Logistic regression of adoption stocking in aquaculture (Model 1)

Dependent variable: Stocking

Variable	B	Wald	Significance
History of collective action in village	5.426	4.678	.031
Presence of specific leader in aquaculture	9.210	5.663	.017
Level of weed infestation	-7.985	4.563	.033
Level of dependence of household on fisheries	1.964	3.758	.053
Community dummy (community management-1, others-0)	5.756	4.137	.042
ln (area of water bodies in acres)	2.795	4.503	.034
Constant	-5.603	3.131	.077
Chi-square	31.18		
DF	6		
Significance	0.000		
-2 log likelihood	16.509		
Cox & Snell R^2	0.395		
Nagelkerke R^2	0.736		

It was important to observe the absence of variables like training, support from government, etc., from the model. These external supports were not found to have any role in the model as the stocking was primarily dependent on the conditions of the water bodies, size of water bodies and community organization and efforts in the multiple use water bodies.

Determinants of Feeding in Multiple Use Water Bodies

In the second model, the logistic regression model was fitted with adoption of feeding to fish as dependent variable. In comparison to the stocking model, the feeding model showed a contrasting picture. The presence of collective action and presence of leadership showed negative coefficients. In other words, the resources based on the community efforts did not encourage adoption of feeding. Similarly, the possibilities of feeding were less in the very old ponds and ponds with higher weed level. But, the level of dependence and number of people involved in the management were the positive factors for adoption of technology. The most important variable for adoption was government support which was not present in the previous model. The government support was required for proper adoption of the technology.

Discussion and Explanation of Determinants

The role of variables, viz., stocking and feeding, in the adoption of the aquaculture technologies is discussed below. Model (1) with stocking as dependent variable explained the factors influencing initiation and start of the aquaculture in the multiple use water bodies, whereas the Model (2) explained factors for further development and intensification of aquaculture.

History of Collective Action — The small multiple use water resources operate under multiple users situation. Therefore, collective action is required among the stakeholders to take decisions on the development of the aquaculture. Collective action institutions facilitate joint resource management, but also include

Table 4. Variables in the model on determinants of feeding (Model 2)

Variables	Values	Unit	Non-adoption	Adoption	Total
Presence of collective work in the village	No (0)	N	19	18	37
	Yes (1)	N	10	15	25
Presence of a specific leader for aquaculture	No (0)	N	14	12	26
	Yes (1)	N	15	21	36
Dependence on fisheries	100% (5)	N	0	1	1
	75% (4)	N	0	2	2
	50% (3)	N	2	8	10
	25% (2)	N	3	6	9
	Marginal (1)	N	15	14	29
	No dependence (0)	N	9	2	11
ln age of pond	years	Mean	3.92	3.35	3.62
ln No. of persons in the group	Nos.	Mean	2.96	2.59	2.76
Community has sufficient knowledge in aquaculture	No (0)	N	25	19	44
	Yes (1)	N	4	14	18
Level of weed infestation	Fullly weed choked (0.1)	N	6	1	7
	Mostly weed choked (0.2)	N	12	5	17
	Half weed chocked (0.5)	N	5	9	14
	Few weeds (0.75)	N	5	12	17
	Clean (1)	N	1	6	7
Support by external agencies	No (0)	N	5	4	9
	Yes (1)	N	24	29	53

Table 5. Predication of logistic model of adoption of feeding in aquaculture (Model 2)

Variable	Observed N	Predicted N	Percentage of correct prediction
Feeding adopted (yes)	33	30	90.9
Feeding adopted (no)	29	25	86.2
Total	62	55	88.7

Table 6. Logistic regression of feeding as dependent variable (feeding yes-1, feeding No-0)) in aquaculture (Model 3)

Variables	B	Wald	Significance
Presence of collective action in village (Yes-1, No-0)	-5.186	6.415	.011
Perception of community having sufficient knowledge (Yer-1, No-0)	-2.378	3.214	.073
Presence of leader for aquaculture in village (Yes-1, No-0)	-3.782	5.880	.015
Government support (Yes-1, No-0)	6.120	7.015	.008
Level of dependence on fisheries for livelihood	3.021	8.940	.003
ln (age of ponds in years)	-4.247	7.681	.006
ln (number of person involved in management)	1.987	6.331	.012
Level of weed in water bodies	-5.469	6.017	.014
Constant	14.410	8.583	.003
Chi-square	50.89		
DF	8		
Significance	0.000		
-2 Log likelihood	34.80		
Cox & Snell R^2	0.56,		
Nagelkerke R^2	0.75		

inter-community dialogue and conflict resolution (McCulloch *et al.*, 1998). In the management of the common pool resources like MAR, the collective action is essential for successful adoption of the technology. But, direct measurement of the collective action is difficult and hence, presence of activities like village development works, cultural programmes, etc., were taken as collective action in the village (Heltberg, 2001). Hence, the dummy variable history of the collective action was taken as variable. The presence of collective action in the village also is expected to influence technology development positively in the aquaculture. It acts positively for the initiation of aquaculture but negatively for the feeding practices. In other words, the villagers together are able to start but are not able to further develop it.

Leadership in Aquaculture — The presence of leadership is considered to be critical for the collective action and coordination of the multiple stakeholders involved in the management of the common resources (McCulloch *et al.*, 1998). In the present case, the role of leadership was critical as management functions like negotiations, coordination, access to information, etc. are being carried out by the leaders. The presence of leadership is expected to have positive impact on the adoption of the aquaculture technology. In the pesent study, the role of leaders was important in the stocking but limited in the feeding and intensification of aquaculture.

Level of Weed Infestations — The infestations of aquatic weeds are major problems in the undrainable multiple use ponds, especially when the resources are not being used properly (Kumar, 1992). The higher level of weed infestation increases the cost of management and reduces the chances of success of aquaculture. Therefore, it can be hypothesized that the higher level of weeds are the disincentives for the adoption of the aquaculture technology. For the present study the level of weed is an ordinal variable measured through five point scale in the order of infestation with clean (0.1), few weeds (0.2), half of the area covered (0.5), mostly covered (0.75) and fully covered (1.0).

Therefore, the variable is expected to influence negatively the adoption of aquaculture. The present study has also provided evidence that the higher levels of weeds are deterrent to initiation and intensification of aquaculture.

Level of Livelihood Dependence — The level of dependence is a perceived value of livelihood dependence on the fisheries and aquaculture. The respondents were asked to put a value on five categories of the dependence, viz., 0, 25, 50, 75 and 100 per cent. The indicator variable was chosen irrespective of the actual benefits accrued from the particular water bodies under the study. The households with higher dependence and greater stake in the fisheries activities are expected to facilitate greater adoption of the technology. The model also has shown higher dependence as a positive contributor for the adoption of aquaculture. In other words, people with greater stake in the fisheries are also interested in adopting new technology.

Management Institutions — The three system of management that co-exist in aquaculture management of the MAR are community, group and individual. The private and group management has the similar characteristics, and therefore, in the present study, the management institutions as a variable was a dummy variable taking value '1' for community management and '0' for others. The community management is expected to have a positive influence on the adoption of technology as the stake of the community is high in the aquaculture development in MAR. The community management has encouraged the adoption of stocking practices but was not found in the second model (2), indicating the constraints of community management in intensification practices like feeding.

Area of Water Bodies — The resources under the study are small multiple use water resources and within these categories a wide range of the sizes are available. The very small size of water resources does not provide incentives for adoption of aquaculture technology as the net economic return from it is low. Therefore, the log of water areas was expected to affect positively the adoption of technology. The model (1) showed that the higher size to be better for adoption of stocking but it did not enter in model (2), indicating lack of clear role of size in adopting feeding practices.

Community Access to Information — The access to information is critical for adoption of the technology (McCulloch *et al.,* 1998). The villages with higher access to technical information are expected to adopt the aquaculture better. The communities having better information are also expected to adopt the aquaculture technology better than others. But, contrary to the expectations, the variable had a negative sign indicating that the perception of better knowledge of community did not support the feeding practices. The variable was also not entered model (2). Hence, the role of the variable was not clear.

Age of Pond — The age of multiple use water bodies varies from 10 years to more than 100 years. It is perceived that in the older ponds, the uses like irrigation, domestic , religious, etc. are more. Moreover, the level of muck in the ponds, and bund conditions are often not favourable for the better water quality management for aquaculture. Hence, it can be hypothesized that the ponds with longer age would disfavour adoption of the aquaculture. The variable had a negative sign in the model (2), whereas it did not enter in model (1), indicating that the age of a pond was a deterrent for intensification of aquaculture but not for initiation of it.

Size of Group — The number of participants in the management of a common pool resources both positive and negative effects (Ostrom, 2002). The large the number of persons in management of aquaculture requires greater resources and efforts for coordination and communications. Hence, the smaller size groups are preferred over the larger groups. On the other hand, the larger number of stakeholders shows greater involvement of the people and provides legitimacy and support to the management. The actual effect of size depends on the context of the management of the resources. In the present context, the more participants in management had a positive effect on intensification effort influencing positively in model (2) but it was not important in model (1).

Government Support — The government support of any kind — economic, training, awareness, inputs supply, etc. — influences positively the adoption of aquaculture technology. In the study, the government support was found to be important in advancing aquaculture but not in initiation of it. In other words, the communities and users themselves can take initiatives at the initial stage of the adoption of technology but for further development and sustained technology growth, the support of government is inevitable. Therefore, greater role needs to be played by the government in encouraging use of multiple use water resources for aquaculture.

Conclusions

The study has found that for the initiation of aquaculture technology, community organization and collective efforts are required. The situation in which the environment and resources are suitable, the organization of management system contributes positively for bringing the water bodies under aquaculture. But, the further development of aquaculture requires support of the government.

The study has also found that the older ponds create unfavourable conditions for aquaculture due to higher level of other uses, accumulation of mucks and weeds. The higher level of weeds is a discouraging factor for the adoption of aquaculture technology. But, when more people are involved in aquaculture, the adoption of technology is higher, which indicates suitability of the community based system for the management of these resources. The consistent variable for initiation and further development of the technology is the level of livelihood dependence on fisheries. With increase in dependence, there are greater possibilities of adoption of technology.

This study has provided enough evidence for the development of management system with a broader participation of the poor people dependent on the fisheries. The government support is required more for the successful adoption of aquaculture technology in the multiple use water bodies.

Policy Implications

The following policy measures are required for the development of aquaculture in the small multiple use water resources.

- Setting of appropriate institutional arrangement for the adoption of technology for aquaculture development in multiple use water resources.
- Improvement of pond environment in the traditional old ponds, especially in the areas of bund repair, muck removal is critical for adoption of aquaculture technologies.
- Weed clearance of the ponds need to be undertaken to encourage adoption of aquaculture technologies.
- Greater involvement of stakeholders in the management of MAR encourages adoption of technologies.
- Ensuring participation of the poor in the aquaculture developments.
- Consistent government support for aquaculture in multiple use resources in the form of training, inputs, financial. etc.

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