Ind. Jn. of Agri. Econ.
Vol.68, No.3, July-Sept. 2013

Land Shaping Models for Enhancing Agricultural Productivity in Salt Affected Coastal Areas of West Bengal – An Economic Analysis

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ABSTRACT

The management of agricultural land to improve farm income in coastal saline areas is quite challenging because, firstly, most of the agricultural area is characterised by monocropping with low-yielding rice varieties during *kharif* season. Under such fragile environment sustaining the livelihoods of these resource poor farmers become a real challenge both for technology developers as well as policy makers. To increase the farm income under the coastal saline environment, strategies have been taken up to increase the adoption of the salt resistant crop varieties and more importantly harvesting, storing and appropriate management through different kinds of land shaping technologies. The study pertains to primary survey on farm households, in South and North 24 Parganas district of West Bengal. The sample farmers were drawn from two blocks, six villages and total sample size of 180 farm households of which half were the beneficiary farmers and the rest was non-beneficiary farmers. In the coastal area the land shaping technique, particularly farm pond and paddy-cum fish models, are unique technology for addressing the key challenges like land degradation (salinity), drainage congestion and scarcity of fresh water for irrigation and in turn have the potential to enhancing production, productivity, income and employment. These techniques particularly farm pond and paddy-cum-fish are a financially viable and attractive proposition for the coastal region. However for larger adoption of these technologies need to address some key issues like socio-economic constraints, some of which can be addressed by research level (e.g. land configuration, soil quality) some other at policy level (e.g. financial incentives).

Keywords: land shaping models, budgeting technique, fisheries, natural resources.

JEL classification: Q15, Q16, Q20

I

INTRODUCTION

The coastal saline soils in India are spread over an area of 3.1 mha in eight states, namely, West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, Gujarat and four centrally administered states/region, viz., Pondicherry, Goa, Daman & Diu, Lakshadweep & Minicoy Island and Andaman & Nicobar Islands (Yadav *et al.*, 1983). The compilation made by Velayutham *et al.,* (1999) on the soil resources and their potentials for different agro-ecological sub-regions (AESR) estimated 10.78 m ha area under coastal agro-ecosystem (including the island) in India. Though there is some variation in the estimation of areas under coastal saline soils as reported in various publications, nevertheless, these figures

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clearly indicate the magnitude and importance of the coastal areas at the national level. This coastal region supports substantial population base with diversified, complex and risky livelihoods pattern.

In West Bengal, the coast line is stretched over 210 km and shared by mainly three districts, namely, South 24 Parganas, North 24 Parganas and East Midnapore. More than 2.45 million population of West Bengal is dependent on this coastal area and 80 per cent of which are engaged in agriculture and the rest on fisheries. However, these livelihood options under marginal environment of coastal salinity are typically characterised with multi-faceted problems such as low crop productivity either due to waterlogged condition (during *kharif* season) or high salinity building up (during *rabi* season). The farming operation often becomes risky due to natural calamities that increases the risk of farming or restricted the farm operation and ultimately increases the instability of farm income. The management of agricultural land to improve the farm income in coastal saline areas is quite challenging because, firstly, most of the agricultural area is characterised by monocropping with low-yielding rice varieties during *kharif* season. Due to the problem of waterlogging, tall rice varieties are cultivated which have low yield potential as compared to high yielding short varieties. Secondly, after rainy season, as the fields gradually dries up salinity building-up occurs and during *rabi* season it becomes difficult to grow any crop due to severe scarcity of freshwater which is essential for management of soil salinity. The available sources of freshwater may be either ground water or harvested and stored rainwater. The problem of lifting freshwater from the ground is fairly acute because the good quality of irrigation water is available at a depth of 700-1000 metres. Under these circumstances, use of groundwater from shallow salt-affected (linked with brackish water) water table often facilitates the salinity building up in the surface soils. Therefore, the management of rainwater for agricultural use becomes extremely important for increasing the crop productivity particularly during *rabi* season. Under such fragile environment sustaining the livelihoods of these resource poor farmers become a real challenge both for technology developers as well as for the policy makers. To increase the farm income under the coastal saline environment, strategies have been taken up to increase the adoption of the salt resistant crop varieties and more importantly harvesting, storing and appropriate management through different kinds of land shaping technologies.

During 2009, with the financial assistance from Global Environment Facility (GEF) through National Agricultural Innovation Project (NAIP), a mega programme was launched under the lead centre Central Soil Salinity Research Institute (CSSRI), Regional Research Station (RRS) Canning Town for implementing different land shaping techniques on farmers' fields in 10 clusters covering 29 villages in the disadvantaged areas of Sundarbans (South 24 Parganas and North 24 Parganas district of West Bengal) and tsunami affected areas of Andaman and Nicobar Islands (CSSRI, 2009). The impact of selected land shaping models have been studied based on the actual field level data as implemented at the farmers' field, particularly in South 24 Parganas district.

Details of Land Shaping Models

Land shaping techniques like farm pond, deep furrow and high ridge, paddy-cum fish cultivation have been developed for restoration and productivity enhancement of degraded (saline) coastal land. These techniques reduced the process of land degradation by alleviating soil salinity and waterlogging problems as well as for creation of irrigation resources in the coastal region. Out of the various land shaping models, farm pond and paddy-cum-fish models have been most popular among the farmers in the coastal region and under the current study the economic analysis has been carried out for these two models. Linear programming technique for resource optimisation was used to optimise land allocation during *rabi* with labour and water constraints under rice based cropping system. A crop schedule for cultivation of multiple crops round the year under different land situation created under farm pond technique was also developed (Ambast *et al*., 1998). The basic features of these two land shaping models are:–

1. *Farm Pond Models (FP)*

About 20 per cent of the farm area is converted into on-farm pond of about 3m depth to harvest excess rainwater. The dug-out soil is used to raise the land to form high land/dike and medium land situations besides the original low land situation in the farm for growing multiple and diversified crops throughout the year instead of mono-cropping with rice in *kharif* season (Figure 1).

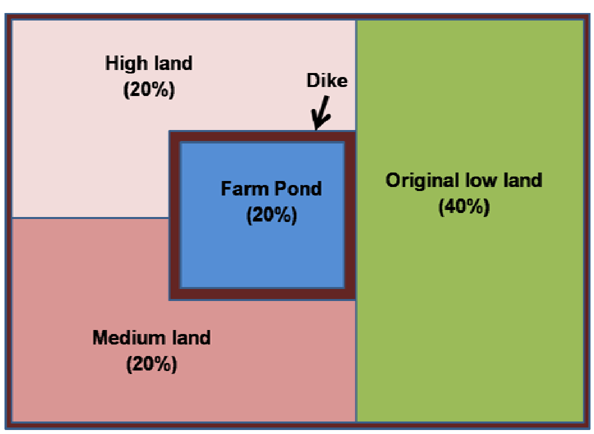

Figure 1. Design of Farm Pond Model

The pond is used for rainwater harvesting for irrigation and pisciculture. Poultry/ livestock farming can also be practiced in the farm along with crops and fishes with the use of pond water. The integrated crop-fish-livestock/poultry-duckery farming is environmental friendly and efficient for integrated nutrient management in the farm. The high land is free from water logging in *kharif* and with less salinity build up in dry seasons and thus, can be used for multiple and diversified crop cultivation throughout the year.

2. *Paddy-cum-fish (PCF)*

Trenches (3m top width × 1.5 m bottom width × 1.5 m depth) are dug around the periphery of the farm land leaving about 3.5m wide outer from boundary and the dugout soil is used for making dikes (about 1.5 m top width ×1.5 m height × 3m bottom width) to protect free flow of water from the field and harvesting more rain water in the field and trench (Figure 2). A small ditch is dug out at one corner of the field as the shelter for fishes when water will dry out in trenches.

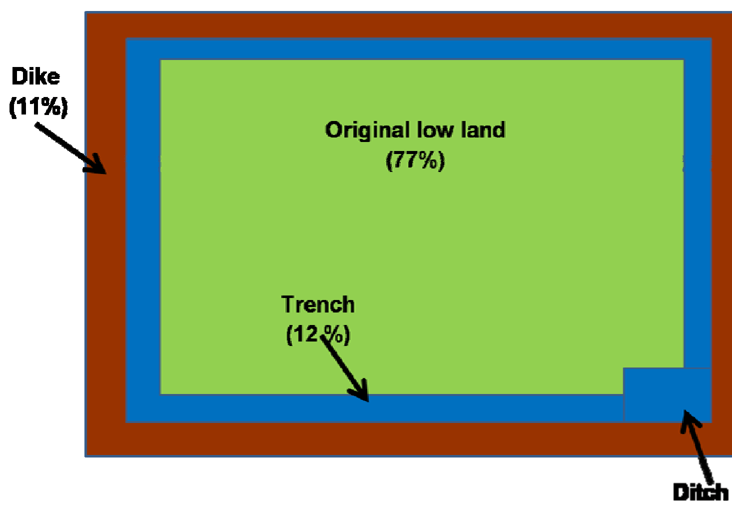

Figure 2. Design of Paddy-cum-Fish Model.

The dikes are used for vegetable cultivation throughout the year. The remaining portion of the farm land including the trenches is used for more profitable paddy + fish cultivation in *kharif* season. The land (non-trench and non-ridge area) is used for low water requiring crops during dry (*rabi*/summer) seasons with the rain water harvested in trenches. The presence of deep trenches in the field provides better drainage condition in the field during the non-monsoon months. During the dry seasons the land can also be used for remunerative brackish water fish cultivation with plenty of brackish water (ground/river water) available in the area. The land can again be used for paddy-cum-fresh water fish cultivation in *kharif* if the brackish water is pumped out (required for harvesting of fishes) and the land is allowed to wash out the salts with a few initial pre-monsoon heavy showers common in the area.

II

METHODOLOGY

Sources of Data

The study pertains to primary survey on farm households in South and North 24 Parganas districts of West Bengal. The sample farmers were drawn from two blocks, six villages and total sample size of 180 farm households. Out of these 180 farm households, half were the beneficiary farmers (under NAIP) and the rest was non-beneficiary farmers. For details on the economics of the land shaping models input-output data from 32 units of farm pond model and 40 units of paddy-cum-fish model have been studied. The primary survey has been conducted during 2009-10 and the input-output data was collected during 2010-2012 period.

Analytical Framework

The socio-economic data of the sample farmers have been analysed through descriptive statistics. The economics of the enterprise has been calculated through farm budgeting technique. Financial analyses of these two land shaping models have been carried out to examine the long term viability of such investment in the coastal environment. The purpose of doing investment analysis for the Land Shaping Models in the study area was to find out whether the investment will yield a reasonable rate of return to all resources engaged for an average unit. The financial analysis was based on the assumptions of all costs and prices are in constant prices (i) Economic life of the models are 15 years, (ii) Discount rate considered @ 14 per cent (as the maximum interest rate charged by the bank in the study area), (iii) First year of the investment has been considered to be planning year, hence no return, (iv) Full benefit of the investment will be realised at 2nd year onward and (v) Incremental costs and incremental return have been computed by deducting opportunity cost (net return from *kharif* paddy) of land from the net return realised from the investment. For this investment analysis, undiscounted cash flow measure of project worth, namely, payback period and discounted cash flow measures of project worth, namely, benefit-cost ratio (BCR), net present value (NPV) and internal rate of return (IRR) were applied.

Having analysed the economics and financial feasibility of these models, it was important to know the different factors that influence the farmers' behaviour towards adoption of these technologies. The farmers have to operate under a host of socio-economic conditions that determines the decision to adopt new or modify their existing technologies. To analyse this behaviour, logistic regression model has been employed and various parameters were included in the analysis to predict the probability of adoption of these technologies. The framework for logistic regression analysis is specified as-

$$Yi = g\,(Zi) \qquad \text{.... (1)}$$

Here Zi is an index variable (or vector of Xki independent attributes) and formally can be written as:

$$Z_i = \text{In}\left(\frac{P_i}{1 - P_i}\right) = \alpha + \beta_k X_{ki} \qquad \text{.... (2)}$$

$$Pi = F\,(Zi) = F\,(Xi) = \frac{1}{1 + e^{-zi}} \qquad \text{.... (3)}$$

Once this equation is estimated, P can be calculated as

$$= \frac{1}{1 + e^{-(\alpha + \beta_k X_{ki})}} \qquad \text{.... (4)}$$

Where

Yi = Status of farmers (Y = 1 for farmer who intend to adopt the land shaping model and Y = 0 otherwise),

Zi = An underlying and unobserved response for the i-th farmer. When Z exceeds threshold Z*, the farmer takes the decision to adopt, otherwise not.

Xki = k-th explanatory variable for the i-th farmer

i = 1,2,3, …, N, where N is the number of farmers

K = 1,2,3,…, M, where M is the total number of explanatory variables

α = constant

β = unknown parameters

and e denotes the base of natural logarithim with a value approximately 2.718.

The variables included in the model were Zi: a binary variable, 1 = farmers adopt land shaping models, 0 = otherwise. X_1 - farm size (ha), X_2 - No. of parcels in farm holdings (No.), X_3 - per cent of lowland area, X_4 - distance of land from residential area (binary var,1=within 1km, 0 otherwise), X_5 - aggregate family income (₹/year), X_6 - per cent of off-farm income (₹/year), X_7 - family size (No.), X_8 - availability of irrigation water (binary variable 1= available for at least 4 months, 0 otherwise), X_9 -

education level (No. of years of education of key respondents), X_{10} - rental value of land (₹/year/ha).

Constraints Analysis

To rank the various constraints for adoption of land shaping models, the Rank Based Quotient (RBQ) analysis was employed. The criteria followed by the farmers listed first and then were asked to rank on the basis of individual priority by giving number 1 to 5. The most preferred criteria was ranked as 1, followed by 2 as lesser important than 3 etc. After interviewing the farmers, the analysis was done to rank those preferences on the basis of RBQ rank. A total 160 farmers including both farmers with and without having any land shaping models (80 from each category) were interviewed for this.

RBQ is a problem identification technique, which is mathematically represented as follows:

$$RBQ = \sum_{j=1}^{n} \frac{fi(n+1-i)*100}{N*n},$$

Where,
N = Total number of farmers
n =Total number of ranks (there are five ranks altogether, so, n = 5)
i = The rank for which the RBQ is calculated (for a problem)
f = Number of farmers reporting the rank i (for the problem).

III

RESULTS AND DISCUSSION

Socio-Economic Pattern of the Farmers

Majority of the farmers (85 per cent) in the study area belonged to the weaker sections of the society (primarily SC) and 94 per cent of the farmers were marginal landholders, the rest were either small farmers (1.7 per cent) or landless (4.1 per cent) (Table 1). The land situation was primarily dominated by low-lying situation (76 per cent) followed by medium (15 per cent) and upland (9 per cent). Despite having low return, agriculture was the major occupation and nearly 42 per cent of the farm families were primarily dependent on agriculture. In the absence of gainful livelihood options in the local area, migration to nearby cities is quite prevalent (32 per cent of farm families) in the study area for search of alternative livelihood options. Cropping intensity in the study area was calculated to be quite low at 120 per cent and the *kharif* paddy dominated the cropping pattern. Low cropping intensity in these clusters is due to non-availability of good quality irrigation water and also due to soil salinity building up in non-monsoon months. The major cropping systems prevailing in the study area were rice-fallow or rice-rice. The proposed technological interventions are envisaged to enhance the cropping intensity as well as farm income through creation of water resources by harvesting and storing of rainwater at the farm level and through promotion of integrated cropping systems like rice – rice + vegetables and rice + vegetables – rice + vegetables.

TABLE 1. SOCIO-ECONOMIC CHARACTERISTICS OF THE SAMPLE HOUSEHOLDS IN COASTAL REGION OF SUNDARBANS

Sl.No. (1)	Particulars (2)	Value (3)
(A)	Demography	
	1. Avg. family size (No.)	5.63
	2. F : M (No. of females per 1000 males)	980
	3. SC (per cent)	85
	4. ST (per cent)	0.09
	5. General (per cent)	15
	6. Illiteracy (per cent)	24
(B)	Operational holding pattern	
	1. Avg. farm size (ha)	0.49 (2.2)
	2. Categories of farmers	
	a. Marginal (per cent)	94.2
	b. Small (per cent)	1.7
	c. Landless (per cent)	4.1
(C)	Land situations	
	1. Low (per cent)	76
	2. Medium (per cent)	15
	3. Up (per cent)	9
(D)	Cropping intensity (per cent)	120

Figures in parentheses indicates average number of parcels/plots per family.

In Sundarbans area, agriculture was the primary occupation of the majority of the households (22 per cent) in the study area followed by daily labourers for non-agricultural activities, migration to other places for alternative livelihood, fisheries, petty business, others including handicrafts and service (Table 2). The average family income of the households in the study area has been estimated to be around ₹ 37251 per family/year out of which the contribution of agriculture was around half of the total income (Mandal *et al.*, 2011). The average operational holding size of farmers was very small (0.49 ha) that too are fragmented over several plots. Though agriculture is the primary occupation of the majority of the people but in general agriculture was contributing low income (less than half of the total income) in the study area of Sundarbans. Under this situation, large-scale migration (52 per cent) was quite prevalent in this area which fetched better income than from agriculture. The agriculture and allied sectors must be made more productive by utilising the existing natural resource base of this region to secure better sustainable livelihood option for the people of this region and security to the rural society. The other income sources of the people in the study area were income from livestock, fisheries, service and business.

TABLE 2. OCCUPATION AND INCOME PATTERN OF SAMPLE HOUSEHOLDS IN COASTAL REGION OF SUNDARBANS

Sl. No. (1)	Particulars (2)	Per cent households primarily dependent (3)	Average income (₹/annum) (4)
(A)	Agriculture	42	16583
(B)	Business	5	48560
(C)	Service	6	94258
(D)	Fisheries	0.7	8843
(E)	Migration	32	45278
(F)	Agricultural labourers	8	11240
(G)	Daily labourers (non-agri)	4	12345
(H)	Others (incl handicrafts)	2.3	22355
(I)	Overall	100	37251

Economics of the Land Shaping Models

Economics of the land shaping models (farm pond and paddy-cum-fish) has been calculated on the basis of actual field level data from the farmers' field. The annual operational cost and returns have been calculated on an average unit under operation and finally on per ha basis. The average area under intervention of farm pond paddy-cum-fish models in the farmers' field has been calculated to be 0.16 ha and 0.18 ha respectively. Initial investment for these models has been estimated to be ₹ 82000 and ₹ 72000 per ha respectively. The major components of the system were paddy, vegetables and fish. The average total cost (operational), gross return and net return from the farm pond models has been calculated to be ₹ 105762, ₹ 244100 and ₹ 138336 per ha per year while the average total cost (operational) gross return and net return was ₹ 112323, ₹ 248879 and ` 136556 per ha per year under paddy-cum-fish model (Table 3).

Besides estimating annual costs and return, also the co-efficient of variation (CV) of these systems have been calculated to assess the stability of the output and returns from the models. As the value of CV increases, the instability of crop output also increases and farmers tend to prefer that enterprise less. The resource poor farmers are normally risk averters and prefer to be safe than sorry; they tend to prefer a lower outcome that is relatively certain to the prospect of a higher average return with a greater degree of risk attached. The coefficient of variation (CV) values under farm pond model indicated that vegetable production has relatively higher instability in production and return as compared to fish. Overall the model provides fairly stable and attractive return to the investment. Similarly, under paddy-cum-fish model the coefficient of variation (CV) values indicated that fish and vegetable production has relatively higher instability in production and return as compared to paddy. But overall the model provides fairly stable and attractive return to the investment.

TABLE 3. ECONOMICS OF FARM POND AND PADDY-CUM-FISH MODEL

Particulars (1)	Total cost (₹/ha) (2)	Production (kg/ha) (3)	Gross return (₹/ha) (4)	Net Return (₹/ha) (5)
Farm Pond				
Vegetables	39130	9875	98500	59370
	-	(46.65)	(39.35)	(35.37)
Fish	66632	1945	145600	78968
	-	(23.49)	(18.53)	(27.55)
Fish + Vegetables	105762	-	244100	138336
	-	-	(21.03)	(25.32)
Paddy-cum-fish model				
Vegetables	30619	5567	78790	48171
	-	(40.96)	(42.59)	(52.32)
Fish	65690	1800	144000	78310
	-	(46.95)	(47.83)	(54.93)
Paddy	16014	3030	26089	10075
		(22.29)	(18.98)	(24.55)
Fish + Vegetables + Paddy	112323	-	248879	136556
	-	-	(24.42)	(23.43)

Note: Figures in parentheses indicates co-efficient of variation of the respective value.

Financial Analysis of the Land Shaping Models

Financial analyses of these two models have been carried out to examine the long term viability in the coastal environment. The purpose of doing investment analysis for the land shaping models per unit in the study area was to find out whether the investment will yield a reasonable rate of return to all resources engaged for an average unit. For this investment analysis, undiscounted cash flow measure of project worth, namely, payback period and discounted cash flow measures of project worth, namely, Benefit-Cost Ratio (BCR), Net Present Value (NPV) and Internal Rate of Return (IRR) were applied. IRR was estimated to be 65 per cent and 54 per cent under farm pond and paddy-cum-fish technologies, respectively. Similarly, NPV was ₹ 286394 and ₹ 261385; BCR was estimated to be 1.74 and 1.62 and payback period was calculated to be 1.75 and 2.24 years, respectively under farm pond and paddy-cum-fish technologies (Table 4). Financial analysis indicated that investment on these land-shaping models is not only profitable but highly attractive proposition and financially feasible.

TABLE 4. FINANCIAL FEASIBILITY OF LAND SHAPING MODELS IN THE COASTAL AREAS OF WEST BENGAL

Criteria (1)	Farm Pond (2)	Paddy-cum-fish (3)	Remarks (4)
Internal rate of return (per cent)	65	54	>discount rate (14 per cent) so feasible
Net present value (₹)	286394	261385	Positive return, feasible
Benefit-cost ratio	1.74	1.62	> 1, feasible
Payback period (years)	1.75	2.24	Recovers initial investment quickly

Determinants of Adoption of Land Shaping Models

Having analysed the economics and financial feasibility of these models, it is important to know the different factors that influence the farmers' behaviour towards adoption of these technologies. The farmers have to operate under a host of socio-economic conditions that determines the decision to adopt new or modify their existing technologies. To analyse this behaviour, Logistic Regression Model has been employed and various parameters were included in the analysis to predict the probability of adoption of these technologies. It was noticed that as the farm size, per cent of lowland area, aggregate family income, family size and educational level increases the probability of adoption of these technologies also increases (Table 5). Whereas as the number of parcels in farm holdings, distance of farm land from residential area, per cent of off-farm income and availability of irrigation water from sources (e.g. canal, creeks, bil etc) increases the probability of adoption of these technologies decreases. While extending the technologies to the farmers' field these socio-economic factors needs to be taken under consideration. However, the rental value of land was not a significant factor to influence the adoption behaviour of these technologies. The probable reason might be, if the land is relatively good (i.e., fetch higher rental value) for cultivation farmers do not like to have their land reshaped than if the land is poor (fetching low rental value).

TABLE 5. FACTORS AFFECTING ADOPTION OF LAND SHAPING MODELS IN COASTAL REGION OF WEST BENGAL

Factors (1)	Name (2)	Co-efficient (3)	SE (4)
Constant		1.3471***	0.0214
X1	Farm size (in ha)	0.435***	0.0473
X2	No. of parcels in farm holdings (No.)	-0.0187***	0.0045
X3	Per cent of lowland area	0.0952***	0.0388
X4	Distance of land from residential area (binary var, 1=within 1km, 0 otherwise)	-0.2110*	0.012
X5	Aggregate family income (₹/year)	0.0871***	0.0126
X6	Per cent of off-farm income (₹/year)	-1.1543***	0.4422
X7	Family size (No.)	0.0675***	0.0548
X8	Availability of irrigation water (binary var. 1= available for at least 4 months, 0 otherwise)	-0.4871***	0.1789
X9	Education level (No. of years of education of key respondents)	0.1510***	0.0984
X10	Rental value of land (₹/year/ha)	0.0511	0.0432
	-2 Log Likelihood		149.52
	Correct Prediction (per cent)		68.93
	No. of observations		180

Constraints in Adoption of Land Shaping Models

The Rank Based Quotient (RBQ) analysis was employed to identify the major constraints for adoption of land shaping models. The criteria followed by the farmers was listed first and then were asked to rank on the basis of individual priority by giving number 1 to 5. The most preferred criteria was ranked as 1, followed by 2 as lesser important than 3 etc. After interviewing the farmers, the analysis was done to rank those preferences on the basis of RBQ rank. A total of 160 farmers including both farmers with and without having any land shaping models (80 each category) were interviewed for this. The major constraints identified for the adoption of land shaping models were marginal land holdings and shape of lands, high initial investment, presence of acid sulphate soil layer after certain depth, distance from residential areas, scarcity of labour availability in time, low marketable surplus, hence high marketing cost or lack of remunerative price, high input prices, poor input supply and output delivery, difficult to reverse the land shaping to original land, availability of quality crop and fish seed and lack of supervision by family members (Table 6).

TABLE 6. CONSTRAINTS IN ADOPTION OF LAND SHAPING MODELS IN STUDY AREA

Sl. No. (1)	Constraints (2)	RBQ Score (3)	Rank (4)
1.	Marginal land holdings and shape of lands	36.19	1
2.	Scarcity of labour availability in time	24.48	5
3.	Low marketable surplus, hence high marketing cost or lack of remunerative price	23.33	6
4.	Distance from residential areas	24.95	4
5.	Acid sulphate soil layer after certain depth	27.71	3
6.	High input prices, poor input supply and output delivery	19.24	7
7.	Availability of quality crop and fish seed	14.76	9
8.	Lack of supervision by family members	12.57	10
9.	Difficult to reverse the land shaping to original land	17.05	8
10.	High initial investment	28.29	2
N	No. of observations	160	

IV

CONCLUSION

In coastal areas the land shaping technique is a unique technology for addressing the key challenges like land degradation (salinity), drainage congestion and scarcity of fresh water for irrigation and in turn have the potential to enhancing production, productivity, income and employment. These techniques particularly farm pond and paddy-cum-fish are financially viable and attractive proposition for the coastal region. However, for larger adoption of these technologies need to address some key issues like socio-economic constraints, some of which can be addressed by research level (e.g., land configuration, soil quality) some other at policy level (e.g., financial incentives). The major constraints for adoption of land shaping techniques are marginal land holdings that too divided into several parcels, high initial investment, presence of acid sulphate soils near surface or at shallow depth at places, distance from residential village etc. Community based rainwater harvesting as well as common pool wasteland may be encouraged in this direction.

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