

## **Crop-Fish Integration through Land Shaping Models for Enhancing Farm Income under Eastern Coastal Region of India**

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### **Abstract**

In the coastal region, farmers view their farming operation as a system in which crop and fisheries are integral parts. The paper has studied the impact of some land-shaping interventions implemented through crop-fish integration. The paper has found that these land shaping models — farm pond, paddy-cum-fish, deep-furrow & high ridge and broad bed & furrow system — have created the land suitable for growing multiple crops and rearing fish. Financial analysis of these land shaping models has indicated that investment on such interventions are financially viable (IRR, 36-48%; NPV, ₹ 0.97-3.67 lakhs; BCR, 1.20-1.58; and payback period, 1.41-2.13 years) and attractive proposition for the coastal region in *Sundarbans* and Andaman & Nicobar Islands. For out-scaling of these technologies on a wider scale, there is a need to address some socio-economic constraints and provide policy support. The proposition of crop-fish integration in agriculture through these land-shaping models has been found quite suitable for enhancing the income and employment in the coastal region of India.

**Key words:** Coastal agriculture, land shaping models, socio-economic impact, crop- fish integration

**JEL Classification:** Q22, Q16

### **Introduction**

The coastal agro-ecosystem of India occupies an area of about 10.8 million ha (Velayutham *et al.*, 1999) and is spread over 7157 km long coastline along the Bay of Bengal in the East coast and Arabian Sea in the West coast. The area is spread across 9 states, 2 Union Territories and 2 groups of Islands. The coastal regions of the country are characterised as one of the

traditionally backward and disadvantaged areas with low agricultural productivity. The cropping pattern is predominantly mono-cropped with low yielding (less than 2.0 t/ha) traditional rice varieties in the wet season (*kharif*). The land and water resources of the coastal zone in India are rich, valuable but under-utilized. Enhancing agricultural production in the region can improve food security and contribute to poverty reduction.

Current productivity of the farming systems including agriculture and aquaculture are far below the

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inherent potential of the region. Agriculture under this marginal environment of coastal salinity is typically characterized with multi-faceted problems such as waterlogging (during *kharif*) or high salinity (during *rabi*). The natural calamities increase the risk of farming or restricted the farming operations and ultimately increase the instability of farm income. The main factors for salinity build-up are: presence of saline groundwater near land surface, excessive and heavy withdrawals of groundwater from coastal plain aquifers, active tidal movement of sea water and poor land and water management. The strategies for improving the farming conditions in coastal salt-affected areas have been focused on (i) developing salt-tolerant crop varieties (mainly rice), and (ii) rainwater harvesting through different land shaping models.

Rice is the major crop grown in this area in both seasons (*kharif* and *rabi*) and therefore, high focus has been laid on developing and dissemination of salt-tolerant rice varieties by the R&D institutions. Besides this, several land shaping techniques for rainwater harvesting have been attempted for enhancing farm production in the region (Ambast, 1998). In these techniques, the configuration of land is changed by soil excavation and making space for on-farm water harvesting. It creates option for multiple cropping enterprise including growing fish and also reduces soil and water salinity (Burman *et al.*, 2013). These land shaping techniques, such as farm pond (FP), paddy-cum-fish (PCF) models, deep furrow & high ridge (DFHR), and broad bed & furrow (BBF) system, are unique measures for addressing challenges like land degradation (salinity), drainage congestion, etc. and making availability of fresh water for irrigation and in turn have the potential to enhance production, productivity, income and employment from agriculture.

The farmers in coastal region view their farming operation as a system where growing crop and fish are integral parts. Therefore, these lands shaping interventions were implemented through crop-fish integration for achieving high impact and adoptability among the farmers.

### Data and Methodology

The information for this paper was drawn from the ICAR-NAIP project on “*Strategies for Sustainable Management of Degraded Coastal Land and Water for*

*Enhancing Livelihood Security of Farming Communities*” (Component 3, GEF funded), implemented during September 2009 - June 2014. The project sites were distributed over 12 clusters in West Bengal and Andaman & Nicobar Islands covering 32 villages in 4 districts. The project was implemented under consortium mode, the ICAR-Central Soil Salinity Research Institute (CSSRI), Regional Research Station (RRS), Canning Town, West Bengal, was the lead centre and partners were Ramakrishna Ashram Krishi Vigyan Kendra (RAKVK), Nimpith; ICAR-Central Institute of Brackishwater Aquaculture (CIBA), Kakdwip Research Centre (KRC), Kakdwip, Bidhan Chandra Krishi Viswavidyalaya (BCKVV), Mohanpur & ICAR-Central Islands Agricultural Research Institute (CIARI), Andaman & Nicobar Islands.

The baseline and end line survey of the project was conducted during 2009 and 2014, respectively (Mandal *et al.*, 2011; CSSRI-NAIP, 2014). The survey was conducted by using pre-structured and tested survey schedule through personal interview method. Several Focus Group Discussion (FGD) and Participatory Rural Appraisals (PRA) were also conducted at all clusters of villages in *Sundarbans* and Andaman & Nicobar Islands. The primary information was collected from 6400 household in 2010. For analyzing economic impact, most popular and high impact land shaping models, viz. farm pond, paddy-cum-fish, deep-furrow & high-ridge and broad bed & furrow system, were considered in the study. The input data on cost of soil excavation, annual operational cost & return for crop and fish cultivation were collected from 1345 farm pond units, 348 paddy-cum-fish units, 65 deep furrow & high ridge units and 51 broad bed & furrow units in the study area. The impact of land shaping on farm productivity, employment generation, farm income per household were studied.

The primary data were analysed using descriptive statistics such as average, percentage, coefficient of variation and standard deviation. The economics of various crops (total cost, gross return and net return) was calculated by farm budgeting technique. Financial viability analyses (Gittinger, 1982) of the land shaping models were carried out to examine the long-term viability of such investments in the coastal environment. The financial analysis was carried out with the assumptions: (i) economic life of the models was 15 years, (ii) discount rate was considered as 14

per cent per annum, (iii) first year of investment was considered as planning year, hence no return, (iv) full benefit of investment was taken from 2<sup>nd</sup> year onwards, and (v) incremental costs and incremental return were computed by deducting opportunity cost (net return from *kharif* paddy) of land from the net return realized from the investment. For this investment analysis, undiscounted cash flow measure of project worth, payback period, discounted cash flow measures of project worth, benefit-cost ratio (BCR), net present value (NPV) and internal rate of return (IRR) were applied. Besides, constraints to larger adoption of these land-shaping techniques were identified through rank analysis.

## Results and Discussion

### Socio-economic Status of Farmers

The socio-economic characteristics of farmers in clusters of *Sundarbans* area and Andaman & Nicobar Islands are given in Table 1. In *Sundarbans* clusters, agriculture was the primary occupation of the majority of people but its contribution was low (less than half of total income). The average family income of the clusters of *Sundarbans* was very low ₹ 22000-25000 per annum. Under this situation, migration was quite prevalent and non-farm sector provided more income than agriculture. Other income sources of the people

**Table 1. Key socio-economic features of the farm households in the study area**

Clusters	Average family size (No.)	Average farm size (ha)*	Marginal farmers (%)	Agriculture as primary occupation (% HH)	Average family income (₹/family/year)**	Cropping intensity (%)
<b><i>Sundarbans</i></b>						
Canning	5.13	0.19 (1.9)	95	45	22291 (63)	121
Basanti	6.25	0.36 (1.25)	85	48	21445 (70)	111
Patharpratima	7.18	0.56 (4)	91	45	25444 (41)	127
Mathurapur II	6.47	0.51 (4)	92	62	13330 (73)	125
Kultali	5.72	0.50 (4)	93	56	23958 (53)	126
Kakdwip	5.20	0.36 (3.24)	89	46	23441 (53)	122
Namkhana	4.72	0.29 (2.43)	91	45	23589 (56)	123
Sandeshkhali	5.00	0.36 (2.35)	86	39	22528 (50)	114
<b>Andaman &amp; Nicobar Islands</b>						
Chouldari	4.00	1.8	30	5	180948 (5)	137
Shoal Bay	7.00	2.6	27	15	199337 (14)	188
Dashrathpur	9.00	2.8	10	10	150666 (7)	146
Deshbandhugram	9.00	2.4	39	25	306875 (39)	188

Note: \* Figures within parentheses indicate number of sub-plots within the average landholdings

\*\*Figures within the parentheses indicate percentage of income from agriculture to total family income.

in the area were livestock, fisheries, services and business.

In Andaman & Nicobar Islands, the average income of a family was ₹ 1.5-3.0 lakhs per annum in all the clusters as at least one member of most families was in government service. The cropping pattern in *Sundarbans* region was primarily mono cropping and rice based. The cropping intensity in the clusters of *Sundarbans* was quite low (114-127%) due to non-availability of good quality irrigation water and building-up of soil salinity in non-monsoon months. The soil salinity building in some clusters was aggravated due to flooding of land with saline water (from saline water rivers) following cyclone-*aila*.

The extent of crop diversification in *Sundarbans* area, estimated by employing Simpson Diversification Index (SID) [ $SID = 1 - \sum(X_i / \sum X_i)$ , where,  $X_i$  = area under the  $i$ th crop], was 0.39, showing low crop diversification. The cropping pattern in clusters of A&N Islands was strikingly different from that in *Sundarbans* region. Besides rice-rice, the plantation crops occupied a significant area in the existing cropping pattern in A&N Islands. The cropping intensity was also high (146-188%) due to the presence of perennial plantation crops in these clusters.

### Impact of Land Shaping Models on Household Farm Economy

The impact of land shaping models have been multifarious that included change in cropping pattern the existing mono-cropping (with *kharif* rice) to multiple cropping, enhancement in cropping intensity, increase in income per hectare, gainful employment and reduction in soil and water salinity through successful on-farm rainwater harvesting and utilization in cropping system.

### Water Harvesting and Impact on Cropping Pattern

The consortium partners in the project implemented different land shaping models across the selected clusters in *Sundarbans* region and Andaman & Nicobar Islands. Around 311 ha of degraded coastal land was brought under various land shaping models and about 12,88,216 m<sup>3</sup> rainwater was harvested in the study area. With the harvested rain water about 250 ha additional area has been brought under irrigated cultivation of crops and vegetables, particularly during

*rabi* season (Table 2). These areas earlier remained fallow during dry season after the harvest of rice in *kharif* due to acute shortage of freshwater for irrigation. Different types of land situations were created through different land shaping models. These land situations have changed the cropping pattern from almost mono-cropped with *kharif* rice to multiple and diversified crops throughout the year and have increased cropping intensity to 166-240 per cent from 100-114 per cent.

### Impact of Land Shaping Models on Farm Income and Employment

In land shaping, different land situations like high land, medium land and low (original) apart from farm pond/ furrows/ trenches, were created in the low-lying and degraded coastal land. The rising of land levels and creation of water-harvesting facilities reduced the problem of drainage congestion. The high land/ridges/dikes were also free from waterlogging during *kharif* season, which provided scope for growing high-value crops and facilitated early sowing of *rabi* crops. These land shaping models have become very popular among the farmers of both *Sundarbans* and Andaman & Nicobar Islands clusters and as a result, income from agriculture has increased manifold vis-a-vis baseline income (Table 3). The average net income per ha of farmland has increased by 6-times, from ₹ 22000 to ₹ 1.22 lakhs in *Sundarbans* clusters and from ₹ 22400 to ₹ 1.0 lakhs (9 times) in Andaman & Nicobar Islands. The increase in net income was more in Andaman & Nicobar Islands clusters than *Sundarbans* clusters due to realization of higher price of produce in Islands.

### Impact of Land Shaping Models on Soil Quality

The creation of different land situations through land shaping models improved the quality of the degraded lands by reducing building-up of soil salinity, increasing soil organic carbon content, nutrients status and soil micro-biological activities. The salinity builds up in soil under different land situations showed significant differences from the original land situation (Table 4). The soil salinity (in terms of  $EC_e$  dS/m) was lowest in the *kharif* season. On drying up of the standing water on field at the end of *kharif* season, the soil salinity increased gradually to the highest value in summer (May). Thus, May was the most critical month for assessing soil salinity impact. This was mainly due to upward capillary flow of saline ground water present

**Table 2. Impact of different land shaping models on cropping pattern in selected clusters of villages under coastal saline environment**

Before intervention (existing cropping pattern)		After intervention (changed cropping pattern)			Cropping intensity (%)	
<i>Kharif</i> season	<i>Rabi</i> /summer season	Land situation created	<i>Kharif</i> season	<i>Rabi</i> /summer season	Before implemen- tation	After implemen- tation
<b>Farm Pond model</b>						
Rice	Mostly fallow	Pond Dikes	Fish Vegetables & fruit crops/ multi-purpose tree species (MPTs)	Fish Vegetables & fruit crops/ multi- purpose tree species (MPTs)	114	193 ( <i>Sundarbans</i> clusters) -200 (A&N Islands clusters)
		High land Medium land	Vegetables HYV Rice	Vegetables Vegetables, low water requiring field crops		
		Original low- land	Rice + fish	Low water requiring field crops/ vegetables, short duration rice		
<b>Deep furrow &amp; high ridge model</b>						
Rice	Mostly fallow	Furrows Ridges	Fish Vegetables & fruit crops/ MPTs	Fish Vegetables & fruit crops/ MPTs	114	186
		Original low land	Rice	Low water requiring field crops/ vegetables		
<b>Paddy-cum-fish model</b>						
Rice	Mostly fallow	Trenches Dikes/ <i>Ail</i>	Fish Vegetables & fruit crops/ MPTs	Fish Vegetables & fruit crops/ MPTs	114	166 ( <i>Sundarbans</i> clusters) -200 (A&N Islands clusters)
		Original low land	Rice	Low water requiring field crops/ vegetables		
<b>Broad bed and furrow model</b>						
Rice	Fallow	Bed	Vegetables &/ fruit crops	Vegetables, pulses &/ fruit crops	100	240
		Furrow	Fish/ rice+fish	Fish		

Notes: 1. Land situations were dominated by low-lying with deep waterlogging in *kharif* season (>30 cm of standing water).

2. Low water requiring crops introduced were cotton, sunflower, etc.

**Table 3. Impact of land shaping models on farm income and employment in coastal India**

Land shaping models	Households involved (No.)	Employment generated (man-days/ household/year)		Net income (₹/household/ ha/ year)	
		Before intervention	After intervention	Before intervention	After intervention
<i>Sundarbans</i>					
Farm pond	1215	87	227	22000 (7700)	139326 (48768)
Paddy-cum-fish	306	87	223	22000 (7700)	126556 (44295)
Deep furrow & high ridge	65	87	218	22000 (7700)	102321 (35821)
<b>Andaman &amp; Nicobar Islands</b>					
Farm pond	88	8	22	10000 (2000)	147600 (32800)
Paddy-cum-fish	42	8	35	24000 (4800)	147991 (32887)
Broad bed & furrow	51	9	48	24000 (4800)	212501 (43350)

Notes: 1. Costs and returns at 2012-13 prices. 2. Figures within parentheses indicate net income on average landholdings (0.35 ha in *Sundarbans* and 0.20 ha Andaman & Nicobar Islands, respectively) under cultivation.

**Table 4. Impact of land shaping models on soil salinity under coastal environment during summer (May)**

Land shaping model	Soil salinity ( $EC_e$ in dS/m) under different land situations created			
	Original land	Low land	Medium land	High land/dikes
No land shaping	16.00	-	-	-
Farm pond	16.00	14.50	7.50	6.00
Paddy-cum-fish	16.20	15.00	-	8.50
Deep furrow & high ridge	15.00	12.20		7.00
Broad bed and furrow (BBF)	2.90		1.18	

Note: Under BBF furrows were made and no different land situations were created.

at shallow depth (<1.0 meter during dry season) following evaporation from the soil surface, which resulted in gradual accumulation of salts in the surface soil. It was observed that the salinity building-up in the soil of different land situations, especially in the medium land and high land/ridges/ dikes was relatively less compared to original salt-affected coastal low land (control). The salinity level in the beds of BBF technique made in the waterlogged soil was much lower (1.2 dS/m) than under saline soils (>2.0 dS/m) (CSSRI-NAIP, 2014).

### Financial Viability of Land Shaping Models

On-farm demonstration have shown the success of selected land shaping models in *Sundarbans* and Andaman & Nicobar Islands in terms of increasing farm income and providing gainful employment to the farmers. However, these land shaping models involved high initial investment, particularly on soil excavation (Table 5). For analyzing the viability of investment, financial analysis of these land-shaping models — farm pond (FP), paddy-cum-fish (PCF), deep-furrow & high ridge (DFHR) and broad bed & furrow (BBF) system

**Table 5. Financial feasibility of land shaping models in the coastal areas of West Bengal and Andaman & Nicobar Islands at 2013-14 prices**

Criteria	Farm pond	Paddy-cum-fish	Deep furrow & high ridge	Broad bed & furrow	Remarks
Initial investment (₹/ha)	145770	135800	87850	192350	Cost of soil excavation
Internal rate of return (%)	46	42	36	48	>Discount rate (14%), so feasible
Net present value (₹)	285059	232450	96817	366501	Positive return, feasible
Benefit cost ratio	1.58	1.55	1.20	1.62	> 1, hence feasible
Payback period (years)	1.41	1.78	2.13	1.67	Recovers initial investment quickly

*Note:* The broad bed & furrow system was implemented in Andaman & Nicobar Islands

— was carried out. The financial analysis has revealed a direct relationship between investment on a land shaping model and values of IRR, NPV, B-C ratio (Table 5). However, payback period was calculated to be 1.41 and 1.78, 2.13 and 1.67 years, respectively under FP, PCF, DFHR and BBF type of land shaping models. Mandal *et al.* (2013) have also examined the financial viability of two land shaping models (FP and PCF) in *Sundarbans*, West Bengal and revealed these models to be financially viable. Financial analysis of all land shaping models under study has indicated that investment on such interventions were financially viable and attractive proposition for the coastal region of *Sundarbans* (West Bengal) and Andaman & Nicobar Islands.

### Constraints to Large Scale Out-scaling of Land Shaping Models

The farmers prefer stability of output with a lower return rather than the adoption of high-cost-high-return technologies wherein instability of output is higher (CSSRI, RRS Canning Town, 2014). To discussions with farmers operating in the study area revealed that major constraints to adoption of these land shaping models were: (i) marginal landholdings and shape of lands inhibits adoption of models, (ii) high initial investment on soil excavation, (iii) presence of acid sulphate soil layer after certain depth that inhibits crop growth, (iv) lack of proper road network, (v) scarcity of labour in time, (vi) lack of timely input delivery system (crop, fish seed, feed and other inputs) due to backwardness and disadvantaged area, (vii) uncertainty (like cyclone *Aila* in 2009) due to natural calamities, (viii) many farmers being smallholders, were reluctant to change their land configuration as again reshaping

of land (if they want to) to original would be cumbersome and costly.

### Conclusions

With technological, scientific and partial financial help to the resource-poor farmers, particularly of small and marginal categories, the land shaping models have been quite successful in enhancing farm income and on-farm employment in the coastal environment of *Sundarbans* and Andaman & Nicobar Islands. Such interventions should be extended to other farmers in the coastal regions. For out-scaling of these technologies on a larger scale, there is a need to address key issues like socio-economic constraints (landholdings and input-output market environment) some of which can be addressed by the researchers (land configuration and soil quality) and some need policy support (financial incentives and convergence with other ongoing schemes). The study has concluded that crop-fish integration in agriculture through land-shaping models has been highly suitable for enhancing the income and employment in the coastal region of India.

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