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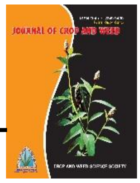

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Farming systems interventions for improving farm production of marginal tribal farmers in coastal West Bengal

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ABSTRACT

Integrated farming system (IFS) is a sustainable and effective means for improving farm income due to its cumulative cost effectiveness, low investment and higher profitability. A field study was conducted over the course of 3 consecutive years (2016-17, 2017-18 and 2018-19) with 116 farm households in 2 villages of Bali Island, Gosaba Block, 24 Paraganas district of West Bengal. The impact of different interventions was studied during 2019-20. The study area was severely affected by 2009 Aila (Cyclone), where farming became a huge challenge due to soil salinity and remarkable reduction of farm animal. Different crop and component specific interventions were introduced in order to augment crop area or animal count. Technological interventions along with capacity building and requisite input supply resulted into increased cropped area (rice area increased 170%) and animal number (35% increase in cow population). The overall effect demonstrated a significant improvement in production (577% increase in rice production), productivity, income, nutritional security, employment opportunities and livelihood of farming communities.

Keywords: Integrated farming system, livestock, livelihood, production, technology intervention

The southernmost part of West Bengal is home to the world's biggest contiguous mangrove habitat, known as Sunderbans. It is world's largest deltaic island, made up of hundreds of smaller islands connected by a complex network of tidal rivers, estuaries and creeks. This deltaic complex consists of 102 islands, among which 54 are inhabited, whereas the remaining islands are home to mangrove forests. This region has been designated as a World Heritage Site by UNESCO in 1987 and as a Global Biosphere Reserve in 1989 by the Government of India. The populated region is spread across 19 blocks, with 13 in the South 24-Parganas and 6 in the North 24-Parganas. Earthen embankments, spanning around 3600 km, prevent salty water of rivers from entering the area. India is one of 27 countries that have been considered to be the most susceptible to the effects of rapid Sea Level Rise (SLR) brought on by global warming (Raha *et al.,* 2014). One of the most noticeable consequences of climate change in Sunderbans is SLR, which is occurring there at an average rate of 3.14 mm annually (Hazra *et al*., 2002).

This area is a representative of a lowland agro-ecosystem, characterized by very less cropping intensity, heavy-textured saline soils with restricted supply of irrigation water. Traditionally, farmers cultivate high-yielding paddy varieties during rainy season and leave their land fallow during dry season (*rabi* and summer), with the exception of marginally growing low-water requiring crops like *moong* and *khesari* that utilizes residual moisture or life-saving irrigation. Water harvested in small tanks is the only source of irrigation during dry period. Though the adjacent metropolitan city Kolkata provides good market for agricultural produces, farmers cannot harness this opportunity due to their limited resources and marginal holdings.

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In a nutshell, agriculture is becoming non-economic and non-viable proposition for them (Ray *et al*., 2016). Natural disasters are the common occurrence and often to such an extent that they cause enormous damage to nearby communities. In 2009, during "Aila" (a powerful storm that hit Sunderbans) almost all the Islands were flooded with salt water from rivers, causing damage to all forms of agriculture and aquaculture. Till now the poor villagers are facing commendable problems in agricultural activities along with malnutrition, starvation and disease.

As a consequence, human trafficking and labour force migration inside and between states have become a common phenomenon. In light of this issues, an initiative has been taken by ICAR-IIFSR (Modipuram) under direct supervision of AICRP on Integrated Farming Systems, BCKV, Kalyani, Nadia, West Bengal with the objectives to augment income generating activities of ST farmers through enhancing yield and profitability of crops, animals, fishery and allied sectors, product diversification and value addition for increasing resource recycling vis-à-vis profit add up and human resource management through natural resource management, especially women belonging to ST farming communities through intensive participatory training.

MATERIALS AND METHODS

Study area

Two villages where tribal farmers predominate are Birajnagar Adibasipara (22˚06.302′N / 88˚44.838′E) and Bali Majherpara (22˚06.299′N / 88˚44.828′E) of Bali-II Gram Panchayat under Gosaba block of South 24 Parganas district were selected. 70% of total farm families in the first village and 77% in second village belong to tribal community. In both villages, the average holding sizes are very small, with 0.23 ha and 0.28 ha, respectively. The area is mainly mono-cropped, where farmers generally grow long duration rice crop with the help of monsoon rainfall. After harvesting the rainy season rice, majority of the fields remain fallow. Very few farmers cultivate *khesari* as a relay crop with the help of residual moisture; some grow vegetable crops in the homestead area with life-saving irrigation.

Soil and land situation

The study area has a flat surface which is between 3 to 8 meters above mean sea level (Hazra *et al*., 2002). Here, all alluvium brought by the river Ganga/Hugli and its tributaries are the main source of soil development. Mostly, soils have a thick texture (silty loam to silty clay) with sub-angular blocky structures that range in reactivity from mild acidic to neutral. In terms of soil fertility, these soils are typically high in available potassium (300 to 350 kg K_2O ha^{-1}), moderate in available phosphorus (13 to 24 kg P_2O_5 ha^{-1}) and low in available nitrogen (96 to 226 kg N ha^{-1}). This region's soils exhibit varying degrees of salinity, which increases with the movement from the north to the southern part. It rises in October and falls again in May and June when the monsoon season arrives. The major components of salts are chlorides and sulphates of Na, Mg, Ca, and K, with an insignificant amount of carbonates and bicarbonates.

Climate

The study region has a hot and humid climate with prevalence of winter, summer and monsoon. Winter officially begins in late November and lasts until the middle of February, during which heavy night time dew is noticeable. The coldest month of the year is usually January, whereas summer typically begins in the middle of March and continues until June, with sporadic pre-monsoon showers in the latter part of the season. July to September is the time span when monsoon lasts. Around the middle of October, rain generally stops. This region's lowest and highest temperature are 13.6 and 31.6°C in winter, 18.6 and 38.3°C in summer, and 23.5 and 34.1°C in monsoon, respectively. All year round, high relative humidity is observed, with monsoon bringing the most. Approximately, 1800mm of average annual rainfall is observed with 25% co-efficient of variation. South-west monsoon provides the majority of yearly precipitation, accounting for almost 80% of it. Most wetted months are July to mid-September with very less or no rains in other months.

Table 1: Bench mark status of different farming systems in Bali Island

Sl. No.	Farming System	No. of Farmers	Holding size (ha)	Family size	Gross return (Rs.)
1	C+D+Sh +F	2	0.5	6	41824
2	C+D+Du+P+G+F	2	0.57	5	37195
3	C+D+G+F	5	0.23	4	17446
4	C+G+F	9	0.57	4	12573
5	C+D+Du+P+F	4	0.16	5	13707
6	C+D+P+F	14	0.33	5	17450
7	C+D+P+G+F	8	0.38	5	21816
8	C+D+Du+F	4	0.35	4	13868
9	C+Du+F	2	0.12	5	3400
10	C+Du+P+F	5	0.67	5	3286
11	C+P+F	10	0.21	5	7190
12	C+P+G+F	7	0.48	3	14047
13	C+D+F	16	0.23	4	15910

14	C	21	0.32	5	9154
15	D	2	0.078	4	5180
16	D+Du	1	0.17	5	4420
17	D+Du+P+F	1	0.01	5	5900
18	D+P	2	0.026	5	4490
19	P	1	0.026	7	1000

N.B. C-crops, D-Dairy, Sh-sheep, P-poultry, Du-duckery, G-goatery, F-fishery

In total, 116 numbers of farmers from these two villages (61 nos. from Bali Majherpara and 55 nos. from Birajnagar Adibasipara) were taken into consideration for the present study. At first, bench mark study has been carried out with the collection of data on yield and income through crops/animal/fishery, crop coverage, irrigation sources and other socio-economic conditions through personal interview with the help of a pre-tested and well-structured schedule. The identified farmers were grouped into 19 farming systems, fishery (water harvesting tank for domestic use) is common component for 85% of them followed by crop component (81%). A significant number of farmers (5%) followed crop + dairy + sheep + fishery system and observed best in terms of gross return (Rs. 41,824/- per household), followed by crop + dairy + duckery + poultry + fishery (Rs. 37,195/- per household) (Table 1).

Production challenges and strategy for their mitigation

The primary factor limiting efficient productivity was farmers' decreased confidence in managing farm activities following the disastrous *Aila*. In order to run agricultural operations, shortage of both funds and inputs like seed, fertilizer, etc. was observed. Other crop specific and animal/fishery specific production challenges along with strategies to address them are mentioned in table below (Table 2).

Table 2: Major production challenges and the options to overcome them

Component	Challenges	Options	Remarks
***Kharif* Rice**	a) Soil salinity after *Aila* b) Poor fertilizer application c) Use of poor quality seed	a) *Dhaincha, azolla and* organic matter application b) Balanced fertilizer c) Certified seed	Rainy season salinity allows rice farming
Chilli	a) Soil salinity after *Aila* b) Irrigation problem c) Thrips infestation	a) Organic matter application b) Plant protection c) Life saving irrigation	Remunerative crop before *Aila*
Sunflower	a) Salinity after *Aila* b) Timely quality seed supply c) Irrigation problem	a)Timely quality seed supply b) Application of organic matter c) Life saving irrigation	Some farmers cultivated before *Aila*
Watermelon	a) Salinity after *Aila* b) Lack of seed c) Irrigation problem	a) Application of organic matter b) Quality seed supply c) Life saving irrigation	Some farmers get remuneration before *Aila*
Milch Cow	a) No fodder due to salinity b) No health care c) Poor breed	Green fodder supply with quax, *azzola* and napier Vaccination, and mineral mixture	Animal population was severely reduced due to *Aila*
Poultry	a) Poor breed b) No health care c) Inadequate feed	a) RIR/Vanaraja breed suitable in backyard farming system b) Supplementation of mineral and vitamin for optimum growth, *azzola* feeding c) Proper vaccination and deworming	Animal population was severely reduced due to *aila*
Duck	a) Poor breed b) No health care c) Inadequate feed	a) Khaki campbel breed suitable b) Supplementation of mineral and vitamin for optimum growth, *azzola* feeding c) Proper vaccination and deworming	Animal population was severely reduced due to *Aila*
Goat	a) Disease problem b) Worm infestation c) Poor and reduced growth	a) Prevention of diseases by proper vaccination b) Control of worm load by regular deworming c) Prevention of poor and reduced growth by supplementation of Vitamin and mineral supplementation	Animal population was severely reduced due to *Aila*
Sheep	a) Poor breed b) No health care c) Inadequate feed	a) Introduction of garol breed b) Control of worm load by regular deworming c) Prevention of poor and reduced growth by supplementation of Vitamin and mineral supplementation	Animal population was severely reduced due to *Aila*

Fishery	a) Improper ratio of carp species b) High mortality c) No scientific knowledge regarding water pH d) No application feed	a) Development good supply chain of fingerlings b) Application cowdung and ricebran c) Maintenance of optimum pH of water with lime d) Supplementation of fish feed	Fishery was looked after by CIFA
Agricultural implements and accessories	a) Harvested rain water is the only source of irrigation b) All the agril. work is done manually c) Poor residue management	a) Supply of pump sets and delivery pipes in group b) Paddle thresher/sprayer supplied c) Vermicomposting and composting was done. Farmers were supplied vermin bag	Good quality branded materials were supplied after formation of group
Capacity building	Famers were lagging behind modern agro-techniques and management of their animal resource	In-situ as well as ex-situ training was provided for crops and animals	Experts from BCKV, CIFA, WBUAFS were hired

Economic Impact Assessment before and after intervention

Comparative study regarding economic impact before and after the intervention phase has been worked out by computing the geometric mean levels of System Rice Equivalent Yield (REY) and their input use by the tribal farm households in Bali Island of Sundarban, West Bengal. The difference has been calculated in percentage.

Percent change in intervention = $\left(\frac{After\ intervention - Before\ intervention}{Before\ intervention} \times 100\right)$

REY (of crop x) = Yx X (Px/Py),

where, REY is rice equivalent yield of other crops and animal products in kg ha^{-1}, Yx is the yield of other crop or animal product, Px is the price of other crop and animal products, Py is the price of rice. Impact of different interventions were explained in terms of seed use before intervention and last year of experiment, NPK requirement, availability of organic matter, need for plant protection chemicals, irrigation hour, availability of machine power, requirement of human labour and ability to produce in terms of REY. All of these indices converted into per hectare for easy understanding.

Data analysis

The residual standard error is a measure of the typical size of the residuals, or the differences between the observed values and the predicted values from the model. A large residual standard error suggests that there is considerable unexplained variability in the data after accounting for the effects of the model. In this case, if the residual standard error is significantly large, it may indicate that there are other factors not accounted for in the model that could explain some of the variability in the "Amount" variable. For this ANOVA followed by Tukey HSD test (honestly significant difference) have been performed for acreage and yield data. The p-value for significance at 5% level is 0.3236 at 3 df, beyond this all the pairwise differences would be statistically significant.

Residual standard error = $\sqrt{\Sigma(y - \hat{y})^2/df}$,

where, y: The observed value. ŷ: The predicted value. df: The degrees of freedom, calculated as the total number of observations – total number of model parameters.

RESULTS AND DISCUSSION

In *kharif* season, rice is one of the most integral components of farming system. After harvesting of rice, pulses and oilseeds are grown by using harvested rain water in farm pond. Due to the occurrence of *Aila in* 2009, soil salinity has increased. Not only the salinity, but there was a huge reduction in number of animals as well as credit supply for farm operation. Previously mentioned crop or component specific interventions were followed step by step for 3 consecutive years (2016-17, 2017-18 and 2018-19). Farmers gained confidence as a result of trainings and the availability of various inputs. Their confidence was reflected with the expansion of cultivated area and the quantity of animals. Significant improvements were noted in the total area under crops and animal population- from 24.41 to 66.10 ha under rice, 0.78 to 1.70 ha under potato, 0.58 to 4.25 ha under chilli, 1.00 to 5.30 ha under *khesari*; in case of animals, number of dairy animals increased from 84 to 114, poultry birds from 192 to 1215, ducks from 60 to 182 and goats from 82 to 350. Enhancement in production was also observed *viz.*, from 43.9 to 297.5 tonne of rice, 6.1 to 37.4 tonne of potato, 0.5 to 6.9 tonne of chilli, 0.5 to 5.8 tonne of *khesari*, 8905 to 13794 lit of milk, 9600 to 85714 eggs of poultry, and lastly 3300 to 17290 eggs of duck. Crop diversification with onion, mustard, sunflower and watermelon was successfully implemented (Table 3). Ansari *et al.* (2014) in north eastern region observed a remarkable increase in production of crops and animals after adopting a proper package of practices. Rao *et al.* (2019) reported that crop +goat +fish system recorded higher rice equivalent yield of 39,610 kg/ha than other systems.

Impact of the whole project was assessed at the end of the study period (2019-20). As a result of growing interest of farmers in the project area, significant expansion of cultivated area was noticed which ultimately increased the seed use (38.88%). Before intervention, rice-fallow and rice-*khesari* were dominant cropping system with low level of cropping intensity (105%). After intervention, several new cropping systems, like rice-moong, rice-*okra*, rice-potato (zero tilled under mulching) were observed as feasible which increased the cropping intensity (150-200%) and production (577% increase in rice). Apart from increasing cropping intensity in field crops, scarce fresh water available in household pond lifted by project pump and delivery pipe gave a significant boost in cropping intensity in homestead area year-round vegetable-vegetable-vegetable system (300% cropping intensity). Mandal *et al.* (2020) reported similar findings while working with 90 farmers in coastal West Bengal. After intervention, they observed 200-300% enhancement in cropping intensity and the income enhanced 2 to 5 times in comparison to baseline. Due to intensification and diversification of cropping system as well as of area expansion, a significant increase (207.11%) in REY was noticed. The results of this experiment is supported by the findings of Upadhaya *et al.* (2022), where they recommended vegetable and legume as viable option for enhancing productivity, profitability and soil health. The data in table 4 show that an increase in use of organic matter (904.94%) due to significant increase in animal population which had reduced the application of chemical fertilizer by 20.88% in the form of NPK. To reduce the drudgery of tribal farmers, one paddle thresher was given to each group consisting of 3 farmers for threshing of rice, whereas one irrigation pump along with 200 ft delivery pipe was given to each group of 5 farmers.

On an average 56% of Indian farmers depend on animal-drawn/manual implements, machines, and hand tools (Singh and Dadlani, 2022), whereas 100% of the farmers in this experiment comes under this category. They use very small equipments like spade, sickle, country ploughs, etc. for performing agricultural operation which increases drudgery. Drudgery is defined as dull, repetitive, time-consuming, irritating and fatigue-causing work. Due to higher use of agricultural machinery (76%), requirement of man power got reduced (12.12%) and significantly got rid of drudgery. The pumps and delivery pipes provided by the project did significant contribution to efficient utilization of most scarce fresh water for agricultural operation. A significant rise in irrigation hours (267%) may be attributed to the increase in crop coverage, crop intensification and crop productivity (Table 4). Solar photovoltaic water pumping system found to diversify the crop and increase crop yield which provides sustainable solution to enhance water use efficiency in agricultural field (Shinde and Wandre, 2015).

Pesticides are indispensable in agricultural production and which have been used by farmers to control weeds, insects and diseases. They have been reported to increase agricultural production remarkably and about one third of global agricultural production depends on agricultural chemical. In general, consumption of plant protection chemicals increases with the increase in cropping intensity (Tudi *et al.*, 2021). In our experiment, increase in cropping intensity led to more consumption of plant protection chemicals (698%) (Table 4).

Table 3: Crop specific/component specific improvements after intervention in the study area

Crop/ animal	Area of crops (ha) / No. of animals for 116 farmer					Yield of crops in tones/ Milk yield (lit) /Egg no. for poultry and duck/Meat (kg) for 116 farmers									
	2015-16	2016-17	2017-18	2018-19	*RSE	2015-16	REY (kg)	2016-17	REY (kg)	2017-18	REY (kg)	2018-19	REY (kg)	*RSE
Kharif Rice	24.41	24.41	28.00	66.10	1.81^{S}	43.9	43900	76.40	76400	126.50	43900	297.50	43900	1.38^{S}
Boro Rice	1.02	2.67	2.36	1.70	0.60^{S}	35.0	35000	13.90	13900	79.10	43900	8.70	43900	0.97^{S}
Potato	0.78	1.82	1.62	1.70	0.49^{S}	6.1	5545	32.70	29727	35.10	31909	37.40	34000	0.99^{S}
Chilli	0.58	2.50	3.20	4.25	0.49^{S}	0.5	3045	4.10	24973	5.60	34109	6.90	42027	0.26^{NS}
Khesari	1	2.00	4.00	5.30	1.89^{S}	0.5	909	1.60	2909	4.10	7455	5.80	10545	2.95^{S}
Vegetables	1.22	2.01	2.02	3.20	0.89^{S}	5.6	4073	15.30	11127	15.30	11127	14.50	10545	1.99^{S}
Onion	-	1.33	1.54	1.65	0.60^{S}	-	0	12.00	21818	16.90	30727	18.60	33818	1.93^{S}
Mustard	-	-	0.08	1.00	0.26^{NS}	-	0	-	-	0.20	909	0.20	909	0.97^{S}
Sunflower	-	0.16	1.09	1.00	0.59^{S}	-	0	0.10	455	1.20	5455	2.10	9545	0.98^{S}
Watermelon	-	2.23	0.98	1.50	0.59^{S}	-	0	18.00	13091	6.00	4364	12.00	8727	0.98^{S}
Dairy	84	84.00	113.00	114.00	0.85^{S}	8905	16190	10810	18293	13899	23521	13794	23343	1.49^{S}
Poultry	192	500.00	425.00	1215.00	0.98^{S}	9600	1309	42500	5795	53125	7244	85714	11688	1.78^{S}
Duckey	60	150.00	160.00	182.00	1.85^{S}	3300	600	11250	2045	14400	2618	17290	3144	1.53^{S}
Goatery	82	180.00	220.00	350.00	0.45^{S}	395	8977	1293	29838	2179	50285	1876	40200	1.28^{S}

Note: Yield of crops and animal in each year were converted into REY and presented corresponding next column, *RSE: Residual Standard Error of difference , S-significant and NS-not significant

Table 4: Economic impact study before and after intervention phases (ha^{-1})

Sl. No.	Particulars	Before intervention	After intervention	Improvement (%)
1	Seed (kg.)	50.68	70.13	38.38
2	NPK (kg nutrient)	192.46	152.28	-20.88
3	Organic Manure (kg)	32.37	325.30	904.94
4	PPC (gm)	0.50	3.99	698.00
5	Irrigation (hours)	1.00	3.67	267.00
6	Machine Labour (hours)	12.36	21.78	76.21
7	Human Labour (hours)	800.58	703.57	-12.12
8	REY (kg. ha^{-1})	3329.26	10224.52	207.11

N.B. PPC-plant protection chemical

CONCLUSION

It can be inferred from the present study that farming system interventions with different critical inputs and capacity building activity have changed the life of *Aila* affected tribal farming communities. A significant confidence among the marginal tribal farmers for conducting farm operations was noticed. Utilizing minor farm equipments such as paddle paddy threshers as well as small pump sets along with delivery pipes and other critical inputs, they diversified and intensified the cropping system as well as farming system. Farm income enhanced significantly for those farmers who practiced crop-livestock-fishery system. In the end, this project led to overall progress in terms of cropped area, animal counts, productivity, reduction in drudgery, food and nutritional security, employment opportunities and economic betterment.

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