J. Indian Soc. Coastal Agric. Res. 42(1):175-188(2024) https://doi.org/10.54894/JISCAR.42.1.2024.145448

Integrated Farming System Options for Marginal Farmers in the Salt-affected Region of the Ganges Delta

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Received: 20.11.2023 Accepted: 20.03.2024

Studies were conducted for two years (2021-22 and 2022-23) in the Sundarbans region of the Ganges Delta, to determine the suitable planting dates for fodder crops as a component of an integrated farming system (IFS) model and to find out the sustainable IFS options for increasing the income of small-holder farmers. Rice bean, para grass, humidicola grass, guinea grass and Hybrid Napier Bajra (HNB) were evaluated as fodder crops on three dates of planting *viz.*, first week of July, first week of August and first week of September during the *Kharif* season. During the *Rabi* season, fodder crops *viz.*, alfalfa, berseem, guinea grass, HNB, humidicola grass, oat, para grass, sorghum, water spinach and Nandi grass were evaluated under three dates of planting *viz.*, first week of December, first week of January and first week of February. During both the seasons, early planting of fodder crops resulted in higher green biomass yield. For the *Kharif* season, the most suitable fodder crops were HNB, para grass and humidicola grass. So far as fodder yield is concerned, sorghum (72-102 t ha^{-1}), HNB (57-129 t ha^{-1}) and oat (48-52 t ha^{-1}) as well as Nandi grass (88 t ha^{-1}) are promising fodder crops during the *Rabi* season. However, inclusion of legume fodders such as rice bean, alfalfa and berseem is recommended to provide a balanced diet to the animals and to maintain soil health. Among the two IFS models (Integrated rice - fish - fodder/mung bean based goat farming and integrated rice-fish-fodder based livestock farming), fodder crops with integrated goat farming were most profitable, however, in both systems, inclusion of the animal enterprise made the system more profitable. Compared to the current mono-cropping of rice, the IFS models were highly profitable (Benefit-cost ratio increased from 1.4 to 3.2-5.2) for small-holders in the salt-affected coastal region of the Ganges Delta.

(***Key words:*** *Coastal region, Economics, Fodder crops, Goat, Pisciculture*)

The coastal and island ecosystems of India are home to millions of the world's poorest and most vulnerable people: the majority of them are below the poverty line due to very low farm productivity and income (Sarangi *et al.,* 2016). The Indian coastal and island region covers 10.8 million ha along 8118 km of coast line and is home to about 14% of the nation's population (Ayyappan and Kumar, 2022). These regions are disadvantaged by poverty, food insecurity, environmental vulnerability and limited livelihood opportunities (Mainuddin *et al.,* 2019). Its land resource is vulnerable to degradation due to combinations of natural, hydrological and anthropogenic factors. The major drivers of land degradation are salinization, acidification, waterlogging with fresh/ brackish water, drainage congestion, erosion, etc. In India, out of 6.73 million ha of salt effected area, about 38% exists in coastal areas. Salinity build-up in coastal land takes place mainly due to salt ingress to aquifers, including shallow ground water, excessive withdrawals of ground water from coastal plain aquifers, sea water ingress, tidal water ingress, low rates of recharge, and poor land and water management. The secondary salinization in the coastal region can be exacerbated by excessive use of irrigation water and fertilizers.

The people of the coastal zone depend mainly on agriculture, aquaculture and allied activities, the productivity of which is very low and insufficient to meet the livelihood requirements (Bell *et al.,* 2019).

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Productivity constraints include soil salinity, prolonged waterlogging during and after the wet season, scarcity of good quality/fresh irrigation water, etc. Lands are generally mono-cropped with *Kharif* (June - December) rice, and have low productivity. However, there are opportunities for enhancing productivity of degraded coastal land and increasing livelihood security of farming communities by adopting farming systems approaches that focus on the efficient utilization and optimal management of the available vast natural soil and water resources of the region. However, the low productive mono-cropping system with limited income generation options from agriculture is fuelling the tendency for migration to cities in search of alternative livelihoods, especially by men. Though some of the farmers practice very small-scale animal husbandry, this was only to supplement household diets. One of the major constraints for intensifying animal farming is the unavailability of sufficient fodder for the animals.

There are cereal fodders *viz.*, maize (*Zea mays* L.), jowar/sorghum (*Sorghum bicolor* L.), oat (*Avena sativa* L.) and grasses (hybrid napier bajra - an inter-specific hybrid between bajra and napier grass), guinea grass (*Panicum maximum* Jacq.), para grass [*Brachiaria mutica* (Forssk.) Stapf] and legume fodders such as rice bean [*Vigna umbellata* (Thunb.) Ohwi and Ohashi], lucerne/alfalfa (*Medicago sativa* L.) and berseem/ Egyptian clover (*Trifolium alexandrinum* L.), that can be grown in this region. In this study, experiments were conducted to determine the suitable fodder crops and integrated farming system models for increasing income of small-holder farmers in the coastal salt-affected region of West Bengal.

MATERIALS AND METHODS

The field experiments were conducted in farmers' fields at Bijoynagar village in Bali island of the Indian Sundarbans. The study evaluated a range of fodder crops sown at different planting dates during the *Kharif* and *Rabi* seasons. The details of fodder crops, varieties used and other agronomic practices are given in Table 1. Alfalfa, berseem, rice bean, oat and sorghum were grown from seeds, whereas guinea grass, hybrid napier bajra (HNB), humidicola grass and para grass were propagated from stem cuttings with two buds called rooted slips. HNB is a semi-perennial grass.

***Table 1.** Details of fodder crops studied in the saline soils of Bali island of the Indian Sundarbans*

Fodder crops	Scientific name	Variety	Manure ($t\ ha^{-1}$)	Fertilizer dose ($kg\ N\text{-}P_2O_5\text{-}K_2O\ ha^{-1}$)	Spacing (row-row (cm) × plant to plant (cm))
Sorghum	*Sorghum bicolor*	CoFS 29	10	80-40-40*	50 × 30
HNB**	Bajra (*Penisetum glaucum*) × Napier grass (*P. purpureum*)	CO-3, CO-4, CO-5, Super Napier	10	80-40-40*	50 × 50
Oat	*Avena sativa*	Kent	5	120-60-40	25
Guinea grass	*Panicum maximum*	CO-1	5	90-50-40*	50 × 30
Para grass	*Brachiaria mutica*	Local	5	60-40-20*	60 × 20
Humidicola grass	*Brachiaria humidicola*	Local	5	50-25-20	100 × 50
Rice bean	*Vigna umbellata*	Bidhan Rice bean 1, Bidhan Rice bean 2	5	20-40-20	30 × 20
Alfalfa	*Medicago sativa*	CO-1	5	25-40-20	25
Berseem	*Trifolium alexandrinum*	BL 1	5	20-40-20	25

*Multicut, after each cut 40 kg N ha^{-1} was applied; **Hybrid Napier Bajra is a semi-perennial grass

In the *Kharif* season of 2022, five fodder crops *viz.*, rice bean, para grass, humidicola grass, guinea grass and HNB were evaluated for three dates of planting (D_1: First week of July, 2022, D_2: First week of August, 2022 and D_3: First week of September, 2022). During the *Rabi* season of 2021-22, nine fodder crops *viz.*, alfalfa, berseem, rice bean, guinea grass, HNB, humidicola grass, oat, para grass and sorghum were evaluated. During the *Rabi* season of 2022-23, ten fodder crops *viz.*, alfalfa, berseem, guinea grass, HNB, humidicola grass, oat, para grass, sorghum, water spinach and Nandi grass were evaluated. For the *Rabi* season, there were three dates of planting (D_1: First week of December, D_2: First week of January and D_3: First week of February). The experiment was conducted as a split-plot design with dates of planting in main plots and fodder crops in sub-plots with three replications of each treatment.

We studied the sustainable intensification options of integrated farming system (IFS) for the marginal farmers in the salt-affected coastal region of the Ganges Delta. The IFS model on rice-fish-fodder and mung bean-based goat farming was studied in a woman farmer's field at the Bijoynagar village of the Bali island with 6 bigha (8000 m^2) of land. The farmer cultivated rice during the *Kharif* season in 5 bigha of land. The farmer got training under the Australian Centre for International Agricultural Research (ACIAR) supported project on improved production practices of fodder crops. She was provided with technical knowhow and the seed inputs for fodder cultivation and the integrated rice-fish-fodder based goat farming model was evaluated in her farm. In this integrated farming system model, fodder cultivation was on 1000 m^2, homestead area including the goat shed was 1500 m^2, cultivated land for rice was 5000 m^2 and fish pond including dyke covered 500 m^2. After harvest of rice, mung bean was cultivated on 4000 m^2. Rain water was harvested in the farm pond, and the water was used for irrigation of crops as well as fish production. Goat rearing was the focus of this IFS, however other enterprises such as one dairy cattle, 16 poultry birds were combined in the homestead area apart from fish pond. The local 'Black Bengal' breed of the goat was used in this study. In the low land, rice was grown during the *Kharif* season and after that mung bean crop was grown using residual soil moisture. A few banana plants were grown on the dykes beside the pond.

The IFS model on integrated rice-fish-fodder crops-based livestock farming was established in another farmer's field in Bijoynagar village in Bali island of Sundarbans region of West Bengal. Training on improved fodder and vegetable crop cultivation technology along with inputs were also provided to the farmer for the integrated rice-fish-fodder based livestock farming. This IFS model was established on the farm area of 9133 m^2, out of which fodder cultivation covered 500 m^2, the fish pond with fruit crops on dykes and homestead area cover 1633 m^2 area (including 250 m^2 area was used for cattle shed), and rice cultivation during the *Kharif* season was on 7000 m^2 (during the *Rabi* season 467 m^2 was used for vegetables). The evaluation of planting dates for different fodder crops and the comparative performances of two IFS models are presented in this paper.

RESULTS AND DISCUSSION

Effect of dates of planting during *Kharif* season

Different varieties of fodder crops were grown to meet the fodder requirement of goats and dairy cattle in the study location. Date of planting had a significant impact on fodder yield (Fig. 1) during the *Kharif* season. The average green fodder yield was 58 t ha^{-1}, 34 t ha^{-1} and 24 t ha^{-1} for July, August and September planting, respectively. However, among the fodder crops, highest mean fodder yield was recorded for HNB (48 t ha^{-1}) followed by para grass (43 t ha^{-1}), humidicola grass (42 t ha^{-1}), guinea grass (30 t ha^{-1}) and rice bean (30 t ha^{-1}).

Effect of dates of planting during *Rabi* season

Planting dates had a significant effect on the performances of fodder crops during the *Rabi* season. Early planting during December after the harvest of *Kharif* rice resulted in highest fodder yield (Fig. 2 a & b). Delaying the planting to January reduced fodder yield by 22-33% and further delay until February, resulted in significant yield penalty upto 50-55%. Among the fodder crops, the best fodder yield was recorded from

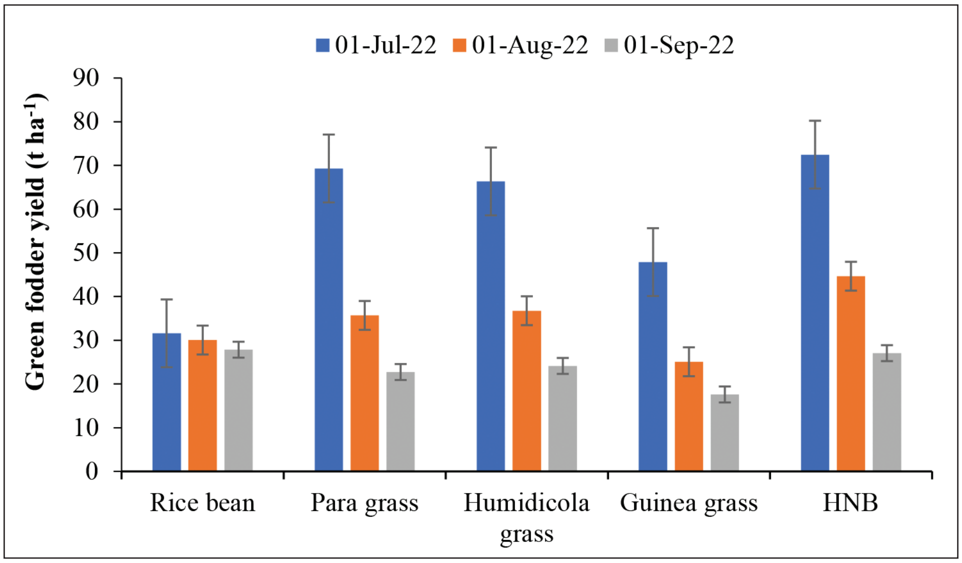

Fig. 1. *Green biomass yield of fodder crops during the Kharif (2022) season under three dates of planting at Bali Island, Sundarbans*

sorghum (72-102 t ha^{-1}), HNB (57-129 t ha^{-1}) and oat (48-52 t ha^{-1}). Nandi grass was also a promising fodder crop for this region with average green fodder yield of 88 t ha^{-1} (Fig. 2b). Even by delaying the planting to February for fodder sorghum and oat, fodder yield of 55 and 37 t ha^{-1}, respectively could be achieved. The yields of legume fodder crops were comparatively less. However, crop diversification with legume crops is essential for the balanced nutrition of animals, and may improve soil health while mitigating the risks of crop failure due to aberrant weather conditions. Hybrid napier bajra, being a perennial fodder crop, has a promising year-round production. It's performance both during the *Kharif* and *Rabi* seasons was better and annual fodder yield was significantly higher. Therefore, maintaining a combination of annual-perennial and cereal-legume combinations and staggered planting dates of fodder crops is beneficial for continuous fodder production on farms and maintaining the soil fertility.

Cultivation of sorghum and oat in rice-fallow patterns of the coastal saline region of the Ganges Delta can play an important role in providing adequate fodder for live stock-based IFS during the *Rabi* season. Additional fodder production will improve the health and nutrition of the existing livestock population in this region and will encourage the increase in livestock population, thereby increasing manure production. This, in turn, adds to the improvement of soil health of the salt-affected region. Sorghum being tolerant to moisture stress (Abreha *et al.,* 2022) and moderately tolerant to soil salinity, performed better as a fodder crop for this region.

Integrated rice-fish-fodder/mung bean based goat farming

In this IFS model the major animal component was goat. For goat rearing during 2021-22, ₹ 23546 was spent for 18 goats, including the initial housing cost of ₹ 20,000 (Table 2). From 18 goats and one dairy cattle about 1.2 tonnes of manure was produced in a year, which was used for improving the fertility of soils used for fodder production. During the subsequent year, the number of goats increased to 42, and the investment on rearing these animals was ₹ 17347. In addition to this, for meeting the fodder requirement of the animals, ₹ 5588 and 14871 were spent on cultivation of diverse fodder crops during 2021-22 and 2022-23, respectively (Table 3). The investment in goats and fodder crops was highly profitable with net income of ₹ 65866 during 2021-22 and ₹ 133782 during 2022-23 with BCR of 3.26 and 5.15, respectively. The goat unit during 2022-23 produced about 2.9 tonnes of manure, which were applied to soil for growing vegetable crops. Nutrient concentrations in the dry manure were: N - 2.8%; P - 0.42%; and K - 0.93%; therefore, there is significant

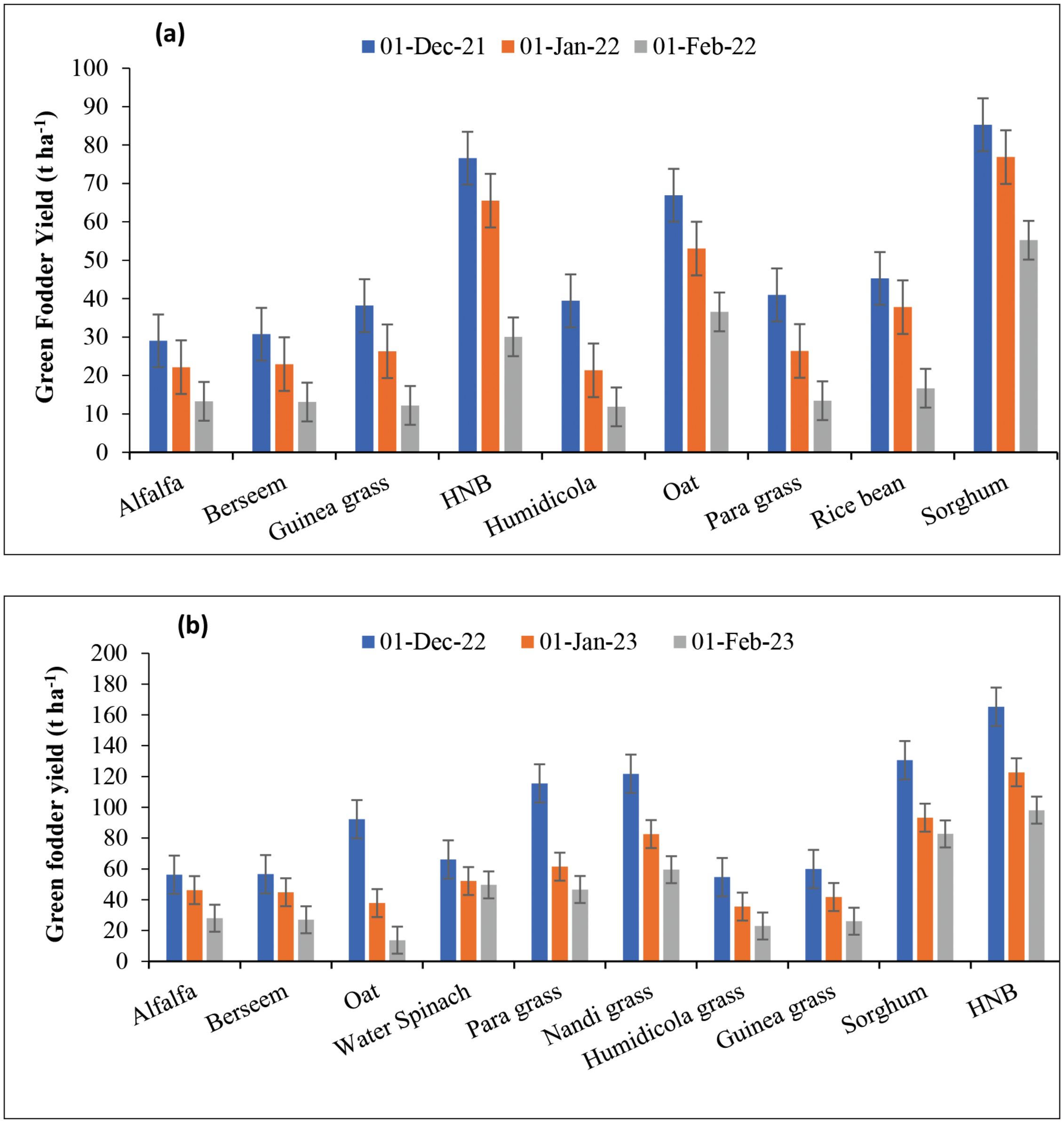

Fig. 2. *Effect of planting dates and fodder crops on green fodder yield at Bali island, Sundarbans during (a) 2021-22 and (b) 2022-23*

potential to reduce fertilizer costs for crop production by substituting goat manure for expensive inorganic fertilizer (Osuhor *et al.*, 2002).

Diverse fodder crops were grown on 1000 m^2 area in 2021-22 and on 2500 m^2 area in 2022-23 to meet the quality and quantity of green fodder requirements for the goat unit. All the fodders produced were used in the farm. HNB combines high quality and faster growth of bajra with the deep root system and multi-cut habit of napier grass. Sorghum, oat and rice bean were suitable fodder crops for goat farming. However, to meet the higher fodder demand with increasing number of animals, cultivation of high-yielding fodder crops such as HNB, sorghum and oat are essential. For utilizing the gaps among fruit trees, guinea grass is a suitable crop. Australian red napier and smart napier were also suitable. Nandi grass is another suitable fodder crop for this region. The grass is very leafy and quite palatable and highly nutritive, containing 5.3 - 6.9% crude protein (Trivedi, 2002).

Table 2. *Cost of rearing goats, cattle and poultry birds in 2021-22 and 2022-23*

Item	Amount	Rate (₹)	Total (₹)
2021-22			
Cost of housing, kids/chicks			20000
Dal Bhusi	25 kg	20	500
Chita Gur	20 kg	35	700
Salt	50 kg	6	300
Vitamin	5 L	100	500
Calcium			750
Total working capital			22750
Interest on working capital @ 7% p.a. for 6 months			796
Total cost of rearing 18 goats, one cattle and 11 poultry birds			23546
2022-23			
Wheat Bhusi	60 kg	35	2100
Mustard Cake	70 kg	35	2450
Maize Bhusi	50 kg	40	2000
Dal Bhusi	60 kg	25	1500
Chita Gur	125 kg	30	3750
Vitamin (Multi)	2 L	850	1700
Salt	150 kg	7	1050
Calcium	10 L	146	1460
Worms (Tablet)	50	15	750
Total working capital			16760
Interest on working capital @ 7% p.a. for 6 months			587
Total cost of rearing 42 goats, one cattle and 11 poultry birds			17347

Rice is the principal crop in this region, and as the staple food it contributes the major share of the calorie requirements of farming families. Also, the low-lying land is only suitable for rice cultivation during the *Kharif* season. However, rice cultivation alone is not profitable as the net return (₹ 9560 - 10281) from 5000 m^2 had a BCR of 1.37 - 1.38 (Table 4). The net returns and the BCR can be increased by adoption of direct seeded rice (DSR) because of the reduced costs of land preparation (Sarangi *et al.,* 2020).

Cultivation of mung bean during the *Rabi*/summer season was profitable with BCR of 1.64 and 1.89 during 2021-22 and 2022-23, respectively (Table 5). This crop not only augments the income of the farmers, but also is highly beneficial for maintaining soil health. In these nitrogen deficient soils, long-term cultivation of the nitrogen-fixing legume like mung bean can build soil nitrogen and addition of the crop (mung bean) residues may improve the soil organic carbon status.

The fodder crops - based goat farming model was highly profitable with net income of ₹ 88190 - 172540 from 8000 m^2 with BCR of 2.23 - 3.07 (Fig. 3a & b). In this model, the highest share (74.7 - 77.5%) of net income was obtained from goat farming. The highest BCR was also for this component followed by pisciculture and *Rabi* mung bean cultivation.

Integrated rice-fish-fodder based livestock farming

This diversified integrated farming system was developed by growing fodder crops round the year. Dairy milk yield was 3 L day^{-1} for about 5 months, of which 2 L day^{-1} was sold in local markets for about 5 months. For another two months, the milk yield was one

***Table 3.** Economics of fodder crops based integrated goat farming in Sundarbans, West Bengal during 2021-22 and 2022-23*

Cost of fodder cultivation	Amount	Rate (₹)	Total (₹)	Amount	Rate (₹)	Total (₹)
	2021-22			2022-23		
Seed	2 kg	100	200	5 kg	120	600
Land preparation	Ploughing by power tiller	350	350	Ploughing by power tiller	1300	1300
Planting	1 person-day	350	350	2.5	400	1000
Fertilizers*			500			1308
Urea	12 kg	11 kg^{-1}		30 kg	11.5 kg^{-1}	
SSP	25 kg	11.2 kg^{-1}		62.5 kg	12 kg^{-1}	
MOP	3.5 kg	25 kg^{-1}		8.5 kg	25 kg^{-1}	
Cost of irrigation			500			1500
Harvesting	4 labourers	350	1400	12	400	4800
Family labour			2100			3860
Total working capital			5400			14368
Interest on working capital @ 7% p.a. for 6 months			189			503
Total cost of fodder cultivation for 1000 m^2 area in 2021-22 and 2500 m^2 area in 2022-23			5589			14871
Cost of goat rearing (from Table 2)			23546			17347
Total cost of fodder cultivation + goat rearing			29134			32218
Returns from fodder crops based integrated goat farming						
Gross Return (Sale of goats and poultry birds, ₹)			95000			166000
Net Return (₹)			65866			133782
BCR			3.26			5.15

L day^{-1}, which was used only for home consumption. Under this IFS model, fodder crops were cultivated on 500 m^2, for which an expenditure of ₹ 2102 - 2384 was incurred (Table 6). All the green biomass produced from fodder cultivation were fed to the dairy cattle. The dairy unit also required various animal husbandry care, vitamins and mineral supplements. The dairy unit resulted in a net return of ₹ 26092 - 31218 with BCR of 2.38 - 2.47 (Table 7).

Pisciculture is another profitable enterprise of this model, which provided nutrition to the farming family as well as additional return from the sales of fish in the local market. The net return from a pond area of 1133 m^2 was ₹ 9365 in 2021-22 and ₹ 14611 in 2022-23, with BCR of 2.15 and 2.60, respectively (Table 8).

Several vegetable crops such as tomato, brinjal, chilli was cultivated in the vegetable production unit on a small area (467 m^2). The vegetables produced were consumed by the family and the surplus amount sold in the local market. A net income of ₹ 5101 - 5800 could be recorded from vegetable production with BCR of 2.27 - 2.29 (Table 9).

Diversification of some of the land for perennial crops such as fruit trees (mango, sapota and coconut) produce additional income as well as reduce the risk due to failure of field crops. These crops also provide nutrition to the family (Table 10). Net income from the10 fruit trees varied from ₹ 12024 - 13044 with BCR of 2.35 - 2.40.

This IFS model also allocated a major land share for rice cultivation to meet the staple food requirement. As in the other model, this component also resulted in the lowest BCR of 1.44 - 1.47 (Table 11). However, this enterprise is the default unit, which provided the grains as well as straw for various household uses. The lowland ecosystem predominant in the coastal region is

Table 4. *Economics of rice cultivation (area 5000 m^2) in 2021-22 and 2022-23*

Item	2021-22			2022-23		
	Amount	Rate (₹)	Total (₹)	Amount	Rate (₹)	Total (₹)
Seed	15 kg	50 kg^{-1}	750.00	15 kg	50 kg^{-1}	825.00
Land preparation	12.5 hr	350 hr^{-1}	4375.00	12.5 hr	350 hr^{-1}	4375.00
Fertilizers						
MOP	50 kg	40 kg^{-1}	2000.00	50 kg	40 kg^{-1}	2000.00
SSP	100 kg	12 kg^{-1}	1200.00	100 kg	12 kg^{-1}	1200.00
Urea	75 kg	12 kg^{-1}	900.00	75 kg	12 kg^{-1}	900.00
Lime	50 kg	12 kg^{-1}	600.00	50 kg	12 kg^{-1}	600.00
Oilcakes	50 kg	35 kg^{-1}	1750.00	50 kg	35 kg^{-1}	1750.00
Transplanting	15 person-days	300 day^{-1}	4500.00	15 person-days	350 day^{-1}	5250.00
Neem oil (10000 ppm)	0.3 L	1700 L^{-1}	510.00	0.3 L	1700 L^{-1}	510.00
Flubendiamide 20% WG (Takumi)	0.05 kg	7000 kg^{-1}	350.00	0.05 kg	7000 kg^{-1}	350.00
Harvesting	15 person-days	300 day^{-1}	4500.00	15 person-days	350 day^{-1}	5250.00
Threshing	10 person-days	300 day^{-1}	3000.00	10 person-days	350 day^{-1}	3500.00
Cost of cultivation			24435.00			26510.00
Interest @ 7% p.a. for 6 months			855.20			967.60
Total cost of cultivation			25290.00			27478.00
Returns from rice cultivation						
Parameters			2021-22		2022-23	
Gross return (₹ ha^{-1})			34850.00		37759.00	
Net return (₹ ha^{-1})			9560.00		10281.00	
BCR			1.38		1.37	

suitable for rice growing during the *Kharif* season and the straw produced from this area is used for feeding the animals, and roof thatching of the dwelling house. There is great scope for using the paddy straw as a mulch for growing vegetables such as potato under zero tillage cultivation after the harvest of rice (Sarangi *et al.*, 2021). Rice-ZT potato with paddy straw mulching-green gram is the most profitable and environment friendly (low water and carbon footprints and less greenhouse gas emissions) cropping system for the coastal saline region of the Ganges Delta.

In the cattle-based IFS model, among the different enterprises, highest net return and BCR was recorded from cattle with fodder from a comparatively small area of 750 m^2 during both the years of study (Fig. 4a & b). The net return varied from ₹ 26092 - 31218 with BCR of 2.38 - 2.47. During the first year, pisciculture in an area of 1133 m^2 produced net return of ₹ 9365 with BCR of 2.15, which significantly increased during the second year with net return of ₹ 14611 and BCR of 2.6 (Fig. 4b). Cultivation of fruit crops such as mango, sapota and coconut on a very small area of 250 m^2 was also profitable during both the years with net return of ₹ 12024 - 13044 and BCR of 2.35 - 2.40. Paddy crop occupied the largest area of 7000 m^2 in this model, which contributed to the net return of ₹ 14425 - 15366, but the BCR was the lowest (1.44 - 1.47) among all the enterprises. After the harvest of paddy, vegetable crops were cultivated in an area of 467 m^2, which contributed to the net income of ₹ 5101 - 5800 with BCR of 2.27 - 2.29. Overall, this IFS model resulted in net income

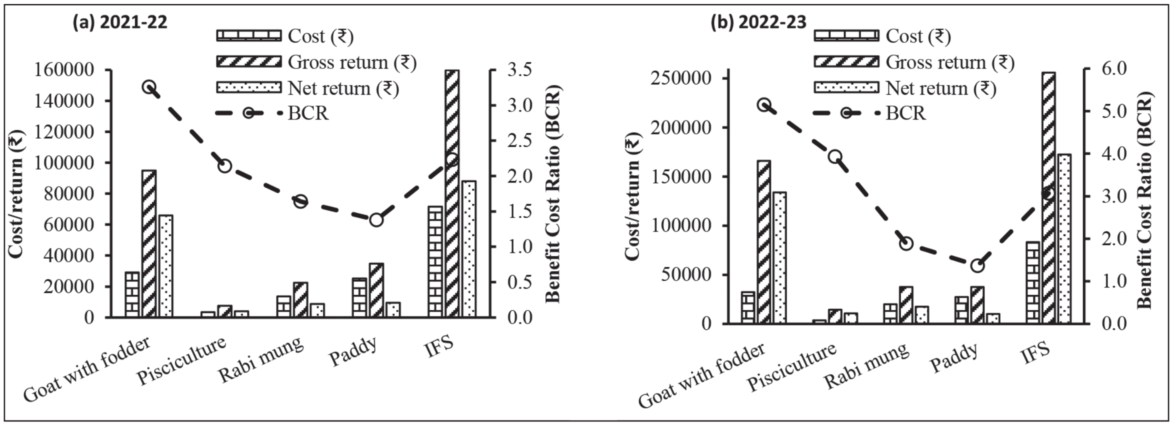

Fig. 3. *Economics of integrated rice-fish-fodder based goat farming during (a) 2021-22 and (b) 2022-23. Total area of the IFS was 8000 m^2 comprising the goat fodder unit (2500 m^2), pisciculture (500 m^2) and paddy land (5000 m^2). After harvest of paddy, mung was cultivated on 4000 m^2*

Table 5. *Economics of Rabi mung bean cultivation (area 4000 m^2) during 2021-22 and 2022-23*

Items	2021-22			2022-23		
Cost of cultivation	Rate (₹)		Amount (₹)	Rate (₹)		Amount (₹)
Hired labour	1/3 of produce	150 kg mung bean	7500	1/3 of produce	167 kg mung bean	12525
Family labour	20	300	6000	20	350	7000
Working capital			13500			19525
Interest @ 7% p.a. for 3 months			236.25			356.33
Total cost of cultivation			13736.25			19881.33
Seed yield	450 kg	50	22500	500 kg	75	37500
Returns from mung bean cultivation						
Parameters						
Gross return (₹ ha^{-1})			22500.00			37500.00
Net income (₹ ha^{-1})			8763.75			17618.67
BCR			1.64			1.89

Table 6. *Cost incurred for cultivation of fodder crops in 500 m^2 area during 2021-22 and 2022-23*

Item	Amount	Rate (₹)	Total (₹)	Amount	Rate (₹)	Total (₹)
	2021-22			2022-23		
Seed/planting material cost	2 kg	100 kg^{-1}	200	2 kg	120 kg^{-1}	240
Land preparation	0.5 hr	350 hr^{-1}	175	0.5 hr	400 hr^{-1}	200
Planting	1 person-day	300 person-day^{-1}	300	1 person-day	350 person-day^{-1}	350
Fertilizers	5 kg urea	11 kg^{-1}	55	5.5 kg urea	11.5 kg^{-1}	63.30
Cost of irrigation	4 hr	100 hr^{-1}	400	4 hr	100 hr^{-1}	400
Harvesting	3 person-days	300 day^{-1}	900	3 person-days	350 day^{-1}	1050
Total working capital			2030			2303.30
Interest on working capital @ 7% p.a. for 6 months			71.05			80.62
Total cost of cultivation for 500m^2 area			2101.05			2383.92

Table 7. *Economics of cattle rearing under IFS in the Bali island of Sundarbans, West Bengal during 2021-22 and 2022-23*

Cost of rearing cattle (Cows: 2, Male animals: 2 and Calf: 1) for one year						
Item	Amount	Rate (₹)	Total (₹)	Amount	Rate (₹)	Total (₹)
	2021-22			2022-23		
Paddy husk	0.5 kg cattle^{-1}	10 kg^{-1}	9125.00	0.5 kg cattle^{-1}	11 kg^{-1}	10037.50
Labour	1 hr day^{-1}	300 day^{-1}	4562.50	1 hr day^{-1}	350 day^{-1}	5322.91
Medicine			1000.00			1150.00
Vitamin			500.00			575.00
Calcium			500.00			570.00
Worms (Vermox)	20	1 dose^{-1}	20.00	25	1 dose^{-1}	25.00
Cost of rearing 5 no. of cattle			15707.50			17680.41
Interest on working capital @ 7% p.a. for 12 months			1099.53			1237.63
Total cost of rearing 5 cattle for one year			16807.03			18918.04
Return from cattle unit						
Sale of male animals	1	12000.00	12000.00	1	15000.00	15000.00
Sale of cows	1	9000.00	9000.00	1	10000.00	10000.00
Sale of milk	2 kg day^{-1} (5 months)	40.00 kg^{-1}	12000.00	2 kg day^{-1} (5.5 months)	44 kg^{-1}	14520.00
Sale of goat	2	6000.00	12000.00	2	6500	13000.00
Returns from cattle rearing						
Gross return from cattle (₹)			45000.00			52520.00
Net return from cattle (₹) Gross return - (cost of fodder cultivation+ cost of cattle rearing)			26091.93			31218.04
BCR			2.38			2.47

Table 8. *Economics of pisciculture (pond area: 1133 m^2) under IFS at Bali Island, Sundarbans, West Bengal during 2021-22 and 2022-23*

Cost of fish cultivation in pond area of 1133 m^2						
Items	Amount	Rate (₹)	Total (₹)	Amount	Rate (₹)	Total (₹)
	2021-22			2022-23		
Fingerlings	12 kg	375 kg^{-1}	4500.00	13 kg	377 kg^{-1}	4901.00
Lime	30 kg	12	360.00	33 kg	13	429.00
Labour	10	300	3000.00	10	350	3500.00
Cost of fish cultivation			7860.00			8830.00
Interest @ 7% p.a. for 6 months			275.10			309.05
Total expenditure of fish unit			8135.10			9139.05
Home consumption	150 kg	100 kg^{-1}	15000.00	153 kg	125 kg^{-1}	19125.00
Sale in local market	25 kg	100 kg^{-1}	2500.00	37 kg	125 kg^{-1}	4625.00
Returns from fishery unit						
Gross return			17500.00			23750.00
Net return			9364.90			14610.95
BCR			2.15			2.60

Table 9. *Economics of vegetables cultivation on 467 m² during 2021-22 and 2022-23*

Cost of vegetable cultivation in cultivated area of 467 m²						
Seed	Amount	Rate (₹)	Total (₹)	Amount	Rate (₹)	Total (₹)
	2021-22			2022-23		
Tomato	5 g	85 g^{-1}	425.00	5 g	87 g^{-1}	435.00
Brinjal	5 g	13 g^{-1}	65.00	5 g	14 g^{-1}	70.00
Green chilli	5 g	45 g^{-1}	225.00	5 g	47 g^{-1}	235.00
Others	30 g	18 g^{-1}	540.00	30 g	20 g^{-1}	600.00
Land preparation	0.66 hr	350 hr^{-1}	233.00	0.67 hr	400 hr^{-1}	268.00
Fertilizers	12 kg	17.5 kg^{-1}	210.00	12 kg	18.5 kg^{-1}	222.00
Transplanting	3 person-days	300 day^{-1}	900.00	3 person-days	350 day^{-1}	1050.00
Insecticide	10 g (Takumi)	7 g^{-1}	70.00	10 g (Takumi)	7.5 g^{-1}	75.00
Harvesting	4 person-days	300 day^{-1}	1200.00	4 person-days	350 day^{-1}	1400.00
Total			3868.00			4355.00
Interest @ 7% p.a. for 6 months			135.40			152.43
Total cost of vegetable cultivation			4003.40			4507.43
Home consumption in 4 months	116.5 kg	32 kg^{-1}	3728.00	117.5 kg	35 kg^{-1}	4112.50
Sale in market in 4 months	168 kg	32 kg^{-1}	5376.00	177 kg	35 kg^{-1}	6195.00
Returns from vegetable cultivation						
Gross return (₹)			9104.00			10307.50
Net return (₹)			5100.60			5800.07
BCR			2.27			2.29

Table 10. *Economics of fruits cultivation under integrated farming system during 2021-22 and 2022-23 in the Sundarbans*

Cost of fruit cultivation (one mango, 4 sapota and 5 coconut plants)						
Item	Amount	Rate (₹)	Total (₹)	Amount	Rate (₹)	Total (₹)
	2021-22			2022-23		
Sapling	10	60 $sapling^{-1}$	600.00	-	-	-
Manure	10	100 $sapling^{-1}$	1000.00	10	150	1500.00
Labour	20	350	7000.00	21	400	8400.00
Total cost			8600.00			9900.00
Interest @ 7% p.a. for 6 months			301.00			346.50
Total cost of fruit cultivation			8901.00			9346.50
Home consumption						
Coconut	150 nos.	15 $coconut^{-1}$	2250.00	145 nos.	17 $coconut^{-1}$	2465.00
Sapota	20 kg	35 kg^{-1}	700.00	17 kg	35 kg^{-1}	595.00
Mango	35 kg	40 kg^{-1}	1400.00	33 kg	40 kg^{-1}	1320.00
Sale in market						
Sapota	45 kg	35 kg^{-1}	1575.00	41 kg	35 kg^{-1}	1435.00
Coconut	1000 nos.	15 $coconut^{-1}$	15000.00	975 nos.	17 $coconut^{-1}$	16575.00
Return from fruit cultivation						
Gross return (₹)			20925.00			22390.00
Net return (₹)			12024.00			13043.50
BCR			2.35			2.40

Table 11. *Economics of rice cultivation (on 7000 m²) during Kharif season of 2022 and 2023*

Cost of rice cultivation in cultivated area of 7000 m²						
Item	Amount	Rate (₹)	Total (₹)	Amount	Rate (₹)	Total (₹)
	2022			2023		
Seed	18 kg	60 kg^{-1}	1080.00	18 kg	63 kg^{-1}	1134.00
Land preparation	12 hr	350 hr^{-1}	4200.00	12 hr	400 hr^{-1}	4800.00
Fertilizers						
MOP	50 kg	30 kg^{-1}	1500.00	50 kg	30 kg^{-1}	1500.00
SSP	50 kg	11.60 kg^{-1}	580.00	50 kg	12.0 kg^{-1}	600.00
UREA	100 kg	11 kg^{-1}	1100.00	100 kg	11.5 kg^{-1}	1150.00
Transplanting	24 person-days	300 day^{-1}	7200.00	24 person -days	350 day^{-1}	8400.00
Insecticide	100 g	7 g^{-1}	700.00	100 g	7 g^{-1}	700.00
Harvesting	30 person-days	300 day^{-1}	9000.00	30 person-days	350 day^{-1}	10500.00
Threshing	15 person-days	300 day^{-1}	4500.00	15 person-days	350 day^{-1}	5250.00
Cost of cultivation			29860.00			34034.00
Interest @ 7% p.a. for 6 months			1045.10			1191.19
Total cost of cultivation			30905.10			35225.19
Home consumption						
Paddy	900 kg	14.5 kg^{-1}	13050.00	910 kg	15 kg^{-1}	13650.00
Straw	60 Pon	12.5 Pon^{-1}	750.00	63 Pon	13 Pon^{-1}	819.00
Sale in market						
Paddy	2140 kg	14.5 kg^{-1}	31030.00	2370 kg	15 kg^{-1}	35550.00
Straw	40 Pon	12.5 Pon^{-1}	500.00	44 Pon	13 Pon^{-1}	572.00
Returns from rice cultivation						
Gross return (₹)			45330.00			50591.00
Net return (₹)			14424.90			15365.81
BCR			1.47			1.44

1 Pon = 30-35 kg

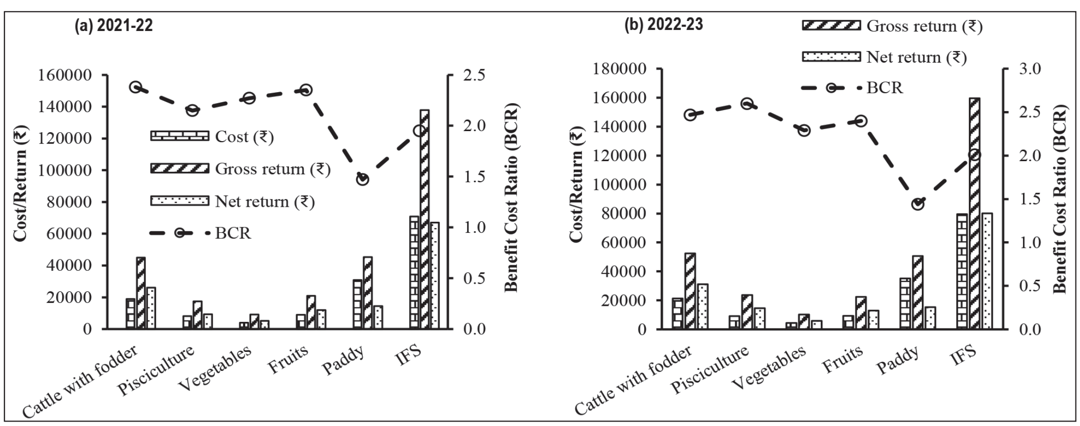

Fig. 4. *Economics of integrated rice-fish-fodder based livestock farming during (a) 2021-22 and (b) 2022-23. Total area of the IFS model was 9133 m² with areas allocated to cattle with fodder cultivation (750 m²), pisciculture (1133 m²), fruit crops (250 m²) and paddy cultivation (7000 m²). Vegetable crops were grown in an area of 467 m² during the Rabi season after the harvest of paddy crop*

of ₹ 67007 - 80039 from an area of 9133 m^2 with BCR of 1.95 - 2.01, with contribution to family nutrition and generation of manures by the cattle for fertilizing the soil for growing crops. The cow dung contains nitrogen, potassium, along with trace amount of sulphur, iron, magnesium, copper, cobalt and manganese (Gupta *et al.,* 2016). The IFS model is a more sustainable system than the monocropping of rice in this salt-affected region.

CONCLUSION

Out of the two IFS models studied, the fodder crops-based goat farming model was found to be more profitable than cattle-based farming. The net return from goat-based farming system from an area of 8000 m^2 was ₹ 88190 - 172540 with BCR of 2.23 - 3.07, whereas the net return from cattle-based farming system with an area of 9133 m^2 was ₹ 67007 - 80039 with BCR of 1.95 - 2.01. Therefore, fodder crops-based goat farming is recommended to be incorporated in the farming system in the salt-affected coastal region of the Ganges Delta. Along with adoption of IFS, the sustainable cropping system options for the study location include the conservation agriculture practices of recycling of crop residues, zero tillage planting of crops and diverse cropping system including legume crops such as mung bean. To minimize soil, weather and market-related risk situations in this region, diversification of enterprises such as inclusion of horticultural crops like vegetables and fruits is recommended. Pisciculture is another important enterprise of this region, and is practiced in dug out farm ponds. Farm ponds help in storage of good quality rain water for cultivation of fish as well as for irrigating the field and horticultural crops during the dry season. Therefore, a combination of rain water harvesting, pisciculture, diverse crops and animal enterprises has the potential to reduce the risks in the salt-affected coastal region, provide improved family nutrition and increase the income of small holder farmers.

CONFLICTS OF INTEREST

The authors declare no conflict of interests.

ACKNOWLEDGEMENT

We are grateful to the Australian Centre for International Agricultural Research (ACIAR) which supported the project on "Mitigating risk and scaling-out profitable cropping system intensification practices in the salt-affected coastal zones of the Ganges Delta".

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