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Research Paper

Productivity, profitability and livelihood improvement through integrated farming system for new alluvial zone of West Bengal

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ABSTRACT

A study was conducted during 2008–09 to 2010–11 on farmers' field utilizing aqua-terrestrial ecosystem situated under new alluvial zone of West Bengal, to find out the productivity and profitability of the integrated farming system especially effective for small and marginal farmers. Experiment comprised 11 enterprises, of which 5 sole system of crops and fishes and 6 treatments of integration of deep-water rice (*Oryza sativa* L.), underutilized aquatic food crops, water chestnut or *singhara* (*Trapa bispinosa* Roxb.) and foxnut or *makhana* (*Euryale ferox* Salisb.) and fish variables (mixture of carp and air-breathing live-fishes) under aquatic, ducks (*Khaki campbell*) in semi-aquatic and vegetables/other perennial tree plantations under arable land was carried out on 1.0 ha area. All the enterprize combinations were productive and profitable than that of sole system either aquatic crop or fishes individually. In these enterprizing combinations it not only led to higher productivity but also generated more income and employment opportunity sustainable for livelihood security including improvement of fertility status of pond-bottom soil. Maximum benefits were obtained from integrated farming system, where foxnut or *makhana* combined with live fisheries in aquatic including other variables practiced under adjacent arable lands, while lower values exhibited with deep-water rice integrated with carp-fishes. Among the sole system, foxnut or *makhana* and live fisheries performed better. Besides integration of fishes, duckery was found to be a good alternative farming system, especially for development of women empowerment in the areas.

Key words : Crop variables, Enterprize combination, Integrated farming systems, Livelihood, Productivity,

Integrated farming system represents a complicated interwoven mesh of soils, plants, livestocks, workers, farm inputs and environmental influences (Shekinah and Sankaran, 2007). Among the different system variables, some of these are necessary to manipulate as per need of the area as well as system approach for making it more productive according to their preferences and aspirations. The integration of crops and animals enables synergistic interaction, which has a greater total contribution than the sum of their individual effects (Edwards *et al.,* 1988). The Indian farming communities are dominantly small and marginal group, with average land holding of <2.0 ha. Hence it is essential to integrate suitable enterprizes at their optimal levels to capture the maximum benefits.

A meager information is available on evaluation of these underutilized aquatic food crops other than rice [water chestnut or *singhara* and foxnut or *makhana* and other important aquatic crops] integrated with fishes (mixture of carp and air-breathing live-fishes) in lowlying ecosystem. However, some studies were conducted and used enterprizes successfully under integrated farming system in the different areas of the country, as it can able to fetch more money owing to its high marketable price and preference of the common people. The introduction of fish along with deep-water rice in waste wetland ecosystems is common for the utilization of food and total productivity (Dutta *et al.,* 1984); Bandyopadhyay and Puste (2001) as well as for improving soil fertility by grazing on aquatic biomass and contributing through fish excreta to nitrogen accumulation at soil surface, enriched in consequence (Brahmanand and Mohanty, 1999; Puste and Das, 2001; Bandyopadhyay and Puste, 2001). To realize the facts, a study on sole as well as integrated farming systems was conducted on farmers' fields utilizing aqua-terrestrial ecosystem under new alluvial zone of West Bengal, India, to find out the suitable and optimize enterprize combinations for sustaining productivity, income generation and employment opportunity through cropping and related com-

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ponents utilizing all possible resources.

MATERIALS AND METHODS

A comprehensive field study was conducted during 2008–09 to 2010–11 on farmers' field utilizing aqua-terrestrial ecosystem (converted it into 1.0 ha basis) situated at Kalinarayanpur, Nadia, India under new alluvial zone (23°N and 89°E and of 9.8 meter above mean sea-level) of West Bengal. Integration of aquatic crops (deep-water rice and other valuable underutilized aquatic food crops) and fishes (mixture of carp and air-breathing live-fishes including snake-head type) under wetland, ducks in semi-aquatic situation and seasonal vegetables and other valuable tree plantations under adjacent terrestrial land system, utilizing altogether total area of approximately 0.50 + 0.50 ha i.e. 1.0 ha were conducted for establishment of all the variables at the beginning of the project.

Sufficient protection was undertaken at the time of field design and layout during very initial part of first year of the experiment (2008–09) before advent of rainy season. For these, need-based earth works were done of existing marshy wetlands for maintaining water level as well as for making big bunds for separation of plots, otherwise ploughing operations or intercultivation or intermittent interference may lead to accelerate the soil erosion. Moreover terrestrial were made for establishing vegetables and other plantations fruitfully. Adjacent dykes or bunds including land system (0.50 ha) along with border area were fully utilized covering seasonal vegetables including trailing types, banana, papaya and other valuable perennial tree plantations (coconut and other forest plantations) *etc.* The enterprises were selected based on the farmers' preferences, popularity and complementary nature of enterprises under aqua-terrestrial ecosystem of the area.

The studies comprised 11 enterprizes, of which 5 sole system, viz. FS_1, deep-water rice (cv. 'Sabita'; FS_2, water chestnut or *singhara* (cv. 'Kalinaraynpur'); FS_3, foxnut or *makhana* (cv. 'Katihar'); FS_4, mixture of carp fishes; and FS_5, mixture of live-fishes; and 6 integrated farming system comprising aquatic crops + fishes along with other enterprises, viz. FS_6, deep-water rice + carp-fishes + ducks + vegetables + banana + coconut + tree plantations; FS_7, deep-water rice + live-fishes + ducks + vegetables + banana + coconut + tree plantations; FS_8, water chestnut + carp-fishes + ducks + vegetables + banana + coconut + tree plantations; FS_9, water chestnut + live-fishes + ducks + vegetables + banana + coconut + tree plantations; FS_{10}, foxnut + carp-fishes + ducks + vegetables + banana + coconut + tree plantations; and FS_{11}, foxnut + live-fishes + ducks + vegetables + banana + coconut + tree plantations (Table 1). In every case, either as sole or integrated system, mixture of carp fishes (rohu - *Labeo rohita* Ham.; catla - *Catla catla* Ham.; and mrigal - *Cirrhinus mrigala* Ham.) and indigenous energy-rich live-fishes including snake-head (shoil - *Channa striatus*; gajar - *C. marulius*; singi - *Heteropnuestes fossilis* and magur - *Clarias batrachus*) maintained in 4 : 3 : 3 ratio were used under aquatic system. In addition, ducklings (*Khaki Campbell)* were distributed maintaining @ 6:2 ratio of female and male of total 8 ducks/woman distributed to 6 IFS women group × replicated 5 women in each IFS family) as semi-aquatic enterprizes, and seasonal vegetables (including leafy and trailing types), papaya (250 female plants), banana (150 plants, both green and ripening type), valuable perennial tree plantations at border line (coconut of 65 plants and other forest tree plantations about 75 saplings *etc.*) under terrestrial land system, respectively, was considered in the study. For calculation of production system in each enterprize (either as sole or integrated system), 1.0 ha area was considered both in sole and integrated system [aquatic crop + fish (0.45 ha) + ducks (0.05 ha) + vegetables (0.15 ha) + banana and papaya (0.10 ha) + coconut (0.15 ha) + other perennial tree plantations (0.10 ha) of shared area for converting it into t/ha basis, respectively]; so, altogether 1.0 ha. For feasibility of understanding, all the yield variables were converted to foxnut equivalent yield (FNEY) in t/ha.

Deep-water rice, water chestnut and foxnut were transplanted during the first week of July, maintaining at 20 cm × 20 cm and 25 cm × 25 cm; 1.5 m × 1.5 m and 2.0 m × 1.5 m and 1.5 m × 1.5 m and 2.0 m × 1.5 m row-to-row and plant-to-plant distance in sole and integrated system, using @ 3–4, 2–3 and 2–3 seedlings/hill respectively. Respective rice and other two crops were manured subsequently, following a well-balanced nutrients @ 3.0 t FYM or 1.0 t neem oilcake + N : P_2O_5 : K_2O @ 20 : 30 : 20 kg/ha and 1.0 t neem oilcake + N : P_2O_5 : K_2O @ 20 : 30 : 20 kg/ha. Besides fertilization, spraying was done to almost all the crops including vegetables with NPK + $ZnSO_4$ @ 0.5% each (altogether 2.0%) at 15 days interval after establishment of the crops. In tree plantation, initially bone dust and FYM @ 250 g and 2.5 kg/plant and during subsequent growth period, manuring @ 250–500 g bone dust and 5.0 kg FYM/plant (2 times, prior to rainy and after rainy season) was done for proper growth and development. In leafy-vegetables, a balanced nutrient combined with organic and inorganic fertilizers were applied @ 1.5 t FYM or 0.5 t neem oilcake/ha + N : P_2O_5 : K_2O @ 20 : 30 : 20 kg/ha and likewise in other vegetables, FYM @ 2.5 t or 0.75 t neem oilcake + N : P_2O_5 : K_2O @ 40 : 30 : 30 kg/ha.

Fingerlings of carp and live-fishes were stocked in sole and integrated system, maintaining @ 9,000 and 6,000/ha (100%) and 5,400 and 3,600/ha (about 60%) of 5–6 g each

carp and 40–50 g each live-fishes, respectively, during the last part of July after establishment of crops. A balanced fish-feed (rice bran + ground mustard oilcake in 1:1 ratio @ 6 times body weight at weekly interval) was supplied to the fish irrespective of the system. Ducklings (*Khaki campbell*, capable of hatching eggs on and from 5–6 months onwards and have the potentiality to hatch about 270–300 eggs/year) of 28–30 days old including necessary duck-feed was provided initially to six women groups. Coconut and other perennial tree plantations (covered 0.25 ha, i.e. 25% area under integrated system) are in grown up stage at the end of third year experimentation (2010-11) and obviously, would be effective fifth year onwards. Recurring pickings and consumption of water chestnut as immature fresh fruits were started from September, continued up to first part of December, while matured foxnut seed kernels were harvested at a time during the last part of December. After harvesting of crops, respective ponds were allowed further for growing fishes and it was continued up to the end of January till netting.

Labourers (irrespective of gender) engaged for different activities in each enterprize were recorded in terms of hours (hr) everyday and converted into mandays/ha/day. Irrespective of sole or integrated system, all enterprizes were managed individually and the results were combined for each system for its output.

Foxnut equivalent yield

For comparison among the crops, fishes and other variables of the enterprises due to heterogeneous characteristics, foxnut equivalent yield in terms of production (t/ha) was determined utilizing the produce value at the time of harvesting with the following formula:

$$\text{FNEY (t/ha)} = \frac{\text{Market price of the crop/fish/other enterprizes to be converted (₹)}}{\text{Price of makhana/t (₹)}}$$

Average market price of deep-water rice, water chestnut, foxnut, mixed of carp-fishes, live-fishes and average price of leafy and other vegetables and banana were considered 15,000, 13,000, 50,000, 73,333, 1,55,000 and 14,715 and 16,000/t, respectively. Profitability and employment generation of various enterprizes were calculated individually and compared based on FNEY. The involvement of labour for up keep in each enterprize under integrated farming systems was considered for comparison, based on employment generation. A regular inventory of the inputs (inclusive labour) and outputs of each enterprize was maintained and converted to monetary terms as per the market value, taking recycling between enterprizes into consideration as a measure of profitability of farming system enterprise. However, for comparison among the various treatments in the experiment, randomized block design (RBD) was considered especially for the calculation of system productivity (FNEY in t/ha), employment generation in each system (mandays) and soil characteristics. Initial and post experimental soil samples were collected from the pond for determination of organic carbon (0.58%), total nitrogen content (0.061%), available P_2O_5 (82.3 kg/ha) and K_2O (204.7 kg/ha) including post experimental pond soil characteristics following the standard as per the method described by Jackson (1973).

RESULTS AND DISCUSSION

System productivity

Sole and integration of aquatic crops-cum-fish culture (as sole FS_1 to FS_5 and as integration FS_6 to FS_{11}) under wetland; duckery under semi-wet; and seasonal vegetables, banana, papaya etc. other than valuable perennial tree plantations (coconut and forest plants) under terrestrial system were considered for compilation among themselves. Values of individual own yields as well as their respective equivalent yield are presented for understanding their yielding ability both as sole and in integrated system including other enterprises those performed under terrestrial or arable lands (Table 1 and 2).

Sole system

It may not be understood when sole as well as shared yield are expressing as such, as all these are heterogeneous in nature, not possible for comparison among themselves (Table 1), so, it was converted to express all the variables of their equivalent yield (Table 2). Comparing with individual yield of deep-water rice, water chestnut, foxnut (FNEY of 1.012, 2.455, 2.962 t/ha) under sole system was greater than that of yield obtained under integrated system of these individual enterprise, particularly with carp and live-fishes in their shared area (45%) as individual enterprises (0.467 and 0.454; 1.238 and 1.231; 1.571 and 1.492 FNEY in t/ha, when combined with crops, respectively). This might be due to less shared area as well as less population in this integrated farming system than that of sole system (Table 2). Likewise, two sole fish variables (carp and live-fishes) were more productive (FNEY of 4.327 and 4.526 t/ha) than that yield obtained in integrated system (FNEY of 2.247 and 2.511; 2.262 and 2.530; 2.223 and 2.585 t/ha, respectively when integrated with the crops), obviously due to more fish population per unit area and provided more shared area (100%) under these sole systems than the later. But considering the yielding ability of these variables under integrated system were obviously more, if it is being converted to 100% area basis (6.03 and

Table 1. System productivity (sole and shared yield under mixed culture in t/ha), mean contribution of components to each enterprize (t) in shared area or in respect to (average and pooled analyzed value of 3 years)

Farming system	Under aquatic ecosystem								Under aqua-terrestrial ecosystem				
	Production of sole crop and fish under aquatic ecosystem (t/ha in 100% area)				Production of mixed culture in aquatic system (t in 45% shared area)				Production of component variables (t per 55% shared area or in respect to monetary value)				
	DWR	WC	Mak	C-fishes	L-fishes	DWR + Fish	WC + Fish	Mak + Fish	Semi-aquatic	Terrestrial system (50% shared area)			
									Ducks (5%) (× 10^3)	Vegs (15%) (10%)	Ban, pap (× 10^3)	Cont (15%)	TPs (10%)
Sole system													
FS_1, DWR	3.37	-	-	-	-	-	-	-	-	-	-	-	-
FS_2, WC	-	9.64	-	-	-	-	-	-	-	-	-	-	-
FS_3, FN	-	-	2.96	-	-	-	-	-	-	-	-	-	-
FS_4, C-fishes	-	-	-	2.95	-	-	-	-	-	-	-	-	-
FS_5, L-fishes	-	-	-	-	1.46	-	-	-	-	-	-	-	-
Integrated Farming System (IFS)													
FS_6, DWR + C-fish + ducks + vegs + ban + cont + TPs	-	-	-		-	1.56 + 1.53	-	-	10.40	2.31	22.85	-	-
FS_7, DWR + L-fish + ducks + vegs + ban + cont + TPs	-	-	-	-		1.51 + 0.81	-	-	10.55	2.32	23.20	-	-
FS_8, WC + C-fish + ducks + vegs + ban + cont + TPs	-	-	-		-	-	4.76 + 1.54	-	10,.50	2.65	23.10	-	-
FS_9, WC + L-fish + ducks + vegs + ban + cont + TPs	-	-	-	-		-	4.73+ 0.82	-	10.90	2.66	23.55	-	-
FS_{10}, Mak + C-fish + ducks + vegs + ban + cont + TPs	-	-	-		-	-	-	1.57 + 1.52	11.05	2.74	23.40	-	-
FS_{11}, Mak + L-fish + ducks + vegs + ban + cont + TPs	-	-	-	-		-	-	1.49 + 0.83	11.15	2.80	23.80	-	-

FNEY, foxnut equivalent yield; DWR, deep-water rice; WC, water chestnut; Mak, *makhana*; C, carp; L, live; Vegs, vegetables; ban, banana; pap, papaya; TPs, tree plantations; cont, coconut. Average market price of DWR, WC, Mak, mixed of carp-fishes, live-fishes and average price of leafy and other vegetables and banana etc. were 15,000, 13,000, 50,000, 73,333, 1,55,000, and 14,715 and 16,000/t respectively.

Table 2. System productivity (individual and total yield in FNEY, t/ha), mean contribution of components to each enterprize (total yield in FNEY, t/ha) and employment generation of farming systems (average and pooled analyzed value of 3 years)

Farming systems	Under aquatic ecosystem					Under aqua-terrestrial ecosystem								System productivity (FNEY in t/ha)	Employment in each system (mandays)
	Production of sole crop under aquatic system (FNEY in t/ha) (100% area)					Production in mixed culture under aquatic system (FNEY in t per 45% shared area)			Component production (FNEY in terms of t per 55% shared area)						
	DWR	WC	Mak	C-fishes	L-fishes	DWR + Fish	WC + Fish	Mak + Fish	Semi-aquatic		Terrestrial system (in 50% shared area)				
									Ducks (5%)	Vegs (15%)	Ban, pap(10%)	Cont (15%)	TPs (10%)		
Sole farming system (FS)															
FS_1, DWR	1.012	-	-	-	-	-	-	-	-	-	-	-	-	1.012	124
FS_2, WC	-	2.506	-	-	-	-	-	-	-	-	-	-	-	2.506	202
FS_3, FN	-	-	2.962	-	-	-	-	-	-	-	-	-	-	2.962	155
FS_4, C-fishes	-	-	-	4.327	-	-	-	-	-	-	-	-	-	4.327	121
FS_5, L-fishes	-	-	-	-	4.53	-	-	-	-	-	-	-	-	4.526	112
Integrated farming system (IFS)															
FS_6, DWR + C-fish + ducks + vegs + ban + cont + TPs	-	-	-	-	-	0.47 + 2.25	-	-	0.208	0.678	0.457	-	-	4.057	317
FS_7, DWR + L-fish + ducks + vegs + ban + cont + TPs	-	-	-	-		0.45 + 2.51	-	-	0.211	0.682	0.464	-	-	4.322	305
FS_8, WC + C-fish + ducks + vegs + ban + cont + TPs	-	-	-		-	-	1.24+ 2.26	-	0.215	0.778	0.462	-	-	4.955	421
FS_9, WC + L-fish + ducks + vegs + ban + cont + TPs	-	-	-	-		-	1. 23+ 2.53	-	0.218	0.782	0.471	-	-	5.232	405
FS_{10}, Mak + C-fish + ducks + vegs + ban + cont + TPs	-	-	-		-	-	-	1.57 + 2.22	0.221	0.807	0.469	-	-	5.291	364
FS_{11}, Mak + L-fish + ducks + vegs + ban + cont + TPs	-	-	-	-	-	-	-	1.49 + 2.58	0.223	0.823	0.476	-	-	5.599	358
SEm±														0.222	9.194
CD (P=0.05)														0.633	26.28

FNEY, foxnut equivalent yield; DWR, deep-water rice; WC, water chestnut; Mak, *makhana*; C, carp; L, live; Vegs, vegetables; ban, banana; pap, papaya; TPs, tree plantations; cont, coconut.
Average market price of DWR, WC, Mak, mixed of carp-fishes, live-fishes and average price of leafy & other vegetables and banana etc. were 15,000, 13,000, 50,000, 73,333, 1,55,000, and 14,715 and 16,000/t respectively.

6.59; 7.785 and 8.36, and 8.43 and 9.06 FNEY in t/ha etc.) than that of even combined sole yields of both crop and fishes (deep-water rice + fishes, water chestnut + fishes and fox nut or *makhana* + fishes etc.).

However, considering the produce value in the market, system productivity of live-fishes was comparatively more (4.526 FNEY in t/ha) than that of other enterprises among the sole system and had least performance in case of deep-water rice (1.012 FNEY t/ha) and this was increased about 4.47 times more than that of later one. Among 3 sole aquatic crops, foxnut produced highest (2.962 FNEY t/ha) followed by water chestnut and deep-water rice (2.506 and 1.012 FNEY t/ha) and this was about 2.93 and 1.21 folds more in favour of *makhana* over these crops (Table 2). Although the system productivity values were the highest in FS_5 but the treatments FS_2 and FS_3 and FS_4 and FS_5, respectively were statistically at par under sole system.

Integrated system

Total production system or system productivity comprised of all the variables (aquatic crop + fish + ducks + vegetables + banana and papaya *i.e.* up to 75%, + rest coconut + other perennial tree plantations i.e. of 25% on shared area basis) under integrated system were compared and shown that all the 6 enterprises (FS_6 to FS_{11}) were varied greatly in terms of FNEY (Table 2). Among the IFS enterprises, highest productivity values had gone in favour of FS_{11} (*makhana* + live-fishes + ducks + vegetables + banana and papaya of 75% shared area, without the values of coconut + other tree plantations, which produced 5.60 t/ha) than that of other 5 integrated systems, while, lowest output exhibited with FS_6 system (FNEY 4.06 t/ha, which comprised deep-water rice + carp-fishes + ducks + vegetables + banana and papaya, without the values of coconut + other tree plantations) and this was near about 38.01% more in former than that of later one. The highest system productivity in FS_{11} may be due to major contribution of live-fishes as well as foxnut crop for their more market price and lucrative in the common market. It is noted that now-a-days, popped-form of foxnut produced from *makhana* seeds is being considered as one of the value-added products, popular in vegetarian belts of the country as well as is being exported to foreign countries. When critically explained statistically it shows that there were no significant differences in between FS_6 and FS_7, and FS_{10} and FS_{11} and among FS_8, FS_9 and FS_{10} treatment, respectively under the integrated farming systems.

Employment generation

Engagement of mandays were comparatively less in sole system than that of mixed farming system, however, among the sole system higher number of labours were engaged for cultivation of water chestnut, because more skilled personnel were required for cultivation as well as recurring pickings of fresh nuts of water chestnut (Table 2). Minimum number of employment generated for the cultivation of sole deep-water rice.

In any integrated farming system, engagement of year-round farm labours including family members irrespective of gender and age, is generally more as compared with conventional cropping system alone, which has been reflected in this study also (Table 2). Among six enterprises, FS_8 generated highest labour employment (421 mandays/year), might be due to more requirement of skilled person-

Table 3. Production economics of each IFS (average value of 3 years)

Farming system	GMR ($\times 10^3$₹/ha)	NP ($\times 10^3$₹/ha)	Benefit: cost ratio
Sole farming system (FS)			
FS_1, DWR	50.60	28.21	1.26
FS_2, WC	125.30	76.10	1.55
FS_3, FN	148.10	94.86	1.78
FS_4, C-fishes	216.35	148.09	2.17
FS_5, L-fishes	226.30	156.55	2.24
Integrated farming system (IFS)			
FS_6, DWR + C-fish + ducks + vegs + ban + cont + TPs	202.85	136.95	2.08
FS_7, DWR + L-fish + ducks + vegs + ban + cont + TPs	216.10	151.63	2.35
FS_8, WC + C-fish + ducks + vegs + ban + cont + TPs	247.75	178.52	2.58
FS_9, WC + L-fish + ducks + vegs + ban + cont + TPs	261.60	191.68	2.74
FS_{10}, Mak + C-fish + ducks + vegs + ban + cont + TPs	264.55	197.17	2.93
FS_{11}, Mak + L-fish + ducks + vegs + ban + cont + TPs	279.95	211.15	3.07

DWR, deep-water rice; WC, water chestnut; Mak, *makhana*; C, carp; L, live; Vegs, vegetables; ban, banana; pap, papaya; TPs, tree plantations; cont, coconut; Average market price of DWR, WC, Mak, mixed of carp-fishes, live-fishes and average price of leafy & other vegetables and banana etc. were 15,000, 13,000, 50,000, 73,333, 1,55,000, and 14,715 and 16,000/t, respectively. GMR, gross monetary return; CP, production cost; NP, net profit; B:C, benefit: cost ratio.

nel for recurring pickings of fresh water chestnut fruits followed by FS_9, which generated second highest labour employment (405 mandays/year), might be due to for proper caring of carp fishes than that of live-fish group. Comparatively lower employment (305 mandays/year) was generated in FS_7 system. Among the sole system, mandays requirement were highest in FS_2 and the treatments like FS_1, FS_4 and FS_5 were statistically at par and among the integrated farming system, treatments FS_6 and FS_7, and FS_8 and FS_9 and FS_{10} and FS_{11}, respectively were also statistically at par.

Production economics

Production economics is the ultimate target of any project for its acceptability to the common beneficiary groups of farming community either small or marginal group of farming community considering its economic viability in any regions. In this study, system productivity corresponding to its benefit over subtracting the cost for cultivation was calculated in terms of gross monetary returns (GMR), net profit (NP) expressed in /ha and ultimate benefit:cost (B:C) ratio of the system (Table 3).

Production economics in all the systems, whether it may be sole or integrated approach were highly differentiated in all the calculated values of GMR, NP as well as B:C ratios (Table 3). In sole system, highest values of GMR (2,26,300), NP (1,56,545) and B:C ratio (2.24) had gone in favour of sole live fishes, might be due to more market price of this fish group. Least performance was shown by deep-water rice (50,600, 28,205 and 1.26) and the former one is 77.78% and 3.22–44.52% more than that of FS_1 and over other sole systems (FS_2 – FS_4) practised in the experiment, might be due to comparatively less productivity (in respect to FNEY in t/ha) corresponding to low output in these treatments than that of FS_5.

Integration of aquatic crops along with 2 types of fish variables were remarkably influenced by the different components used in the experiment (Table 3). Out of 6 integrated system, highest values of GMR (2,79,950), NP (2,11,145) and B:C ratio (3.07) exhibited with FS_{11} combination corresponding to highest productivity of the system (5.60 FNEY in t/ha), where foxnut + live-fishes + ducks + vegetables + banana and papaya other than benefits from coconut plantations + tree plantations, were done utilizing aqua-terrestrial ecosystem, might be due to more sharing values of both live-fishes as well as foxnut seeds in the market. Among the farming systems, least returns obtained with FS_6, where deep-water rice + carp fishes + ducks + vegetables + banana & papaya without coconut + tree plantations were done and this was probably due to less output as well as less market price of the produces. The increment in treatment FS_{11} over FS_6 and over others treatments (FS_7 - FS_{10}) were to the tune of 47.60 and 4.78–30.64%, might be due to more productivity in respect to FNEY in t/ha as well as more market value of the produces. Integration of different variables in various types of enterprises would have been benefited by the farming communities observed in different locations of the country Kathiresan, (2010); Channabasavanna and Biradar (2007) and Ramrao *et al.* (2006).

Table 4. Fertility status of post-experimental pond bottom soil of the system (pooled of 3 years)

Farming system	Organic carbon (%)	Total nitrogen content (%)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
Sole farming system (FS)				
FS_1, DWR	0.61	0.064	87.2	208.4
FS_2, WC	0.69	0.071	96.6	216.6
FS_3, FN	0.73	0.075	103.3	234.1
FS_4, C-fishes	0.59	0.063	84.1	206.8
FS_5, L-fishes	0.64	0.066	88.1	211.2
Integrated farming system (IFS)				
FS_6, DWR + C-fish + ducks + vegs + ban + cont + TPs	0.62	0.065	89.7	217.9
FS_7, DWR + L-fish + ducks + vegs + ban + cont + TPs	0.68	0.067	93.5	223.5
FS_8, WC + C-fish + ducks + vegs + ban + cont + TPs	0.71	0.074	98.5	236.7
FS_9, WC + L-fish + ducks + vegs + ban + cont + TPs	0.73	0.076	102.2	239.1
FS_{10}, Mak + C-fish + ducks + vegs + ban + cont + TPs	0.76	0.079	115.2	246.7
FS_{11}, Mak + L-fish + ducks + vegs + ban + cont + TPs	0.79	0.081	121.5	256.6
Av. value	0.686	0.0709	98.1	227.1
SEm±	0.028	0.0023	3.94	5.93
CD (P=0.05)	0.086	0.007	12.06	18.13

DWR, deep-water rice; WC, water chestnut; Mak, *makhana*; C, carp; L, live; Vegs, vegetables; ban, banana; pap, papaya; TPs, tree plantations; cont, coconut; Av., average.

Soil characteristics

Pond bottom soil was remarkably influenced by different enterprises practised in the experiment either as sole or integrated system, combined with aquatic crops and different fish variables (Table 4). With regards to the effect of individual crop and/or fish culture as well as farming system on the soil characteristics, almost all the characters were differed significantly and with higher values than that of their initial status [organic carbon (0.58%), total nitrogen content (0.061%), available P_2O_5 (82.33 kg/ha) and K_2O (204.72 kg/ha), respectively]. Among the sole system, categorically being highest values with respect to all parameters in foxnut cultivated plots (FS_3) and live-fishes (FS_5) followed by water chestnut, deep-water rice and carp-fishes, where as among the integrated farming system it was highest with FS_{11} treatment, in which foxnut was combined with live-fishes [organic carbon (0.79%), total nitrogen content (0.081%), available P_2O_5 (121.47 kg/ha) and K_2O (256.58 kg/ha), respectively], which may be due to accumulation of relatively higher amount of organic matter causing higher available N, P and K status in the soils. Foxnut and live-fishes among the crops and fishes performed better to improve the N, P and K status of pond-bottom soil in comparison to other variables. In combined system, greater values obtained especially, when foxnut was combined with live-fishes might be due to these are more congenial to move in foxnut cultivated plots and due to the addition of higher amount of biomass and organic matter content in the pond bottom-soil. Lower results obtained either as sole or in integration of deep-water rice and carp fishes under integrated farming system, may be due to less effective to produce lower quantity of biomass or humus in consequence.

Results of three years experiment on utilizing aqua-terrestrial ecosystem in IFS made under new alluvial zone of West Bengal, reveal that maximum benefits had gone in favour of integrated farming system, where foxnut was combined with live-fishes in wet situation along with other variables practiced under arable lands, generated more income and employment opportunity sustainable for livelihood development and food security including development of fertility status of pond-bottom soil. Over long run of the system for a considerable period, recycling of farm and animal wastes applying to cropping systems, would be a vital source of plant nutrients, especially in this multi-system enterprises.

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