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Productivity Improvement of Pond-Based Production System through Integration of Horti-Livestock-cum-Pisciculture

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Abstract: The present study on pond-based production system model was undertaken at ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar during 2018-2020. The cropping system on pond bunds includes three tier model of litchi cum banana/papaya and seasonal crop based system along with vermi-compost, livestock and makhana with fish culture in pond comprised with 4 models *viz*., Integration of different components like fruit, seasonal vegetables, fish and dairy under model-1(Fish+litchi+banana+vegetables +dairy+vermi-compost) was economical than other models in terms of net return with highest net income of Rs 1,19,400 followed by model-2 (Fish+duck+litchi+papaya+vegetables) which recorded net income of Rs 66,175, and lowest in model-4 (Two row of litchi + papaya in between two litchi plants + field crops and makhana with fishery) of Rs 48,225. The higher benefit: cost ratio (1.58) was obtained with model-2 followed by model-1 (1.46). The system economic efficiency in terms of net return as Rs/day and sustainable value index was also markedly higher with model-1 (Rs. 327/day and 0.73). The highest total system employment generation was also observed in model-1 (385 man-days/year) followed by model-2 and model- 4.

Keywords: Horticulture, Livestock, Pisciculture, Integrated farming system, Eastern India

Land being a non-renewable resource is an essential component to all primary production systems. In India, the excessive demand of land for both agricultural and non-agricultural purposes has resulted in the development of huge stretches of different kinds of wastelands (Patel et al 2020a). Majority of the farmers in India are small and marginal. They often follow a monoculture approach which leads to low farm income. Presently, most of the farmers are concentrating mainly on crop production, which is subjected to a high degree of risk and uncertainty in income due to crop failure by various factors. In this context, integrated farming system (IFS) ensures the highest standard of food production with minimum environmental impact even under highly vulnerable climatic condition (Kumar et al 2015). This integration of components of ecosystem results in sustainable production (Ansari et al 2014). Integration of crop and livestock component has been highly productive, profitable, and environmentally sustainable (Gill et al 2010, Yadav et al 2013). It is a reliable means of obtaining higher productivity with substantial nutrient economy in combination with maximum compatibility and replenishment of organic matters by way of effective recycling of organic residues/wastes (Solaniappan et al 2007). Many attempts have been made to integrate the desirable features of farming system research into mainstream agriculture to develop more relevant, realistic client-oriented and location-specific technologies. Sustainable development through horticulture with livestock and fish based production system has been emerged as a viable way of improving farmers income (Patel et al 2020a). The substantial area of Bihar state is under waterlogged and marshy condition. Majority of the area falls under those districts which are suitable for the litchi cultivation but, the waterlogged area having drainage problems are not fit for production of litchi (Patel et al 2021). Some parts of Bihar remain waterlogged (> 1m surface water logging) for 4-5 months and become unproductive during *Kharif* and very low utilization in *Rabi* season also. Efficient rainwater harvesting and recycling provided new livelihood options for the resource poor farmers by increase in productivity and diversified the agricultural production by growing of remunerative agricultural and horticultural crops integrated with composite pisciculture (Das et al 2014). The low lying waterlogged area of the centre has been converted in to ponds. Plantation of fruit crops along with seasonal crops and integration of livestock on pond dyke while fisheries in pond through integrated approach of farming system has been developed. Keeping the view, a multi-enterprise horticulture, livestock and pisciculture based integrated farming with pond based production system has been implemented in representative deep low lying areas (1.5-2.5 m water depth) for comparative evaluation of different pond based production system models.

MATERIAL AND METHODS

The present study on pond based production system model was undertaken research farm of ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar during 2018-2020. The experiment site was located at about 26°5'87" N latitude, 85°26'64" E longitude at 210 m asl. The four models of integrated farming system comprised with fruit crops, seasonal crops, makhana, livestock, duckery, and fishery were imposed on ponds and their bunds in different combination including recycling of crop residue for vermi-compost production. The size of the experimental low lying area was 0.80 ha (ponds with dyke) and rain water was accumulated in the ponds during rainy season from the catchment area of about 5 ha. The cultivation of seasonal crops like maize, mustard, faba bean and vegetables like cow pea, cabbage, cauliflower, knol-khol, broccoli and pea were done as intercropping with litchi+banana and litchi+papaya combinations. Livestock like cattle (cow) and duck were reared on pond bund while makhana and fishery in pond. The cropping system on pond bunds includes three tier model of litchi cum banana/papaya and seasonal crop based system along with vermi-compost, livestock and makhana with fish culture in pond comprised with 4 models in 2000 m^2 area (Table 1).

Litchi cv. Shahi and China were planted on pond bunds with 6x6 m spacing during 2014 whereas banana cv. Grand Naine and papaya cv. Pune Selection-3 were planted at 2 m spacing as per different models in 2017. Fingerlings of *Pangasius* fish (locally known as *Jasar*) maintaining 8000/ha stocking density of 25-30 g were released in ponds during June and harvested in t March. Concentrate feed for fishes were purchased from market and expenditures on feed items were included in the cost of production. One vermi-compost unit was established to recycle the crop residue and cattle dung. One unit of cattle (2 cows) was also integrated to fulfil the milk and FYM requirement. Two months old five ducks (Khaki Campbell) was also introduced and sheltered in one fish pond which started laying eggs after 150 days. An improved cultivar of makhana was also integrated in one pond with fish culture. Seeds of makhana were sown during January and harvested after nine months of crop growth in October. Standard package of practices were followed for cultivation of litchi, banana, papaya, vegetables, field crops, makhana and rearing of duck, cattle and fishes (Kumar et al 2012). Soil sample collected from study site and analyzed at the beginning of experiment and 3 years after experimentation from pond bunds.

The comparative profitability, soil health and employment generation of different components in each model were compared across the different models for a period of three years to identify the suitability of model components, cropping sequence and sustainability of IFS. Profitability and employment generation of various components of each model were calculated individually and computed model wise. The labourers engaged for different activities in each component were recorded in terms of hours every day and converted into man-days/year. The involvement of labour for up keep in each enterprise under different models was considered for comparison, based on employment generation (man-days). The system economic efficiency (SEE) was calculated on the basis of net returns obtained from the system divided by 365 days (time year) (Mukherjee 2010). The sustainability is

Table 1. Allocation of area under different components in farming system (2000m^2 area under each model)

Farming system model	Components wise area (m^2)									
	Fish	Litchi	Banana	Papaya	Vegetables	Dairy	Vermi-compost	Duck	Field crop	Makhana
Model 1: Fish+litchi+banana+vegetables+dairy+vermi-compost	1200 (60)	180 (9)	220 (11)	-	150 (8)	225 (11)	25 (1)	Shelter on fish pond/bund	-	-
Model 2: Fish+duck+litchi+papaya+vegetables	1400 (70)	250 (12)	-	200 (10)	150 (8)	-	-	-	-	-
Model 3: Fish+litchi+banana+field crop	1500 (75)	200 (10)	150 (7)	-	-	-	-	-	150 (8)	-
Model 4: Fish+makhana+litchi+papaya+field crop	1600 (80)	175 (9)	-	125 (6)	-	-	-	-	100 (5)	Grown in pond with fish

Figure in parenthesis is percentage of area occupied in each component expressed as sustainable value index (SVI). Sustainability values index for each model was calculated following the formula SVI = NR–SD/MNR (Bohra and Kumar 2015), where NR stands for net returns obtained under any model, SD stands for standard deviation of net returns of all models and MNR stands for maximum net returns attained under any model. The suitability and viability of model was identified for their existence based on their net returns, SVI and improvement in soil fertility attained over a period of time.

RESULTS AND DISCUSSION

Yield attributes: In model-1, fish component occupied 60% area followed by horticultural crops about 28% area and cattle (dairy) 8% along with a vermi-compost unit was set up to recycle the agro-waste into the system. The fish produced from the model-1 was in bigger size (850-1250 g) as compared to other model (650-950 g). Fish reared under this model attained bigger size could have got more nutritious feed due to liking of cow urine and litter residue material in pond. Growth of litchi plants cv. 'Shahi' and 'China' was quite vigorous and gave the fruit yield ranged from 20-28 kg/tree at 5 years after planting. Banana cv. 'Grand Naine' yielded 15.5-29.5 kg bunch weight in main as well as ratoon crop. Similarly, papaya yield ranged from 10.5 to 23.5 kg fruits/tree with average fruit weight of 0.80-1.48 kg/fruit. However, fruit weight depends on number of fruit per branch or plants (Lal et al. 2023a and b). Production of vermi-compost by using crop residues like banana pseudo stem, litchi leaves, and farm grasses has been done. It was observed that vermi-compost production from banana pseudo stem was faster than other residues due to easily decomposition and conversion into vermi-compost by the earth worm followed by farm grasses and litchi leaves. Two cross bread cow reared under model-1 produced average milk yield of 8.5-10.5 litre/day. Ducks (Khaki Campbell) reared under model-2 started laying eggs at 5 months of age and dropping of ducks were fed to fish reared in pond. The seeds of makhana were shown in pond with fish (model-4) maintaining of about 2.5-3 foot water depth throughout the growing period. The harvesting of makhana seed was done during October month and recorded 15.5 kg yield.

Table 2. Comparative performance of economics in different farming system models

IFS models	Components	Gross return (Rs.)	Cost of cultivation (Rs)	Net income (Rs)	Benefit : Cost ratio
Model 1	Fish	161000	110000	51000	1.46
	Litchi	3000	1000	2000	3.00
	Banana	2200	950	1250	2.32
	Vegetables	1900	750	1150	2.53
	Dairy	185000	140000	45000	1.32
	Vermi-compost	25000	6000	19000	4.17
	Total	378100	258700	119400	1.46
Model 2	Fish + Duck	170000	110500	59500	1.54
		3000	1200	1800	2.50
	Litchi	4200	1350	2850	3.11
	Papaya	1650	700	950	2.36
	Vegetables	2000	925	1075	2.16
	Total	180850	114675	66175	1.58
Model 3	Fish	171500	121250	50250	1.41
	Litchi	3600	1250	2350	2.88
	Banana	1550	625	925	2.48
	Intercropping	1750	925	825	1.89
	Total	178400	124050	54350	1.44
Model 4	Fish + Makhana	145500	110500	35000	1.32
		11500	1750	9750	6.57
	Litchi	3250	1100	2150	2.95
	Papaya	1125	450	675	2.50
	Intercropping	1450	750	650	1.93
	Total	162825	114550	48225	1.42

Economics: Integration of different components like fruit, seasonal vegetables, fish and dairy under model-1 found highly economical than other models in terms of net return (Table 2). In all the models major share of income received from fishery component. The highest income of Rs 119400in terms of net return was obtained in model-1 with maximum share of income obtained from fishery (42.71%), dairy (37.69%) and vermi-compost unit (15.91%). Model-2 recorded net income of Rs 66175 followed by model-3 (Rs 54350) and lowest in model-4 (Rs 48225). The highest share of net return (89.91%) was realized from fish and litchi fruit (4.31%). The net income under model-3 also recorded similar pattern to model-2 with major share from fish (92.46%) and litchi crop (4.32%) component. However in model-4, fish contributes the major share of net income but, as compared to other models realization of profit was less due to poor growth of fish recorded under this model which could be might be due to integration of makhana with fish would have hampered the growth of the fishes. The highest net return of Rs 35000 was obtained from fish followed by makhana (Rs 9750) and litchi (Rs 2150) under model-4. The higher benefit: cost ratio (1.58) was obtained with model-2 (followed by model-1(model-3 () and model-4). Though net return was higher and benefit: cost ratio was comparatively lesser in model-1 than model-2. This may be due to higher the expenditure incurred in model-1 due to cost of cows rearing. This higher expenditure on rearing of cattle was due to purchase of concentrate feed material from the market. Kumar et al (2011) also observed the similar pattern of obtaining the lesser B:C ratio under cattle component integrated with farming system in eastern India.

System economic efficiency and sustainable value index: The system economic efficiency (SEE varied among the models (Fig. 1). The higher SEE was with model-1 (Rs. 327/day). The trends of SEE were followed in the order of mode-1 > model-2 > model-3 > model-4. The inclusion of more suitable remunerative enterprises would increase the productivity and net income and thus provide the better SEE (Kumar et al 2015, Patel et al 2020b). Sustainable value index among the models varied due to different components (Fig. 1). They higher the value of SVI was associated with model-1 (0.73). The trends of SVI were followed in the order of mode-1 > model-2 > model-3 > model-4.

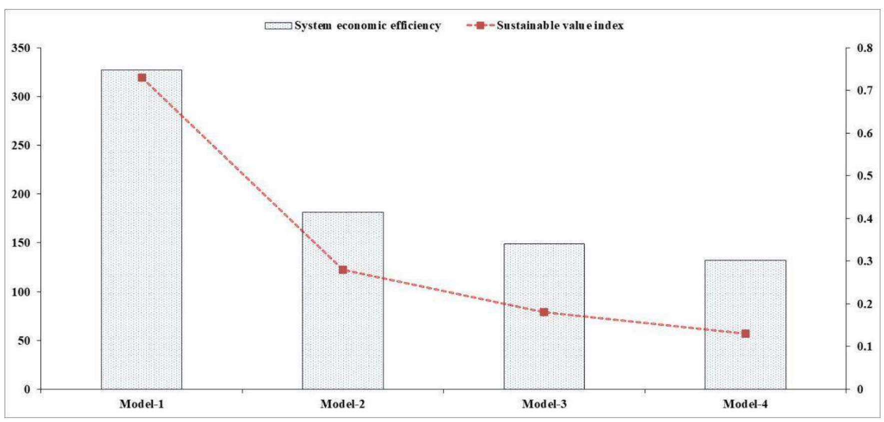

Fig. 1. System economic efficiency and sustainable value index of different IFS model

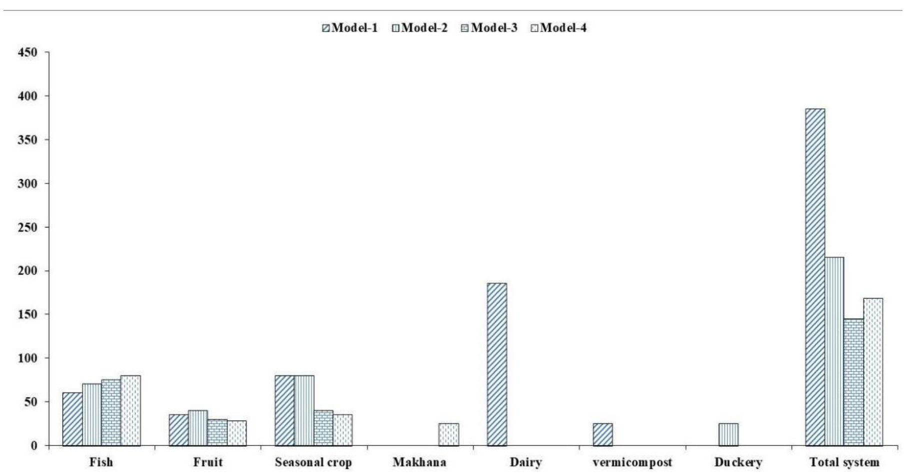

Fig. 2. Employment generation by different components under various farming system model (2000 m^2)

Table 3. Initial and final (parenthesis) soil health values

IFS Model	pH	EC	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Model-1	8.15 (8.00)	0.09 (0.11)	0.60 (0.78)	102.50 (116.52)	42.50 (45.58)	87.55 (100.15)
Model-2	8.00 (7.98)	0.10 (0.15)	0.62 (0.75)	105.25 (114.50)	41.25 (43.52)	91.00 (97.50)
Model-3	8.25 (8.10)	0.11 (0.16)	0.65 (0.70)	110.32 (117.25)	42.75 (45.50)	87.52 (94.50)
Model-4	8.28 (8.15)	0.10 (0.16)	0.65 (0.73)	103.25 (113.15)	40.82 (42.80)	89.25 (95.50)

Employment generation: Integration of different enterprises under farming system models had increased the employment opportunity on yearly basis (Fig. 2). The integration of fish, fruits, vegetable and dairy component in the system showed greater employment opportunity and it was almost double than the model-3 and model-4. The highest total system employment generation was observed in model-1 (385 man-days/year) followed by model-2 and model- 4. However, model-3 generated the least employment (145 man-days/year). Combining of livestock, vermi-compost and makhana cultivation with other enterprises would have increase the labour requirement and thus provide scope to employ more family labours round the year. Ravisankar et al (2007), Kumar et al. (2011) and Patel et al (2020b) also reported the similar trend.

Soil health: Soil sample collected from study site and analyzed at the beginning of experiment and 3 years after experimentation from pond bunds. Integration of different components in a system and recycling of by products and farm wastes has been practiced in all the models. Pseudo stem with leaves obtained as crop residues from banana, leaves and plant stump from vegetables and other seasonal crops were utilized for mulching of plant basin and also incorporated in to the soil during land preparation. There was marked improvement in soil health status (pH, EC, soil organic carbon and NPK) was observed as compared to initial soil status after completion of three years of study (Table 3 , 4). Soil pH was decreased slightly in all models after completion of 3 years. EC increased from initial value of 0.09-0.11 to 0.11 to 0.16 dsm^{-1} among the different models which indicates the positive effect of different components in amelioration of soil salinity. Soil organic carbon content (OC) was also markedly improved from 0.60 to 0.78, 0.62 to 0.75, 0.65 to 0.70 and 0.65 to 0.73% in model-1, model-2, model-3 and model-4, respectively. These significant changes were more pronounced, where seasonal crops integrated with livestock, fishery, and subsidiary component with respective IFS model. Similarly, all the major available nutrient i.e. NPK in soil after 3 years were improved markedly with all the four established model. However, recycling of organic manures obtained from different components added N, P_2O_5 and K_2O into system as a whole, which can minimize the dependency upon inorganic fertilizer up to some extent, provides good soil health on long-term basis. Acharya and Mondal (2010) reported residues recycling in each model revealed an integration of crop with allied components resulted in higher model productivity, profitability as well as soil health over years. Hence, results on integration of different components with crop in a system depending upon their suitability and preferences were found encouraging in agro-climatic condition of northern Bihar.

CONCLUSION

The integration of different components like fruit, seasonal vegetables, fish and dairy under model-1 (Fish+litchi+ banana+vegetables+dairy+vermi-compost) returned with highest net income of Rs 1,19,400 followed by model-2 (Fish+duck+litchi+papaya+vegetables) which recorded net income of Rs 66,175, and lowest in model-4 (two row of litchi + papaya in between two litchi plants + field crops and makhana with fishery) of Rs 48,225. The higher benefit: cost ratio (1.58) was obtained with model-2 followed by model-1 (1.46). The system economic efficiency and sustainable value index was higher in model-1 (Rs. 327/day and 0.73).

AUTHOR CONTRIBUTIONS

Conceptualization: RKP, Formal analysis: NL, AK. Investigation: RKP, KS, AK. Methodology: AK. Supervision: RKP, NL, AK, KS. Writing – original draft: RPK. Writing–review & editing: RKP, NL.

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