



Productivity improvement of low lying area with litchi (*Litchi chinensis*) based integrated system

R K PATEL*, KULDEEP SRIVASTAVA, S D PANDEY, AMRENDRA KUMAR, S K PURBEY and VISHAL NATH

ICAR-National Research Centre on Litchi, Mushahari, Muzaffarpur, Bihar 842 002, India

Received: 02 January 2019; Accepted: 30 August 2019

ABSTRACT

The present study was carried out at ICAR-National Research Centre on Litchi, Muzaffarpur during 2014-2017 for sustained productivity, profitability, employment generation and soil health. Four different models comprised of rain water harvesting, fish culture, and intercropping of annual and vegetable crops with litchi (*Litchi chinensis* Sonn.) + banana and litchi+papaya in different combinations on pond dykes. Rain water accumulated in the ponds during rainy season with the storage capacity (7.29 million litre water) varied from of 1.62-2.16 million litre of water per pond. Among different models, model 1 recorded the highest total system productivity in terms of LEY (25.49 t/ha), production efficiency (140.67 kg/ha/day), net return (₹ 159950/ha) and system economic efficiency (438.23 ₹/ha/day). Sustainable value index (SVI) among the models varied due to different component and expressed 2 to 3 time's higher value than existing system. Model 1 recorded highest SVI (0.78) and existing model (0.25) recorded lowest. Relative production and economic efficiency of the different models were also computed over the crop based existing system and value ranged from 521.72 and 67.64 in model 4 to 529.38 and 116.15 in model 1, respectively. Integration of fish, fruits, vegetable and crop component in the system showed greater employment opportunity and it was almost double than the crop based existing system. The highest employment generation was observed in model 1 (331 man-days/ha/year) as compared to existing system (150 man-days/ha/year). Marked improvement in soil health status (pH, EC, soil organic carbon and NPK) was observed as compared to initial soil status after three years of study.

Key words: Eastern India, Integrated farming system, Low lying area, Rainwater harvesting

In low lying area, water is available in the surface of the land and stands seasonally for 4-5 months during monsoon or even for most part of the year. This condition prevails usually in lands located in plain areas associated with the drainage congestion. This type of land situation is not preferred for growing of most of the fruit crops including litchi due to water-logging and swampy condition. The major problems associated with this wasteland are poor drainage and water accumulates only due to high rains during monsoon months resulting in crop failure. Some parts of Bihar remain waterlogged (>1 m surface water) for 4-5 months and become unproductive during *kharif* and very low utilization in *rabi* season too. Rainwater harvesting and its recycling can increase productivity and diversify agricultural system in integrated manner (Das *et al.* 2014). Restoration of seasonal waterlogged lands is possible through integration of various techniques of land treatment (land shaping). Further the harvesting of excess water through suitable land shaping involves modifying the surface of the farm land for conservation of excess

rain water and making the land surface suitably shaped for successful cultivation of fruit along with seasonal crops on pond dyke and fisheries in pond through integrated approach of farming system.

The gradual degradation of resources has become a problem of major concern and calls for location specific measures to optimize crop productivity on sustained basis (Kumar *et al.* 2012). 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). Keeping in view, a multi-enterprise horticulture based integrated farming with pond based production system has been conceptualized and implemented in representative deep low lying areas (1.5-2.5 m water depth) to develop and evaluate the performance of pond based production system model for the eastern region of India.

MATERIALS AND METHODS

Studies on pond based integrated farming system models were carried out at research farm of ICAR-National Research Centre on Litchi, Muzaffarpur during 2014-2017. It involved construction of ponds for rain water harvesting, seasonal crops, fruit crops and fishery in

*Corresponding author email: rkpatelicar@gmail.com

different combination including recycling of crop residue for vermicompost production. The experiment site is located at about 26°5'87" N latitude, 85°26'64" E longitude at an elevation of 210 m. The soil of the experimental block was clay loam in texture. The size of the experimental block was two acre. The waterlogged low land area was converted into ponds of about 2.5-3 m depth. The dug out soil was used to form high land pond dyke of 10-12 m width during creation of pond. The pond dykes were used for growing of seasonal crops like maize, mustard, faba bean and vegetables (cow pea, cabbage cauliflower, knol-khol, broccoli, pea) as intercropping with litchi (*Litchi chinensis* Sonn.) + banana and litchi+papaya combinations. The cropping system on pond bunds includes three tier model of litchi cum banana/papaya and seasonal crop based system comprised with 4 models (model I: Two row of litchi and banana + seasonal crops, model II: Two row of litchi and papaya + seasonal crops, model III: Two row of litchi + banana in between two litchi plants + seasonal crops, model IV: Two row of litchi + papaya in between two litchi plants + seasonal crops) along with traditionally existing cropping system practiced in low lying area (fallow-mustard-moong) to compare with different models. Under existing cropping system, fields were remained fallows during rainy season due to accumulation of water. After receding of stagnated water, mustard was sown in winter followed by moong during summer. Litchi cvs. Shahi and China were planted on pond bunds with 6 × 6 m spacing whereas banana cv. Grand Naine and papaya cv. Pune Selection-3 were planted at 2 m spacing as per different models. 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 the month of March. Concentrate feed for fishes were purchased from market and expenditures on feed items were included in the cost of production. Standard package of practices were followed for cultivation of litchi, banana, papaya, seasonal crops and rearing of fishes.

Total area under model wise was allotted as 2360 m² (litchi: 8%, banana: 4%, Intercropping: 3%, fishery: 85%) for model 1, 2378 m² (litchi: 8%, papaya: 5%, Intercropping: 5%, fishery: 84%) for model 2, 1824 m² (litchi: 2%, banana: 4%, Intercropping: 6%, fishery: 88%) for model 3, 1780 m² (litchi: 2%, papaya: 2%, Intercropping: 6%, fishery: 90%) for model 4 and, 2000 m² for existing system model but the data have been extrapolated on hectare basis to compare the system. Soil sample collected from study site and analyzed at the beginning of experiment and 3 years after experimentation from pond bunds.

For comparison among the fruits, seasonal crops, fishes and other variables of the enterprises due to their heterozygous nature, litchi equivalent yield in terms of production (t/ha) was calculated utilizing the produce value. Litchi equivalent yield (LEY) of each model was determine following the formula LEY (q/ha) = total income from the enterprises i.e. crop/fish (obtained through multiplication of yield and market price of the enterprises) divided by price of litchi (₹/q). Average market price of litchi was

considered ₹ 2800 per quintal. The labourers engaged for different activities in each component were recorded in terms of hrs every day and converted into man-days/ha/day. The system productivity of different models was calculated as ratio of system productivity to total duration of the system in days and expressed as kg/ha/day. System economic efficiency was calculated on net returns/ha divided by 365 days (time year) and expressed as ₹/ha/day (Mukherjee 2010). Relative production efficiency (RPE) denotes the capacity of the system for production in relation to existing system and expressed in percentage. It is calculated with formula $RPE = EYD - EYE / EYE \times 100$, where EYD stands for equivalent yield under improved/diversified system, EYE stands for existing system yield (Singh *et al.* 2014). Similarly, relative economic efficiency (REE) of the system denotes the comparative measure of economic gains over the existing system and expressed in percentage. REE calculated following the formula = $DNR - ENR / ENR \times 100$, where DNR stands for net return obtained under improved/diversified system, ENR stands for net return of the existing system (Samant 2015). The sustainability is expressed as sustainable yield index (SYI) and sustainable value index (SVI). The SYI was calculated following the equation suggested by Singh *et al.* (1990) as: $SYI = Y / Y_{max} \times d$ where y is the mean yield, d the standard deviation and Y_{max} is the maximum yield obtained. In the concept of SYI, low values of standard deviation and greater value of SYI indicates greater sustainability of the system. Sustainability values index (SVI) for each model was calculated following the formula $SVI = NR - SD / MNR$ as described by 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

Water harvesting ponds: Four ponds were constructed in low lying area which remained fallow and unutilized due to water stagnation for about 4-5 month from July to November. These four ponds [30 m (L) × 30 m (B) × 1.8 m (D), 40 m (L) 30 m (B) × 1.8 m (D), 35 m (L) × 30 m (B) × 1.8 m (D) and 30m (L) × 30m (B) × 1.8 m (D)] had the catchment area of the farm about 6 hectare. The soil excavation work was done through soil excavating machine. Rain water from whole catchment area was accumulated in the ponds during rainy season with the storage capacity (7.29 million litre water) varied from of 1.62 to 2.16 million litre of water. Ponds were utilized for fish culture and providing irrigation for winter, seasonal (Nov-March) and fruit crops (litchi, banana, papaya) grown on bund of the ponds.

Economics of water harvesting: Four newly constructed pond together having the water storage capacity of 7.29 million litre. Total expenditure incurred for construction of four ponds was about ₹ 4 lakhs and hence cost of per litre

harvested water was ₹ 55/1000 L water during first year of pond construction. Considering 75% capacity harvesting of water and a minimum life of pond 20 years with the maintenance cost of about 5% every year (₹ 20000/year), a total of 109 million water would be harvested. Therefore, considering the 20 year life span of the ponds, the cost of harvesting water would be a negligible amount of ₹ 7/1000 L.

System productivity: Productivity of different components (fruit/seasonal, crops/fish) integrated in each system has been expressed as litchi equivalent yield (LEY) (Table 1) revealed that the contribution of fruit crops towards the system productivity among the models varied from 0.39 to 1.26%, 0.94 to 1.35% for seasonal crops and 97.54 to 98.49% for fish. The highest total system productivity in terms of LEY was recorded in model 1 (25.49 t/ha) comprised with components (litchi/ banana, 1.26 t/ha) + vegetable intercropping, 0.24 t/ha + fish, 24.93 t/ha) followed by model 2 (25.2 t/ha), model 3 (25.19 t/ha) and model 4 (25.18 t/ha) while existing system (fallow-mustard-moong cropping system) recorded very less LEY (4.05 t/ha) as compared to integrated models. The highest LEY under different integrated model over existing system might be due to major contribution of fish component and horticultural crops for their more yields per unit area and market price as compared to seasonal crops grown under existing system. System production efficiency of different models (Table 1) revealed that integration of different components in the system showed the highest efficiency (138.75-140.67 kg/ha/day) over the existing cropping system (18.43 kg/ha/day). Korkanthimath and Manjunath (2009) in Goa and Kumar *et al.* (2011) in Bihar also found that integrated farming systems are much better over existing cropping system.

System profitability: Pooled of 3 years data on comparative performance of economics calculated based

on gross return and production cost in various farming system (Table 2). Integration of different components of fruit, seasonal crops and fish in various models were highly economical than existing cropping system in terms of net return and system economic efficiency. The highest net return was obtained in model 1 (₹ 159950/ha) integrated with litchi + banana + vegetables + fish followed by model 2 (₹ 155800/ha) comprised with litchi + papaya + intercropping + fish and least (₹ 74000/ha) under conventional cropping system (fallow-mustard-moong cropping sequence). Among the different integrated models, highest system economic efficiency was recorded in model 1 (438.23) while existing system practiced in low lying area found least economic efficient (87.62). The highest net return and system economic efficiency under integrated model 1 over other models including existing system may be because of integration of banana and vegetable components which contributed higher yield than other crops and subsequently attributed towards higher income per unit of area. Kumar *et al.* (2011) and Ansari *et al.* (2014) also reported increase in net income through integrated system than conventional practice. This might be due to integration of more suitable remunerative enterprises which could have increase the production and net return and thus improve the better SEE than existing system.

System sustainability and relative economic efficiency: Sustainable value index (SVI), relative production efficiency (RPE) and relative economic efficient (REE) of different models were also studied (Table 2). Sustainable value index among the models varied due to different components. All the models expressed 2 to 3 time higher value of sustainable index than the existing system. Markedly higher the values of SVI was associated with model 1 (0.78) followed by model 2 (0.76) and lowest in conventional system (0.25). This might be due to inclusion of suitable remunerative enterprises; ultimately increases net income of the system and thus provide the better SVI. Relative production and economic efficiency of the different models were also computed over the crop based existing system. The RPE and REE among the models varied from 521.72 and 67.64 in model 4 to 529.38 and 116.15 in model 1, respectively. The highest RPE and REE under model 1 might be due to more equivalent yield and net returns obtained from this model in comparison to other models and thus indicate the betterment of the system.

Employment generation: Integration of different enterprises under farming system models had increases the employment opportunity on yearly basis (Fig 1). The variation in employment generation was noticed in different models due to inclusion of various components. However, integration of fish, fruits, vegetable and crop component in the system showed greater employment opportunity and it was almost double than the crop based existing system. The highest man-days was generated in model 1 (331 man-days/ha/year) followed by model 3 (330 man-days/ha/year), model 4 (327 man-days/ha/year) and model 2 (322 man-days/ha/year) than existing system (150 man-days/ha/year). Combining of other enterprises would have increase

Table 1 Productivity of different components in various farming system models (pooled of 3 years)

Farming system	Component productivity			Total system productivity in terms of LEY (t/ha)	System productivity (kg/ha/day)
	Fruit	Seasonal crop	Fish		
Model 1	0.32 (1.26)	0.24 (0.94)	24.93 (97.80)	25.49	140.67
Model 2	0.27 (1.07)	0.29 (1.15)	24.64 (97.78)	25.20	140.55
Model 3	0.27 (1.07)	0.34 (1.35)	24.57 (97.54)	25.19	138.75
Model 4	0.10 (0.39)	0.28 (1.11)	24.80 (98.49)	25.18	139.27
Existing system (Fallow-mustard-moong)	-	4.05 (100)	-	4.05	18.43

Figure in parenthesis indicate per cent contribution to the total system productivity, LEY: Litchi equivalent yield.

Table 2 Comparative performance of economics, sustainability performance and relative efficiency in different farming system models (pooled of 3 years)

Farming system	Gross return ($\times 10^3$ ₹/ha)	Cost of cultivation ($\times 10^3$ ₹/ha)	Net return ($\times 10^3$ ₹/ha)	System economic efficiency (₹/ha/day)	Sustainable yield index	Sustainable value index	Relative economic efficiency (%)	Relative production efficiency (%)
Model 1	713.74	551.43	159.95	438.23	0.63	0.78	116.15	529.38
Model 2	705.25	549.45	155.80	426.85	0.62	0.76	110.54	522.22
Model 3	705.28	569.86	135.40	370.97	0.62	0.63	82.98	521.98
Model 4	705.14	585.86	124.05	339.87	0.62	0.56	67.64	521.72
Existing system	113.50	39.50	74.00	220.00	-0.21	0.25	0.00	0.00
SD	265.60	235.10	34.51	87.62	-	-	-	-

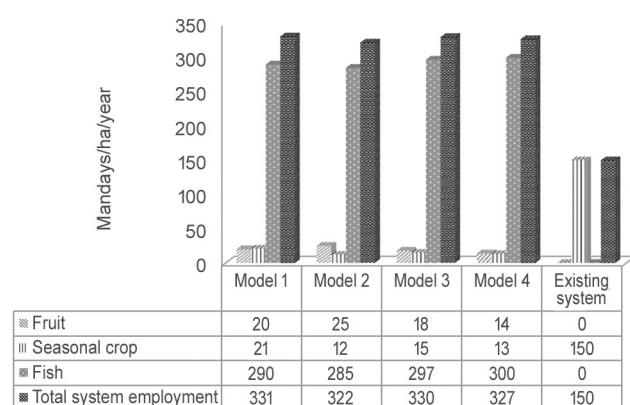


Fig 1 Employment generation in different farming system models.

the labour requirement and thus provide scope to employ more family labours round the year without giving much relaxation in lean season as observed in existing system. Ravisankar *et al.* (2007) and Kumar *et al.* (2011) also reported the similar lines of results in their investigation.

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. Pseudostem 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) as compared to initial soil status after completion of three years of study. Soil pH was declined from its initial level from 8.40 to 7.99 while EC increased from 0.11 to 0.20 dS/m after completion of 3 years. It clearly indicated the positive effect of different components in amelioration of soil salinity, which will improve the soil health in longer perspectives. The organic carbon content was also improved markedly during the study from its initial level 0.85-0.97%. Similarly, all the major available nutrient, i.e. NPK in soil were improved markedly after 3 years of study. The nitrogen content increased from

102.0 to 148.2 kg/ha, phosphorus from 25.2 to 35.5 kg/ha and potassium content from 83 to 102.5 kg/ha. 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 Nagaland under the Eastern Himalayas.

REFERENCES

- Acharya D and Mondal S S. 2010. Effect of integrated nutrient management on the growth, productivity and quality of crops in rice (*Oryza sativa*)-cabbage (*Brassica oleracea*) - greengram (*Vigna radiata*) cropping system. *Indian Journal of Agronomy* **55**(1): 1-5.
- Ansari M A, Prakash N, Bishya L K, Sharma P K, Yadav J S, Kabuei G P and Levis K L. 2014. Integrated farming system: An ideal approach for developing more economically and environmentally sustainable farming system for the Eastern Himalaya Region. *Indian Journal of Agricultural Sciences* **84**(3): 356-62.
- Bohra J S and Kumar R. 2015. Effect of crop establishment methods on productivity, profitability and energetics of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) system. *Indian Journal of Agricultural Sciences* **85**(2): 217-23.
- Das A, Munda G C, Azad Thakur N S, Yadav R K, Ghosh P K, Ngachan S V, Bujarbaruah K M, Lal B, Das S K, Mahapatra M K, Islam M and Dutta K K. 2014. Rainwater harvesting and integrated development of agri-horti-livestock-cum-pisciculture in high altitudes for livelihood of Tribal farmers. *Indian Journal of Agricultural Sciences* **84**(5): 643-9.
- Korkanthimath V S and Manjunath B L. 2009. Integrated farming system for sustainability in agricultural production. *Indian Journal of Agronomy* **54**(2): 140-8.
- Kumar R, Deka B C, Thirugnanavel A, Patra M K, Chatterjee D, Borah T R, Barman K K, Rajesha G, Talang H D, Kumar M and Ngachan S V. 2015. Comparative evaluation of different farming system models suitable for small and marginal farmers of Nagaland. (In) *National Seminar on Sustaining Hill Agriculture in Changing Climate (SHACC)*, Agartala, Tripura, December 5-7, pp 8-10.
- Kumar S, Singh S S, Meena M K, Shivani and Dey A. 2012. Resource recycling and their management under integrated

- farming system for lowlands of Bihar. *Indian Journal of Agricultural Sciences* **82**(6): 504–10.
- Kumar S, Singh S S, Shivani and Dey A. 2011. Integrated farming systems for Eastern India. *Indian Journal of Agronomy* **56**(4): 297–304.
- Mukherjee D. 2010. Productivity, profitability and apparent nutrient balance under different crop sequence in mid hill condition. *Indian Journal of Agricultural Sciences* **80**(5): 420–2.
- Ravisankar N, Pramanik S C, Rai R B, Nawaz S, Biswas T K and Bibi N. 2007. Study on integrated farming system in hilly upland areas of Bay Islands. *Indian Journal of Agronomy* **52**(1): 7–10.
- Samant T K. 2015. System productivity, profitability, sustainability and soil health as influenced by rice based cropping systems under mid central table land zone of Odisha. *International Journal of Agriculture Sciences* **7**(11): 746–9.
- Singh D K, Kumar P and Bhardwaj A K. 2014. Evaluation of Agronomic Management Practices on Farmers' Fields under Rice–Wheat Cropping System in Northern India. *International Journal of Agronomy* (10): 1–5.
- Singh R P, Das S K, Rao U M B and Reddy M N. 1990. Towards sustainable dry land agricultural practices. *Bulletin, Central Research Institute for Dry land Agriculture, Hyderabad*, pp 5–9.