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Comparative evaluation of different integrated farming system models for small and marginal farmers under the Eastern Himalayas

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ABSTRACT

Integrated farming system (IFS) ensures efficient utilization of available farm resources, increases unit productivity and income that are pre-requisite for sustainable livelihood of small and marginal farmers. The present study was conducted to evaluate the performance of four IFS model developed in ~ 1.0 acre area, at ICAR Research Complex for North Eastern Hill Region, Nagaland Centre, Jharnapani, Medziphema, Nagaland. The major components in IFS models were agriculture, horticulture, livestock and subsidiary components like fishery, vermicompost, mushroom and azolla. The field crops, vegetables and livestock components were included in IFS model considering topography of land, soil texture and preference for the tribal livelihood. The performance in terms of component wise productivity, profitability, employment generation and sustainability value index (SVI) were evaluated in consecutive three years (2012–2015). The combinations of subsidiary components in agriculture + horticulture + poultry + fishery in IFS model (model–4) gave the highest net returns (₹ 32040) followed by the model with agriculture + horticulture + fishery + piggery + vermicompost (model 3) with net profits of ₹ 21230. In field crops component, cropping sequence of rice-*toria*-mungbean system was found to be the best in terms of productivity among the tested IFS models except in model 1. In terms of employment generation, IFS model-4 has shown maximum man-days engagement (395 days), followed by 350 days in model-3. Based on sustainability values index (SI) derived from different IFS models, maximum SVI values was recorded in model-4 (0.71) followed by model-3 (0.47). Therefore, the intensification of IFS model with crop, horticulture, fishery and livestock or poultry should be popularized among the small and marginal farmers on a larger scale, as it provide scope for higher returns, year round employment and sustainable livelihood in longer perspectives of Eastern Himalayas.

Key words: Integrated farming system, Eastern Himalayas, Net returns, Sustainable value index

In North-Eastern Hill (NEH) region of India, *jhum*/slash and burn agriculture and valley cultivation is the mainstay of economy (Deka *et al.* 2011). This cultivation practice has reduced the fallow cycle to 3 to 5 years from 15 to 20 years in the past (Kumar *et al*. 2016). The rainfed agriculture occupies ~65% of the total cultivated area in the region and characterized by difficult terrain, wide variations in slope and altitude, land tenure system and cultivation practices (Kumar *et al*. 2016). Declining productivity under *jhum* cultivation with time and its negative impact on environment hazard has become a global concern. However, terrace cultivation in the region has limited value because of heavy leaching losses of nutrients occur even if runoff losses are checked by bund (Kumar *et al*. 2017a). It was reported that the loss of 88.3 thousand tonnes of soils having 10.7, 0.37 and 6.1 thousand tonnes of NPK, respectively per annum in NEH region due to *jhuming* (Kumar and Meena 2016). 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.* 2014). 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*. 2015a). With perspective of available resources accessible to the farmers, IFS has revolutionized conventional farming of livestock, aquaculture, horticulture, agro-industry and allied activities

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in many agrarian countries including India (Kumar *et al.* 2011). Integration of crop and livestock component has been found highly productive, profitable, and environmentally sustainable (Gill *et al.* 2010, Yadav *et al.* 2013). It is a reliable means of obtaining the 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). Improvement in soil structure and fertility status, weed suppression and disruption of pests/diseases cycles created by diverse crop sequences and livestock presence are among the other key features that makes the farming system remunerative (Tracy and Davis 2009, Chatterjee *et al.* 2016). Many attempts have been made to integrate desirable features of farming system research into mainstream agriculture to develop more relevant, realistic client-oriented and location-specific technologies. About 80% operational farm holdings in India being <1.0 acre engaged mostly with cereal production and frequently suffers from erratic rainfall (Kumar *et al*. 2016). In Nagaland, extreme rainfall deficit was recorded during month of June and July 2009, that resulted in complete failure cultivation of cereal and huge economic loss to marginal farmers of the state. Thus, small and marginal farmers can take suitable crops along with horticulture, animals, fisheries, poultry/duckery and other components that would minimize the risks, and provide additional income and employment from same piece of land (Kumar *et al*. 2015b, 2015c). Thus, the present study was designed to develop and evaluate the performance of IFS model comprising agriculture and allied components in land simulating small and marginal farmers under the foot hill agro-ecosystem of Nagaland condition.

MATERIALS AND METHODS

Integrated farming system models in the present study were developed at experimental farm, ICAR Research Complex for NEH Region, Nagaland Centre, Jharnapani, Nagaland during 2012-13 (25°45’24” N and 93°50’26” E; an altitude of 281 m amsl). During the study period, the average mean monthly maximum and minimum temperatures varied from 23.8 to 33.0°C and 9.3 to 25.3 °C, respectively. The average maximum and minimum relative humidity varied from 56% (January) to 90% (August) and 3% (February) to 84% (August). The average annual rainfall in the region was 1406.1 mm with maximum rainfall during July to August and almost no rainfall during November to February (Source: Agromet Observatory and Automatic Weather Station, ICAR Nagaland Centre, Jharnapani, Medziphema). During period of 2012-2015, four IFS models comprising agriculture, horticulture, livestock and subsidiary components in 1.0 acre area for each model were established aiming land holding of small and marginal farmers in the Nagaland.

All four IFS models were developed in an area of about 1.0 acre (~4000 m^2), which comprised agriculture, horticulture, piggery (Ghungroo/Ghungroo-Hampshire crossbreed), fishery (Rohu, catla, silver carp, common carp and mrigal), poultry (Vanaraja), and duckery (*Cherra Chambli*). The area of various components varied with different models (Fig 1). IFS model-1 consisted of horticulture (peach, litchi, Khasi mandarin, mosambi, banana and seasonal vegetables), fishery, and piggery (3 pigs capacity). IFS model-2 consisted of agriculture (paddy-linseed/*toria*), horticultural crops (mango, guava, pineapple and seasonal vegetables), and fishery with a duckery unit at the bank of pond. IFS model-3 was developed with agriculture (maize-*toria*-mungbean), horticulture (mango, banana, Assam lemon and seasonal vegetable crop), fishery, and piggery (5 pigs capacity). The IFS model-4 has comprised agriculture (paddy-*toria*-summer mungbean), horticulture (mango, banana, Assam lemon, papaya and seasonal vegetables), fishery and poultry (50 birds capacity). A mushroom unit and *azolla* tank (15 m^2) were included exclusively in this model. A vermicompost unit was kept in all the four models for effective conversion of bio-waste into compost. Some quantities of litter and dung materials from poultry/ducks and pigs were allowed to drop in fish pond as a source of feed materials to the fish species reared. The litter/dung materials, grasses, and plant wastes collected in different models were partly decomposed and used for the production of vermicompost using the vermicompost unit

Table 1 Initial and final soil health in different IFS models

Soil character	IIFS Model							
	Model 1		Model 2		Model 3		Model 4	
	Initial (2012)	Final (2015)	Initial (2012-13)	Final (2015)	Initial (2012-13)	Final (2015)	Initial (2012-13)	Final (2015)
pH	4.27±0.14	4.33±0.06	4.67±0.14	4.71±0.09	4.71±0.14	4.76±0.02	4.33±0.14	4.38±0.04
EC (dS/m)	0.08±0.01	0.04±0.01	0.14±0.14	0.05±0.01	0.15±0.14	0.05±0.01	0.19±0.14	0.03±0.01
OC (%)	0.72±0.02	0.78±0.03	1.26±0.14	1.38±0.06	0.69±0.14	0.75±0.01	0.66±0.14	0.72±0.02
Available N (kg/ha)	100.4±0.13	105.75±1.52	213.3±0.14	218.44±2.32	137.98±0.14	141.15±0.57	150.5±0.14	153.98±1.12
Available P_2O_5 (kg/ha)	101.1±0.12	102.66±1.99	78.3±0.14	79.86±2.93	190.4±0.14	191.28±0.48	64.4±0.14	65.08±1.12
Exchangeable K_2O (kg/ha)	173.4±0.17	176.61±2.12	168±0.14	170.64±2.93	172±0.14	173.50±0.54	264.8±0.14	268.23±1.22

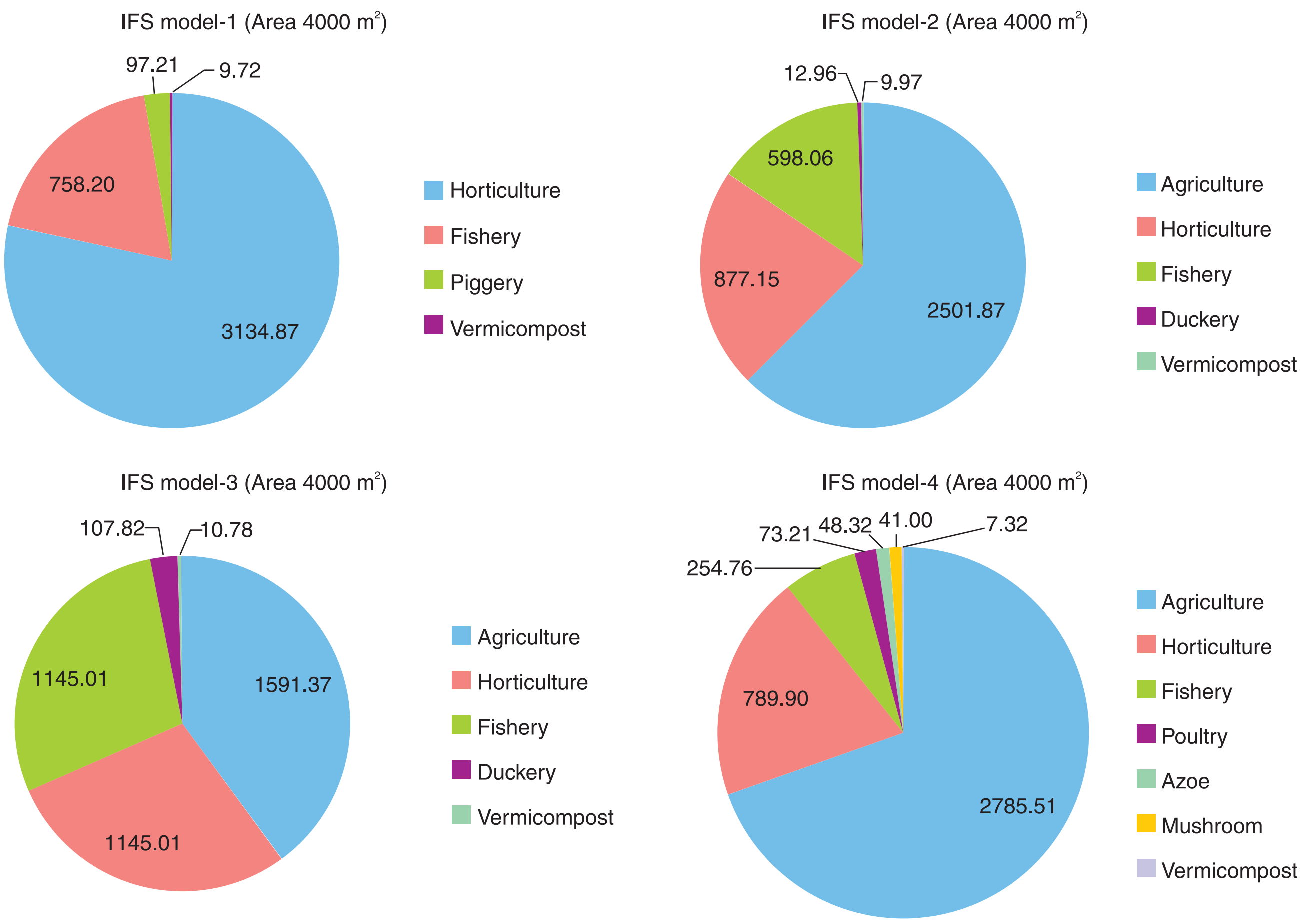

Fig 1 Component wise area coverage in different developed IFS models at ICAR Nagaland Centre.

established in the IFS models. The performance of these models was evaluated at the end of third year (2014-15).

Parameters studied

The comparative productivity, 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 under Nagaland. Soil pH, EC (1:2.5 soil: water suspension), oxidizable organic carbon, alkaline-$KMnO_4$ nitrogen, available phosphorous, and exchangeable potassium (Rao and Reddy 2009) were estimated in all the four IFS models. Soil samples were collected twice (initial and after three years) at 0-15 cm depth. The collected soil samples were air dried, ground and sieved through 2 mm sieve and used for analysis. The total production was recorded for each commodity in each model and expressed as kg. The yield of paddy, maize, linseed, mungbean and *toria* was calculated at 12% moisture content. Fruits and vegetables yield were calculated at fresh weight basis. The cost of cultivation and gross returns were worked out based on ICAR Farm fixed rate, which is lower than the market rate and expressed in Indian national Rupees (₹). Net returns and benefit cost ratio (B: C ratio) were calculated based on the following formula.

Net return = Gross return (₹ /acre) – Cost of cultivation (₹/acre)

B: C ratio = Gross return (₹/acre)/Cost of cultivation (₹/acre)

Sustainability values index (SVI) for each model was calculated following the formula as described by Bohra and Kumar (2015)

SVI = NR–SD/MNR

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. System economic efficiency (SEE) was calculated based on the net returns obtained under the various IFS model during the years and divided by 365. The suitability and viability of IFS model was identified for their existence based on their net returns, SVI, employment generation and improvement in soil fertility attained over a period of time.

RESULTS AND DISCUSSION

Productivity and profitability

The performance of integrated farming system models were assessed at institute level before popularizing in the farmers' field. Model-1 mainly consisted of horticulture components, which occupied around 80% area. The fruit trees were planted during June 2012 and they are in vegetative stage after 3 years. The tuber crops (Elephant foot yam and colocasia) and seasonal vegetables (beans, radish) were cultivated during June-November, 2014. The yield of tuber crops, viz. colocasia var. Muktakeshi and elephant foot yam var. Gajendra was 150 kg and 250 kg, respectively in 6 months after planting. Besides, crops like beans and radish were cultivated and production was 7 kg and 10 kg, respectively. This model consisted of two shallow fish ponds and the fish species like *rohu, catla* and common carp were grown. However, only 6 kg fish was harvested. Water stagnation in these two ponds was low due to percolation and leaching loss that affects the fish production. The production of fish could be enhanced if the water level in the pond was maintained. Under piggery component, three female pigs were kept under low input management condition with kitchen waste and locally available roughages. Out of three pigs, one pig was slaughtered at an average weight of 80 kg in one year and remaining two was bred through artificial insemination. After keeping replacement stock for extension of piggery unit, three piglets were sold @ ₹ 2,500/pig at post weaning. In this model, a net income of ₹14,840 was achieved, out of which, maximum income came from piggery component (Table 2). Since, fruit crops are still in vegetative stage, net income from total horticulture component was in negative. Among the horticultural crops, the tuber crops contributed the maximum income. It was identified that tuber crops in combination with piggery holds the potential for generating income with the minimum input in IFS model having the minimum scope for agricultural crops (Kumar *et al*. 2015a). The vermicompost unit in this model did not yield any compost due to poor survival of vermiworms. Plant biomass and pig dung obtained in this model were decomposed and incorporated in the soil. The benefit: cost ratio in the model was 1.48.

There was integration of four major components in IFS model-2, viz. agriculture, horticulture, fishery and duckery. In agriculture, paddy-linseed based cropping system was followed in an area of 2500 m^2. Paddy var. RCM 10 was planted in June 2014 and harvested in October, 2014. The total production of paddy (grain) was 715 kg which was sold @ ₹ 15/kg. The straw yield was 3000 kg, which was sold @ ₹ 1.5/kg. Thus, paddy fetches a total gross income of ₹ 11725 (Table 2). During *rabi* season (November 2014-March 2015), linseed var. Sweta was cultivated on same field. Poor germination and survival of linseed plants

Table 2 Comparative performance of economics and employment generation of different IFS models (after 3 years)

IFS model	IFS components	Gross returns (₹)	Cost of cultivation (₹)	Net incomes (₹)	Benefit: cost ratio	Employment generations (man-days/yr)
Model-1	Horticulture	8170	8200	-30	-	170 (60*)
	Fishery	720	600	120		15
	Piggery	29250	21000	8250		45
	Vermicompost	-	-	-		10
	Total	45640	30800	14840	1.48	240
Model-2	Agriculture	16025	4100	11925		100 (60*)
	Horticulture	2425	930	1595		50
	Fishery	2400	1650	750		15
	Duckery	5330	8000	-2670		20
	Vermicompost	720	500	120		10
	Total	26900	15180	11720	1.78	195 (60*)
Model-3	Agriculture	7400	3900	3500		140(60*)
	Horticulture	12145	1741	10404		90
	Fishery	2040	1000	1040		25
	Piggery	19650	10800	8850		85
	Vermicompost	1050	450	600		10
	Total	42285	17891	24394	2.35	350 (50*)
Model-4	Agriculture	21350	5600	15750		150 (60*)
	Horticulture	7810	1055	6615		70
	Fishery	2730	2000	730		15
	Poultry	22360	14000	8360		35
	Mushroom	2550	5640	-3115		70
	Azolla	3000	500	2500		10
	Vermicompost	1800	600	1200		10
	Total	61600	29395	32040	2.11	360 (60*)

*Existing employment generation of the respective model following the traditional farming.

due to less soil moisture drastically reduced the production. Only 40 kg of linseed have been harvested as against the 75 kg from 2500 m^2 area. A gross return of ₹ 1600 has been gained from linseed. The perennial horticultural crops like mango, guava, and Assam lemon were planted during 2012. The annual fruit crops like pineapple and banana were planted in May 2014 and seasonal vegetables, i.e. bottle gourd and pumpkin were cultivated during June-November 2014 which covers an area of 877 m^2 for generating the income round the year. The total gross return from these components was ₹ 2425 against cost of cultivation (₹ 930) and fetched net profit of ₹ 1595. In the fishery unit, rohu, catla, and common/silver carps were released (600 m^2) and managed with duck droppings as feed material. Duckery shed was constructed with locally available materials at the bank of the fish pond and droppings from ducks were allowed to drop in the pond as a feed material to fish species. A total of 20 kg fish was produced and a net return of ₹ 750 was generated. Duck unit (100 ducks) generated only 41 kg due to poor growth of duck and higher cost of ducklings that resulted in huge loss. The return from duckery is only economical, when proper care and feeding and vaccination has been taken (Solaniappan *et al.* 2007) In vermicompost unit, 60 kg of vermicompost was produced that generates an additional income of ₹ 120. Overall this model generated gross returns of ₹ 26900 against the cost of cultivation of ₹ 15180 and net profit was ₹ 11720. Among the different components, paddy gave maximum profit followed by horticultural components. The benefit: cost ratio in this model was 1.78. The farmers of Northeastern region of India grow only paddy during June to October in wetland system and the land kept fallow after that. In this model, paddy-linseed cropping system was followed, hence the cropping season was extended upto March. The water stored in the fish pond was used to grow linseed.

The IFS model-3 consisted of field crops (maize-*toria*-mungbean), horticultural crops (mango, banana, Assam lemon, and seasonal vegetable crops) and a fishery unit which were developed in almost equal proportion of the area along with a piggery unit consisting of 5 Hampshire crossbreed pigs. In agricultural component, cropping intensity was achieved up to 300% by introducing crop sequence of maize-*toria*-mungbean with the supplemental irrigation from pond water during *rabi* (*toria*) and summer season (mungbean). The maize var. Vijay Composite was sown during May 2014 and harvested during September 2014. The toria var. TS 38 was sown during November 2014 and harvested during February 2015. The mungbean was cultivated during March – May 2015. Among the field crops, the returns were maximum in maize during *kharif,* whereas due to less rainfall and poor survival rate, the yield of *toria* and mungbean was not up to the level. Among horticulture components, vegetables, viz. bottle gourd, pumpkin and ridge gourd occupied the major area and generated a net profit of ₹ 5890. In fruit crops, Assam lemon (2 year old) occupies major area and gave net returns of ₹ 2359. In fishery component, only 17 kg fish was harvested and remaining were left to grow in next season. The pig unit generated net profits of ₹ 8850 from sale of pork from five pigs. About 88 kg vermicompost was produced from crop residues and pig dung, and vermicompost was incorporated in the soil for production of seasonal vegetables. Among all different components in IFS, piggery unit contributed the maximum returns with overall net income of ₹ 24394 (Table 2). This was due to fact that system as a whole provided an opportunity to make use of by-product or waste materials of one component as input for another component to reduce the cost of production of different enterprises and finally production cost of whole system (Kumar *et al*. 2014). The benefit: cost ratio in this model was 2.35. Piggery and horticultural components in this model gave maximum profit which in turn increased the benefit: cost ratio.

In IFS model 4, field crops occupied major area, in which paddy-*toria*-mungbean cropping system was followed. The paddy var. RCM 10 was transplanted in June 2014 and harvested during October 2014. After harvesting of paddy, *toria* (TS 38) was planted in November 2014 and harvested in February 2015. During the summer, mungbean (T-1) was sown on March 2015 and harvested in June 2015 and their entire green biomass was incorporated into the soil. Horticultural intervention was made in 790 m^2, which included fruits crops *i.e*. banana, Assam lemon and mango and vegetable crops. Bund of pond area was utilized effectively for cultivation of seasonal vegetables like ridge gourd, pumpkin, bottle gourd and cucumber by making a *pandal* over it. Low cost poultry unit was made to rear 60-70 Vanaraja birds for meat purpose. The birds were sold at 1.5-2.0 kg body weight (10-12 weeks old). Fish species like rohu*, catla*, silver carp, mrigal and common carp were reared for 3-4 months till sufficient water level maintained in the pond. At the end, grown up fishes were harvested and sold. After harvesting fish, unused water from pond was utilized as life saving irrigation for production of *rabi* and summer crop. This helps in increasing cropping intensity from 100 to 300%. Outcome from this food chain understood better synergistic component among agriculture-poultry-fishery-component. Mushroom unit included in this model, which produced oyster mushroom (*Pleurotus ostreatus*) during March to September 2014. Further, *azolla* unit produced fresh green *azolla*, which was used as poultry feed and as green manure in rice field. Model-4 gave gross income of ₹ 61600 (Table 2) and net income of ₹ 32040. Of which, agricultural component contributed gross income of ₹ 21350 next to poultry rearing. In poultry, a total of 172 kg of chicken was produced from three batches of birds reared that contributed gross income of ₹ 22360. Higher expenditure incurred for poultry rearing was due to higher cost of concentrate feed mixtures from the local market. However, cost of concentrates could be minimized up to 50% if it was prepared at household level by incorporating grain residues (Kumar *et al.* 2011). In horticultural components, 125 kg fruits (mango, papaya), 272 kg of seasonal vegetables (banana, ridge gourd, sponge gourd, pumpkin, cucumber, amaranthus, chilli, cowpea, bhindi) were harvested. About

600 kg biomass from fruits/vegetable/green *azolla* and 3000 kg of paddy straw were obtained. Paddy straw was sold as feed materials for animals and some of them were used for production of mushroom bed. About 150 kg of vermicompost was produced with recycling of these materials. Similarly, 600 kg of green *azolla* was produced and these were effectively utilized for various purposes, e.g. source of nutrient for lowland rice; feed materials for poultry and production of vermicompost (Kumar *et al*. 2017b). Benefit: cost ratio in this model was 2.11.

Employment generation

Integration of different components in IFS model has increased employment opportunity in all the four models (Table 2). Horticulture based farming system model (model-1) provided an ample scope for employment generation. The cultivation of vegetables/fruit crops required regular farm labours. Out of different components, horticulture crops particularly fruits/vegetables created more employment opportunities (170 man-days/yr). Besides this, integration of fish-cum-piggery and vermicompost increased it further to 240 man-days/yr in model-1. Similarly in model-2; generation of employment was increased from 60 to 195 man-days after integrating crop + horticulture + fishery + duckery + vermicompost. After incorporation of one more crop into system over traditional cropping system of growing paddy alone, there was an additional employment of 40 man-days/yr. The other enterprises like horticultural crops, fishery, duckery and vermicompost generated an additional employment of 50, 15, 20, 60 and 10 man-days, respectively. In model-3, each component effectively contributed in employment generation for farm families round the year. Among the model components, crops and vegetables cultivation generated maximum employment (210 man-days/yr) followed by piggery (85 man-days/yr). All together this model generated employment for 350 days. Out of all four models, model -4 was the best in terms of employment generation (360 man-days/yr). Among model components, crops and vegetables cultivation (120 man-days/yr) generated the maximum employment followed by mushroom cultivation (70 man-days/yr). An extra employment of 90 man-days/yr was generated from crop components due to inclusion of toria/mungbean over traditional cropping system of paddy alone (60 man-days/ yr). Combining of crops with other enterprises would increase labour requirement and thus provide scope to employ more family labours round the year without giving much relaxation in lean season as in traditional agriculture observed by Ravisankar *et al.* (2007) with integration of crop + horticulture + goat + poultry into the system. Similar lines of results were reported by Kumar *et al*. (2012), Kumar (2015a, 2015s, 2015c) in their investigation.

System economic efficiency

In the integrated farming system, the pre-requisite is to generate the regular income to sustain the livelihood and minimize the risk of crop failure. Therefore, it is necessary to compute system economic efficiency, so that more remunerative integrated faming system may be identified and further promoting it to the farming community of the NEH regions under Eastern Himalayas. System economic efficiency (SEE) was also varied among models during the study (Fig 2). Results revealed that the markedly higher SEE was recorded in model 4 (₹ 88/ day) followed by model 3 (₹ 67/day). The lowest values of these attributes were associated with model 2 (₹ 32/day). The trends of SEE were followed in the order of model 4> model 3> model 1> model 2. This might be due to inclusion of more suitable remunerative enterprises which increase the productivity and net income and thus provide the better SEE (Kumar *et al.*2015, 2011, 2012). In model-4, suitable components were added that increased the system economic efficiency (Kumar *et al*. 2017).

Sustainable value index (SVI)

In integrated farming system, since more than one component is involved, yields and net returns assessment of this system becomes important. In these situations, obtaining maximum sustained level of yield is more desirable. Sustainable value index (SVI) also varied among models during the study (Fig 2). Markedly higher values of SVI were associated with model 4 (0.71) followed by model 3 (0.47). The lowest values of these attributes were associated with model 2 (0.08). Trends of SVI were followed in the order of model 4 > model 3 > model 1 > model 2. This might be due to inclusion suitable remunerative enterprises, which ultimately increased net income of model 4 and model 3 and thus provide better SVI (Kumar *et al.* 2015a).

Soil health

Initial and final soil analysis presented in Table 1 showed that the pH of the soil was acidic (<7.0) in all the four models. Marked improvement in soil fertility status (pH, EC, soil organic carbon and available nitrogen, phosphorous

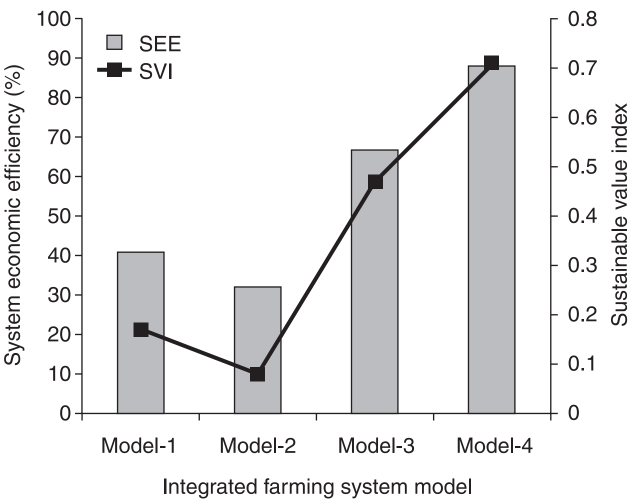

Fig 2 System economic efficiency (SEE) and sustainable value index (SVI) of the integrated faming system models developed under Nagaland agro-climatic condition

and potassium) were observed in all IFS models after completion of three years of study over its initial soil status (Table 1). Soil pH and EC of different IFS models increased and declined respectively. The soil pH increased from 4.27 to 4.33 in model-1, 4.67 to 4.71 in model-2, 4.71 to 4.76 in model-3 and 4.33-4.38 in model-4 after completion of 3 years. The soil EC markedly improved from 0.08 to 0.04 dS/m in model-1, 0.14 to 0.05 dS/m in model-2, 0.15 to 0.05 dS/m in model-3 and 0.19 to 0.03 dS/m in model-4. The soil organic carbon content also improved markedly over the years in the IFS models during the study. It increased from 0.72 to 0.78% in model-1, 1.26 to 1.30% in model-2, 0.69 to 0.75% in model-3, and 0.66 to 0.72% in model-4 after completion of 3 years. Recycling of farm waste (birds/animal waste and crop residues including locally available weeds) through vermicompost and its application in different IFS models helps in amelioration of soil acidity (pH), soil electrical conductivity (EC) and soil organic carbon, which will improve soil health status in longer perspectives. Converting farm waste into vermicompost effectively utilizes crop residues/else, burning of these crop residues has deleterious effects on environment.

Similarly, all the major nutrients, *i.e.* NPK in soil were improved markedly after three years in all four established models. There was increase in nitrogen content in different models and it ranged from 3.48 to 5.3 kg/ha. The available phosphorous content increased after three years and it ranged from 0.68 to 1.56 kg/ha. Maximum increase in nitrogen and available phosphorous content was noticed in model-1. The exchangeable potassium content increased in all the models after three years and it ranged from 1.5 to 3.43 kg/ha. The maximum increase in exchangeable potassium content was noticed in model-4. The 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. The residues recycling in each model revealed an integration of crop and allied component resulted in higher productivity, profitability as well as soil health over the years (Acharya and Mondal 2010, Kumar *et al*. 2015c). Similarly, additional nutrients gained by recycling of waste/by-products over raw wastes were confirmed by Baishya *et al*. (2004) and Kumar and Kumawat (2014). 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.

Conclusion

From this study, it can be concluded that the adoption of the IFS models not only ensured economic returns but provides regular employment even in less than one acre of land, which is usually non-sustainable if mono-cropping is being practiced. However, when economic aspect of different models are considered, combination of crop + horticulture + poultry + fishery model ranked first in respect of net returns and SVI because of incurred expenditures were lowered. Out of four different IFS models evaluated, IFS model-4 performed well and gave highest net income of ₹ 32040. The synergistic effect of integrating different components in this IFS model helped to increase the net profit. In addition to that, selling of biomass (paddy straw) and recycling of by-products /farm waste effectively through vermicomposting generated additional income. Further, the IFS models would conserve resources through efficient recycling of residues within system to make it sustainable for food security at household or farm level. Therefore, dissemination of such IFS models with more intensification would help in promoting sustainability in agriculture and its allied sectors besides enhancing in productivity, economic returns, generating employment and maintaining soil health.

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