Coconut based integrated farming: A climate-smart model for food security and economic prosperity

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Abstract

A coconut-based integrated farming system (IFS) model suited for lowlands was developed at the Integrated Farming System Research Station (IFSRS), Karamana, Kerala state, India, under Kerala Agricultural University. The area of the model was decided as 0.2 ha, matching the average per capita land availability of a marginal farmer in the state. Apart from the major crop coconut, intercrops, such as vegetables, fruit crops, spices, fodder and tuber crops were included in the model. The allied enterprises integrated were livestock, azolla, and agroforestry. Tree components of the model comprised of teak, jack, breadfruit, garcinia and mango. Research data for five years revealed that the model generated food products above the requirement of a four-member family, and the surplus production could contribute to farmer's income. The productivity under the IFS model was enhanced ten-folds compared to that under the sole crop of coconut for the same area. Plant nutrients were generated within the farm through organic recycling, which contributed to the substantial saving of chemical fertilizers. The system was found climate-smart because of reduced use of chemical fertilizers and net negative emission of greenhouse gases mostly achieved through agroforestry. This IFS model could also ensure considerable employment generation. The model could be adopted by farmers of lowland tracts of Kerala having similar agro-climatic features for better economic returns and environmental benefits.

Keywords: Benefit:cost ratio, carbon sequestration potential, coconut equivalent yield, diversity index, greenhouse gas emission, integrated farming systems, nutrient recycling, sustainability

Introduction

Coconut has the status of a plantation crop worldwide. Among the main coconut producing states in the country, Kerala ranks first in area and production. Coconut is raised in 7.61 lakh ha and occupies 29.6 per cent of the gross cropped area. However, with respect to productivity, it is fifth, next to Andhra Pradesh, Tamil Nadu, West Bengal and Karnataka (CDB, 2017-18). Unlike several countries where coconut is grown in large gardens, Kerala has a unique feature of coconut-based home gardens that have evolved in response to the pressure of shrinking land resources coupled with high population density. Enhancement of productivity from coconut gardens is extremely important, and

a switch to integrated farming becomes increasingly important in this context.

Integrated farming is currently recognized as the most viable strategy in enhancing agricultural production and farm income. Optimum utilization of farm resources through judicious recycling, on-farm generation of organic manures to substitute chemical fertilizers and generation of employment opportunities around the year are the other major benefits of integrated farming. Coconut, the major crop of coastal tracts of India when grown as a monoculture, often leads farmers to distress mainly due to crop loss associated with the pest and disease incidences and market price fluctuations. However, it has been well established that resorting to coconut-based

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integrated farming can enhance the yield from the unit area and bring about a considerable hike in farm income, apart from environment-friendly effects resulting from saving fertilizers. The social relevance of such systems also is quite promising, as evidenced by the generation of more employment opportunities.

Materials and methods

The experiment was carried out at the Integrated Farming System Research Station (IFSRS), functioning under Kerala Agricultural University at Thiruvananthapuram in Kerala, India, a network centre of the All India Co-ordinated Research Project (AICRP) on Integrated Farming Systems, the apex body coordinating research on integrated farming at national level in India. The experimental site was a lowland (5 m above mean sea level) and was located at 8°28'25" N Latitude and 76°57'32"E Longitude. The soil type was riverine alluvium of sandy clay loam texture.

The station has developed and validated integrated farming models matching Kerala's major crops/cropping situations. A highly successful coconut-based integrated farming system model of 0.2 hectares has been developed by the station, which especially suits the land area and other resources of marginal farmers of the state. The establishment of the IFS model was initiated in the year 2011-12.

Research work carried out for five years suggests that the model is quite successful in generating higher yields, better income, and eco-friendly in terms of on-farm generation of nutrients and providing a negative balance of greenhouse emissions. The

various components included in the model are detailed in Table 1.

Coconut trees (West Coast Tall) of 15 years of age, established on bunds raised on the lowland, at a spacing of 7.5 x 7.5 m, were selected. Water channels of about 2 m depth were naturally formed between the bunds due to soil excavation from the low lying tract. These channels were utilized in raising fish species *viz.,* Genetically Improved Farm Tilapia (GIFT). Different intercrops comprising of fruit trees (papaya, rose apple), vegetables (vegetable cowpea, ash gourd, amaranthus), spice crops (ginger, turmeric, garcinia, cinnamon), fodder crops (guinea grass, para grass), beverage crops (cocoa), tuber crops (cassava, coleus) *etc.,* were planted in the interspaces of coconut. All along the boundaries of the model, miscellaneous trees were planted, like breadfruit, mango, jack *etc.* Azolla was raised in two separate pits of 2 m^2 each, and it served as fish feed. A dairy unit comprising a cow and a calf was introduced as an integral component of the model. A bee hive that reared stingless honey bees helped in the pollination of vegetables raised in the model. Once the model was well established and yields stabilized by 2014-15, research data were recorded.

On-farm generation of plant nutrients obtained from the byproducts (crop residues, dung, cow's urine, stall wash and nutrient-rich silt from fish pond) were quantified for five years starting from 2014-15. The fertilizer equivalent of plant nutrients generated and the energy equivalent of fertilizers saved was worked out for all these years. The various products from the model were equated as coconut equivalent yield (CEY) and worked out for five years. The economics of the model in terms

Table 1. Coconut based IFS model (0.2 ha)

Components	Net area (m²)	Gross area (m²)
Coconut on bunds and adjoining area (30 nos.)	1480	1480
Teak trees along the border (15 nos.)	400	400
Multitier cropping (in interspaces of coconut) papaya (6), clove (1), nutmeg (1), cocoa (1), rose apple (1), mango (1), jack (1), bread fruit (1), spices (ginger + turmeric), tuber crops, fodder crops and azolla (in a shallow pit of size 2 x 1 x 0.2 m³, lined with silpaulin)	20	620
Cow unit: Cross bred (1+1)	100	100
Freshwater fish (GIFT: Genetically Improved Farm Tilapia) reared in trenches dug between the bunds planted with coconut	0	400
Total	2000	3000

of gross returns, net returns and benefit: cost ratio were also worked out. Greenhouse gas emission is a measure of the carbon sequestration potential of any IFS model, and the net emission of greenhouse gases from the model was worked out for the years 2017-18 and 2018-19 as per the guidelines suggested by the Inter-Governmental Panel on Climate Change. The various sources for the release of greenhouse gas were worked out based on farm activities like the use of inorganic fertilizers, plant protection chemicals, use of energy (operation of farm machinery and consumption of fuel) *etc.* Activities like crop residue recycling, the addition of organic manures and sequestration of carbon in soil and plant biomass, contributed mostly through agroforestry, were accounted as sinks for greenhouse gases. Carbon sequestered in the soil and plant biomass was estimated as per the life cycle approach suggested by Yadav *et al.* (2017). Also, the employment generation potential of the system, which is much related to the IFS model's social relevance, was worked out for all these years.

The sustainability yield index (SYI) for each treatment was computed as suggested by Singh *et al.* (1990).

SYI = (A-SD)/Ymax, where, A = average yield over the years for a particular treatment, SD = standard deviation for the treatment and Ymax = maximum yield (average) obtained in any of the treatments over the years. The diversity index was calculated by computing the reciprocal sum of squares of the share of the gross revenue received from each individual farm enterprise in a single year.

Results and discussion

Nutrient generation from the model

Data on the generation of major plant nutrients *viz*., nitrogen, phosphorus and potassium from the coconut-based IFS model in different years under the study are presented in Table 2. The major sources of plant nutrients were crop residues, dairy outputs including cow dung, cow's urine, stall wash *etc.* Nutrient-rich pond silt, which was excavated from the fish rearing channels in alternate years, was also a source of plant nutrients. The nutrient content of these resources was estimated every year, and the plant nutrient generation was quantified by multiplying the nutrient content by the quantity of each resource produced every year.

On an average, plant nutrients to the tune of 177 kg nitrogen, 89 kg phosphorus and 98 kg potassium were generated annually from the model. These nutrients were recycled into the system itself, thereby saving considerable quantities of chemical fertilizers. The fertilizers equivalent of the nutrients generated is presented in Table 3. Chemical fertilizers to the tune of 386 kg urea, 446 kg rock phosphate and 163 kg muriate of potash could be saved as a result of on farm generation of organic manures. This way, an approximate amount of ₹ 8236/- could be saved annually on fertilizers. Such a considerable saving of fertilizers is definite to impact the environment positively. Several researchers have pointed out the need to shift from fertilizer intensive nutrient management to an integrated nutrient management strategy. Ghosh (2004) opined that intensive use of fertilizers could certainly damage soil quality in the long run. A judicious blend of chemical fertilizers with organic manures is always the right option for plant nutrition. One of the harmful effects of chemical fertilizers, as pointed out by Chandini Kumar *et al.* (2019), include the release of toxins during the manufacturing process, which can cause air pollution. When the wastes of chemical fertilizers are disposed of untreated in nearby water bodies, it can cause more harmful effects such as water pollution. In these ways, fertilizers as crop production input are depleting our environment and ecosystem. Any reduction of chemical fertilizers in crop production by resorting to integrated nutrient management is always appreciable.

Table 2. On-farm generation of major plant nutrients from the 0.2 ha model (kg)

Nutrients (kg)	Period under study					
	2014-15	2015-16	2016-17	2017-18	2018-19	Average
Nitrogen	173	127	199	222	166	177
Phosphorus	68	69	105	117	87	89
Potassium	71	76	113	125	103	98

Table 3. Fertilizer equivalent of nutrients generated; price and energy equivalent of fertilizers saved

Year	Fertilizers (kg)			Energy equivalent of fertilizers saved (mega joules)	Price equivalent of fertilizer (₹)
	Urea	Rock phosphate	Muriate of potash		
2014-15	376	340	119	12034	6721
2015-16	276	345	127	8971	6244
2016-17	432	525	189	13973	9522
2017-18	482	585	209	16152	10594
2018-19	360	435	172	11735	8097
Average	386	446	163	12573	8236

The energy equivalent of fertilizers saved was worked out for individual years, and the average value arrived is presented in Table 3. On an average, 12573 Mega Joules of energy could be saved every year by saving fertilizers. Reports suggest that fertilizer manufacture is an energy-intensive industry. It has been estimated that fertilizer production accounts for approximately 1.2 per cent of the world's energy, of which about 93 per cent is consumed by nitrogen-based fertilizers (Yuan, 2014). To optimize energy inputs and to reduce greenhouse gas emissions from agricultural fields, a reduction in the quantity of chemical fertilizers is much essential (Woods *et al*., 2010). This can be attained by the on-farm generation of plant nutrients through organic recycling, thereby reducing the purchase of chemical fertilizers. In this context, saving fertilizers, thereby bringing down the energy expenditure on the same, as successfully achieved in this coconut-based integrated farming system model, is of considerable significance in environmental benefits.

Carbon sequestration potential of the IFS model

The net emission of greenhouse gases from any farming system model is a good indicator of the carbon sequestration potential of the model. Greenhouse gas emission from the model was worked out for two consecutive years *viz*., 2017-18 and 2018-19 and the data is presented in Table 4. The net negative emission of greenhouse gases could be well related to the farming activities and component selection followed in the model. The model can be rated as climate-smart. Crop residues and dung and urine obtained from livestock components could generate considerable quantities of plant nutrients, thereby reducing the quantity of chemical fertilizers. The animal component was the major source for greenhouse gas emissions, contributing 91 and 79 per cent during 2017-18 and 2018-19, respectively. The role of livestock in GHG emission is noticed through the release of methane and nitrous oxide (Moran and Wall, 2011; Grossi *et al*., 2019)

The inclusion of tree components in the system, like teak, mango, jack, garcinia, rose apple, breadfruit *etc*., along with the main crop coconut (Table 1), contributed to the buildup of above and below-ground plant biomass, which could sequester much carbon. Agroforestry/ tree component contributed over 90 per cent carbon sequestration

Table 4. Greenhouse gas emissions from the IFS model

Carbon emissions/ sequestration	Components	Period	
		2017-18	2018-19
Source		kg CO_2 equivalent	
	Crop (cropping systems/ horticultural crops / fodder)	141	462
	Animals (livestock/ poultry/ fish)	1451	1747
	Total	1592	2209
Sink	Agroforestry	18313	18394
	Biomass / compost incorporated	1576	1249
	Total	19889	19643
	Net emission	-18297	-17434

during both the years - 18313 and 18394 kg CO_2 equivalent in 2017-18 and 2018-19, respectively. This justifies the negative value for greenhouse gas emission from the model. Trees belonging to *Tectonia* (Teak) species have very higher carbon sequestration potential and thereby offer much to ecosystem services (Pichhode and Nikhil, 2017). The inclusion of 15 teak trees in this IFS model as boundary planting justifies the higher C sequestration. Carbon sequestration by trees belonging to 45 species was estimated by Prasadan and Jithila (2018), and they noticed higher sequestration rates with tree species *Artocarpus heterophyllus*. The IFS model under study included tree components belonging to *Artocarpus* species *viz., A. heterophyllus* (breadfruit) and *A. integrifolia* (jack). This also justifies the net negative emission of greenhouse gases from the model.

More use of nitrogenous fertilizers results in the release of important greenhouse gas nitrous oxide. Integrated farming systems can help mitigate the emission of greenhouse gases through the on-farm generation of manures, thereby reducing the reliance on nitrogenous fertilizers, as reported by Pathak *et al.* (2014). This observation is in agreement with the present study where on-farm generation of plant nutrients largely saved external purchase of chemical fertilizers.

Yield, economics and employment generation potential of the model

Data generated on yield and economics of the model are presented in Table 5. From the table, it is inferred that the average value for coconut equivalent yield is 13227 coconuts from an area of 0.2 ha. As the average value for coconut productivity from 0.2 hectares in the state is only 1378 nuts, it is evident that a switch to the integrated farming model can very well enhance production up to even tenfold. This is of very high significance as far as a marginal farmer is concerned. By shifting to an integrated farming approach, the farmer could well enhance production from the limited available land area and could satisfy most of the nutritional demands of the farmer's household. The diverse production from the 0.2 ha IFS model for the period under study is detailed in Table 6. The annual requirement for an average four-member family including four adults under low-cost diet management (Swaminathan, 2010) is presented.

Table 5. Yield, economics and employment generation from the IFS model

Year	Coconut equivalent yield (nuts 0.2 ha^{-1})	Gross returns (₹)	Net returns (₹)	B:C ratio	Employment generation (man days per year)
2014-15	12213	183201	52781	1.40	79.5
2015-16	10776	183191	56922	1.45	69.0
2016-17	13704	232962	52595	1.28	101.0
2017-18	14274	242663	69055	1.4	90.0
2018-19	15170	257891	60919	1.31	87.0
Average	13227	219982	58454	1.37	85.3

Table 6. Diverse food products obtained from the model

Year	Food products				
	Coconut oil (kg)	Milk (litre)	Fruits (kg)	Vegetables (kg)	Fish (kg)
2014-15	137	2434	105	558	133
2015-16	95	2884	35	322	81
2016-17	170	2030	445	1205 *	225
2017-18	95	2884	88	597	155
2018-19	85	3127	38	756	106
Average	116	2672	142	688	140
Annual requirement for a four-member family (adults) under a low-cost diet plan (Swaminathan, 2010)	66	183	44	429	120

*Cassava and ash gourd accounted as vegetables justify the enhanced vegetable production during 2016-17

Table 7. Sustainability index of the model

Enterprise	Yield data (2014-2019)					Mean yield	Max. yield (Ymax)	Standard Error	Standard Deviation	Sustainability Index
	14-15	15-16	16-17	17-18	18-19					
Main crop (Coconut)	2170	1583	2267	1357	1133	1702.0	2267	223.07	498.80	0.531
Intercrops	663	357	1650	685	794	829.8	1650	217.53	486.31	0.208
Dairy	2434	2884	2030	2884	3127	2671.8	3127	195.67	437.53	0.715
Fisheries	2434	2884	2030	2884	3127	140.0	225	24.63	55.08	0.377

The production from the model is higher than the requirement, and surplus food items could be marketed to generate income. The gross returns from the model were estimated to be ₹ 2,19,982. The average net income from the model was worked out as ₹ 58,454. The benefit: cost ratio of the model was 1.37 and remained higher than 1.0 all these years. This indicates that the model is consistent in generating better profits. The potential of an integrated farming approach in enhancing farm income and contributing to family nutrition, as noticed in the present study, has been reported in many studies. Swarnam *et al.* (2016) reported that the inclusion of livestock components along with diverse crops in an integrated farming system model of 0.75 hectares could significantly enhance the food diversity and help meet the dietary requirement of a family of five members. Gurjar and Swami (2019) reported integrated farming as the most viable approach for attaining food and nutritional security.

Behera and Mahapatra (1999) reported that IFS could enhance the income of small and marginal farmers of India. In a study conducted in the semi-arid tracts of the Telangana region, India, Ramana and Sridevi (2017) reported that, with the adoption of integrated farming (horticultural crops + buffalo + goat), the net farm income enhanced

up to ₹ 1.5 lakh per hectare. In contrast, the average income of farmers of the region was only ₹ 54,000 per hectare.

The social relevance of the model in terms of employment generation potential is detailed in Table 5. On an average, 85 person-days could be generated from the model annually. Khan and Parashari (2018) reported that integrated farming systems offer employment opportunities during off-farm seasons, especially for the care and management of livestock. In a study conducted at Bulandshahr in U.P, employment opportunities and income generation were seen much enhanced for women labourers with the adoption of the IFS approach.

Sustainability and diversity indices of the model

From the study, the dairy component was identified as the most sustainable (0.715). When combined with other enterprises on scientific lines, the dairy enterprise offers great opportunities for increasing farm income, as reported by Vinodakumar and Desai (2017). The diversity index (value) was worked out for all the years under study. From the second year onwards, there was a considerable enhancement in DI, peaking in the third year of study (3.316), attributed to the enhanced

Table 8. Diversity index of the model

Enterprises	2014-15	2015-16	2016-17	2017-18	2018-19
Main crop (Coconut)	26030	19000	34000	19000	17000
Intercrops	7741	10111	34022	38731	58995
Dairy	109530	129780	97440	138432	150096
Fisheries	39900	24300	67500	46500	31800
Gross returns	183201	183191	232962	242663	257891
Mean	45800	45798	58241	60666	64473
SE	22240.47	28146.69	15265.63	26560.3497	29836.383
SD	44480.945	56293.384	30531.278	53120.699	59672.767
Diversity index	0.845	1.875	3.316	2.540	2.435

income from diverse components of the model. In support of this, Swarnam *et al.* (2016) reported that the inclusion of different components with diversified species of crops in an integrated farming system could contribute to income generation, thereby improving the value diversity index of the system

Conclusion

Based on the results, it could be concluded that the components were carefully selected in the coconut-based integrated farming system model and were found complementary. Resource recycling is very well practised within the system. The model is essentially climate-smart because of its less reliance on chemical fertilizers, more carbon sequestration and net negative emission of greenhouse gases. The data suggest that diverse food production contributes to family nutrition, and the surplus could be marketed in generating income. Enhancement of income from diverse components could also contribute to a higher diversity index of the model. The model is consistent in yield performance and is profitable over the years. Lowland farmers of a similar agro-climatic tract could well adopt this model for food security and economic and environmental benefits.

Acknowledgement

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