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Integrated farming systems for sustainability in agricultural production

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ABSTRACT

Integrated Farming Systems (IFS) seem to be the possible solution to the continuous increase of demand for food production, stability of income and improvement of nutrition particularly for the small and marginal farmers with limited resources. Integration of different agriculturally related enterprises with crop activity as base, will provide ways to recycle produces and waste materials of one component as input through another linked component and reduce the cost of production which will finally enhance the total income of the farm. Research carried out at ICAR Research Complex Goa. On rice based IFS revealed that rice-brinjal+mushroom+poultry as best one interns of rice equivalent yield (21.49 t/ha), employment generation (392 man days), energy efficiency and economics. In coconut gardens, integration of fodders (napier bajra hybrid + *Centrosema*) for supporting dairy unit proved the best based on above criteria used in rice based IFS. Similarly integration of cardamom in are canut gardens, arable crops and livestock in cashewnut, and poultry/duck-fish IFS were found more profitable and sustainable.

Key words: Farming systems

Goa, a small state in the West coast of India, has a geographical area of 3,70,100 ha, with 34,112 land holdings, more than 80 % of which are being below a ha. The average holding size of farmers is below 0.5 ha. These small land holdings are further characterized by undulating terrain with diverse soil conditions. The marginal uplands with shallow soils are dominated by cashew crop. However, the local food habits of rice-fish curry, use of coconut in most of the culinary preparations and cashew for beverage and food needs to be met continuously by the agricultural sector. Further, the local milk production is only one third of the present demand to meet the daily minimum basic requirement (0.25 litres / head). The present situation is forcing Goa state to import essential agricultural commodities like milk, eggs, vegetables, rice, flower, etc. from neighbouring states. These requirements are expected to increase sharply in the years to come due to the increase in population, tourism and scope for export. The mid lands, valleys and coastal areas are covered by coconut and arecanut while in the low lying areas, rice is cultivated predominantly. The valleys have immense potential for cultivation of horticultural and other commercial crops. While export from Goa is presently centred around cashew and shrimps, there is a great scope for other commodities like flowers, fruits, spices, meat products, etc.

Mixed cropping is a common practice in most of the arecanut gardens cultivated in valleys and lowlying areas. Crops like banana, pepper etc., are very common as mixed / inter crops in most of the arecanut and coconut gardens of the state. Further, integration with dairy by growing forage crops on bunds and recycling of organic manure are also common in few pockets. However, the forage crops cultivated are low yielding and breeds of cows are mostly non- descript / locals or local crosses resulting in lower yields.

IFS research in West coast of India

To identify the exact outcome of the possible complementarities of different components meant for integration, a study involving crop as base activity is inevitable. The choice of components in the farming system must ensure that the interaction among the components is complementary with least competitiveness. To put in practice the concept of recycling of resources more efficiently, it is necessary to study the linkages and complementarities, the knowledge of which will help to develop farming system in which the waste of one enterprise is more efficiently used as input in another enterprise within the system.

ICAR Research Complex for Goa has identified the different farming system models involving rice, coconut, etc. involving the possible crop combinations and integration with livestock and fish species. Research efforts of this institute have clearly indicated that intercrops in coconut with high yielding forage grass–legume mixture and integration with dairy through recycling of manurial resources are productive and profitable. Further, the generation of employment was also substantial. Watershed models involving bio-engineering measures for soil and water conservation, identification of suitable land use systems, water harvesting and recycling, rehabilitation of mine reject soils for crop production, etc. have also been attempted by the institute.

Package of practices for similar systems involving rice- mushroom and poultry, rice-fish, duck-fish, poultry-fish systems were also developed at the institute. The results clearly show the supremacy of system approach with increased productivity, employment generation and profitability.

Rice based farming systems for rainfed lowlands

Field experiments were conducted for three crop seasons during 1999-2002 at ICAR Research Complex for Goa, Old Goa. The experiment was conducted in a split-plot design with three replications. The manurial resources from the rice based cropping systems and allied agro-enterprises of dairy, poultry and mushroom production *viz.* farm yard manure, poultry manure, paddy straw with mushroom spent substrate (in 2:1 ratio) along with a control (no manure) formed the main plot treatments. Rice ('Jyothi') based cropping systems suited to the location *viz.* rice-groundnut ('DH-3-30'), rice- cowpea ('V-118'), rice- brinjal ('local Agassaim'), rice-sunnhemp with rice-fallow system (to assess the economic loss on fallowing which is an important present problem of the region) as control constituted the sub treatments. The manures were applied to rice crop at planting and the quantity depended on the availability of the resource within the system. All the crop residues were incorporated *in situ* after the crop harvest. The recommended dose of fertilisers were applied to the crops.

For comparison of different cropping systems, rice grain equivalent yield was worked out by converting the economic yield of groundnut, cowpea, brinjal and sunnhemp on the basis of marketable price ratio for each crop and rice and expressed in kg/ha.

Mushroom production was integrated with the crop components using the paddy straw, which was available within the system. Broken rice and rice bran formed the ingredients of a formulated feed for the integrated poultry unit. The returns were calculated based on the prevailing market price for inputs and produces during the period.

Soil samples (top 30 cm depth) were collected before the start of the experiment and after harvest of each crop analysed for chemical properties as per the standard procedures.

The sustainability was assessed quantitatively through Sustainable Yield Index (SYI) which denotes the minimum guaranteed yield as a percent to the maximum observed yield with high probability as per Singh *et al.* (1990).

Sankar and Reddy (2005) inferred that highly sustainable practices are with a sustainability index of 0.96. Further, SYI is an approach to evaluate the minimum yield likely to be achieved in relation to changes in soil organic carbon and available NPK status of soil.

Performance of integrated enterprises

The average production of mushroom was 493 kg / 1000 bags of one kg capacity (on wet weight basis). The production was spread over the year with storing of paddy straw obtained from the system.

The requirement of feed for poultry formulated using the ingredients obtained from rice production system was nearly the same (2.35 kg/bird) as compared to the control feed (2.47 kg/bird) (Table 1).

Table 1. Performance of broiler chicks reared with formulated feed

Variables	Formulated feed	Control feed
Total feed requirement for 72 birds (kg)	169.00	177.80
Feed consumption (g / bird)	2,350.00	2,470.00
Feed conversion (g feed /g gain)	2.14	21.70
Livability	94.40	91.70
Av. weight of birds at 42 days (g)	1,207.00	1,186.00
Weight gain (g / bird)	1,161.00	1140
Dressing per cent	77.30	76.20
Poultry waste production (g / bird)	667.00	673.00
Manure production (kg)*	140.40	140.90
Feed cost (Rs/kg)	6.36	8.10

* Poultry + coir waste litter

Table 2. Productivity (t/ha) of integrated farming systems

Farming system	Component productivity			Rice grain equivalent yield
	Crop	Poultry	Mushroom	
Rice cropping alone	4.31 (100)	–	–	4.31
Rice – groundnut + mushroom + poultry	6.56 (39)*	6.06 (36)	4.31 (25)	16.92
Rice – cowpea + mushroom + poultry	7.66 (43)	6.06 (34)	4.31 (23)	18.03
Rice - brinjal + mushroom + poultry	11.12 (52)	6.06 (28)	4.31 (20)	21.49
Rice – sunnhemp + mushroom + poultry	4.99 (33)	6.06 (39)	4.31 (28)	15.36

*Figures in parenthesis indicate per cent contribution to the total system productivity

The feed conversion efficiency in terms of feed required to produce a unit gain in weight was better with formulated feed (2.14 g feed/g gain) as compared to the control feed. The average weight of the birds at the age of marketing was slightly higher with formulated feed (1.21 kg), with better liveability (94.4%) and dressing per cent (77.3) over the control feed. Although poultry manure production was higher with the control feed (673 g/bird), the overall feed efficiency was better with formulated feed. Further, there was a substantial reduction in the feed cost to Rs.6.36 / kg of formulated as against Rs.8.10/kg of control feed. The better performance of integrated mushroom and poultry units indicated that these enterprises are complimentary with rice production. The cost of maintenance of mushroom was cheaper (only 38.8 % of poultry), owing to the cheaper raw material for its cultivation.

Productivity of the integrated systems

The contribution of crops towards the system productivity ranged from 33 to 52 %, while poultry and mushroom contributed 28 to 39 % and 20 to 28 % respectively (Table 2). The highest system productivity (rice grain equivalent yield, RGEY) was recorded with rice-brinjal system integrated with mushroom and poultry production. This was followed by rice-cowpea and rice- groundnut system integrated with mushroom and poultry production. Rice-brinjal with mushroom and poultry system recorded nearly 400 % more productivity, of which 240 % was contributed by allied enterprises *viz*. mushroom (100%) and poultry (140%). Similarly, rice-cowpea sequence cropping integrated with mushroom and poultry gave 318 % more productivity over rice alone.

Poultry and mushroom production when maintained with recycled by-products of rice production system such as paddy straw, rice bran and broken rice, the dependence and cost incurred on externally purchased inputs was greatly reduced. A better market for the products *viz*. mushroom, poultry etc. resulted in substantial benefits to the system. Chandrashekaran *et al*. (1994) working in Cauvery Delta area and Northwestern zone of Tamil Nadu opined that integrated farming systems are much better over existing cropping systems.

Thus, integration of poultry and mushroom production with recycling of by-products obtained from rice system enhanced the productivity of marginal rice lands substantially.

Economic analysis of the system:

The pooled economic analysis of the system (Table 3) revealed that rice-brinjal system integrated with mushroom and poultry was highly economical with the highest net returns. The system also recorded a moderate B:C ratio with better per day net return. Rice-cowpea system integrated with mushroom and poultry was next best in terms of net returns. The system with a lesser cost of production had a better benefit-cost ratio (1.16) with highest per day net return (Rs 238/day). However, rice cropping alone has the least net returns. Although the system had lower cost of production, resulted in higher benefit : cost ratio. The net return per day was very poor.

Pooled mean analysis of the farming system study indicated that inclusion of mushroom and poultry enterprises incurred an additional cost of Rs.41,700/ha mainly for the poultry feed and mushroom spawn. The cost of formulated feed prepared on the farm using the ingredients of rice production system, was cheaper by Rs. 1.75/kg (21.5% less). Between poultry and mushroom, the cost of maintenance of the latter is much cheaper (only 38.8% of poultry) owing to the cheaper raw material (paddy straw) for its cultivation.

Thus, the results of the present study on selection of profitable cropping systems and their integration with suitable enterprises and recycling of wastes have clearly brought out the possibility of linking rice production with different related components for increased profitability.

Employment generation

The data on employment potential showed (Table 3) that rice-brinjal system integrated with mushroom and poultry is labour intensive (392 man days/ha) involving sufficient manpower requirement particularly the women labour force which was almost three times of men labour requirement. Rice-groundnut integrated system was also labour intensive involving 350 man days/ha. The ratio of

Table 3. Economics (x10^3 Rs/ha) and employment generation of rice based IFS (pooled over three years).

Farming system	Cost of production	Net return	B : C ratio	Per day net return	Employment generation		
					Men	Women	Total
Rice cropping alone	15.41	19.21	1.25	150	24	90	110
Rice - groundnut + mushroom + poultry	66.49	60.65	0.91	173	58	292	350
Rice – cowpea + mushroom + poultry	63.51	73.43	1.16	238	55	290	345
Rice – brinjal + mushroom + poultry	82.89	77.31	0.93	204	78	314	392
Rice – sunnhemp + mushroom + poultry	59.10	52.75	0.89	183	52	257	309

Table 4. Energy (x10^3 MJ/ha) budgeting for rice based integrated farming systems.

Farming system	Pooled mean energy		
	Total input	Total output	efficiency
Rice – fallow	11.56	78.18	6.76
Rice-groundnut + mushroom + poultry	46.08	102.86	2.24
Rice – cowpea + mushroom + poultry	43.79	105.63	2.41
Rice – brinjal + mushroom + poultry	52.03	165.33	3.18
Rice – sunnhemp + mushroom + poultry	41.44	100.91	2.44

women labour force requirement was nearly five times of men suggesting most of the activities are women labour oriented.

The present investigation revealed that adoption of an intensive cropping system like rice-brinjal could bring in additional employment opportunities to the tune of 118 man-days/ha over mono-cropping of rice (101% more). Thus, the family labour got an additional employment on their own farm, that too in the off season which could earn exactly double the wages (Rs. 15,440 /ha) for labour employment compared to growing of rice alone (Rs. 7,720/ha). Further, when these intensive cropping systems are integrated with labour intensive enterprises like poultry and mushroom, an additional 164 mandays of employment could be expected. Thus, the total labour employment opportunities were enhanced three and half times within the same farm. Rice-cowpea + mushroom + poultry and rice-groundnut + mushroom + poultry farming systems are also equally good in enhancing the manpower absorption capabilities on the farm which recorded 213.6 and 218.2 % more man-days over control. The additional labour employment opportunities of the farming systems could be attributed to labour intensive nature of the integrated enterprises like poultry which alone contributed 24.2 % of the man-days.

Energy budgeting

The mean total energy input varied considerably among the farming systems (Table 4). Integration of poultry and mushroom enterprises with rice-brinjal system required the highest energy input (52,030 MJ/ha) rice cropping alone without any rice based crops or enterprises recorded the least requirement of energy. Irrigation and fertilizers for the brinjal and feed for poultry were the main components for increased energy input although use of rice bran and broken rice as supplements for poultry feed partially reduced the energy requirements of the system.

The mean energy output varied considerably with different systems. Integration of mushroom and poultry production with rice-brinjal system recorded the highest energy input.

The higher energy output in this system was mainly due to the higher productivity of the cropping system which is well suited to the agro-climatic conditions. Monocropping of rice with no enterprise linkage recorded the lowest pooled mean energy output as the system productivity was poor.

The energy efficiency which is the ratio of energy output to input varied widely among the farming systems. Cropping rice alone was found to be more energy efficient (6.76) as the integrated enterprises were not energy efficient and this was followed by integrated system of rice-brinjal + mushroom + poultry (3.18). However, rice-groundnut system integrated with mushroom and poultry recorded the lowest energy efficiency (2.24). The lower energy efficiency in the integrated systems was mainly due to the higher calorific value of the commercial inputs utilised in the production system.

Table 5. Grain yield (kg/ha) of rice as affected by cropping systems and recycled manurial resources.

Cropping system		Manurial resource				
		M_0	M_1	M_2	M_3	Mean
Rice – Fallow						
	2000-01	4230	4039	4134	4917	4330
	2001-02	4.87	4443	4467	5333	4733
	Mean	4459	4240	4301	5125	4532
Rice – Groundnut						
	2000-01	3855	4789	5143	5065	4713
	2001-02	4872	5461	5774	5527	5409
	Mean	4364	5125	5459	5296	5061
Rice – Cowpea						
	2000-01	4635	3747	4876	3866	4281
	2001-02	5167	5688	5055	4573	5121
	Mean	4901	4718	4966	4220	4701
Rice – Brinjal						
	2000-01	4904	4093	4172	5150	4655
	2001-02	5350	5250	4830	5761	5298
	Mean	5127	4672	4501	5456	4977
Rice – Sunnhemp						
	2000-01	3523	5153	3505	3956	4034
	2001-02	4868	5866	4766	5610	5278
	Mean	4196	5510	4136	4783	4656
Mean	2000-01	4229	4364	4426	4590	4402
	2001-02	4989	5342	4978	5361	5168
	Mean	4609	4853	4702	4976	

	Manurial resource	Gropping system	Interaction
'F' Test	NS	NS	NS

Base year (1999-2000) yield of rice is 4292 kg/ha.

Sustainability of the system

Sustainability of the system was assessed based on the effects of cropping systems and the recycled manures from the integrated enterprises on soil and its impact on the subsequent rice crop over the period. Further, the sustainability was quantitatively assessed based on the SYI.

Cropping systems had a profound influence in improving grain yield of rice in subsequent seasons. The mean rice grain yield was enhanced by 18 % of base year (769 kg/ha increase) with rice-groundnut system as compared to rice–fallow system which recorded the least (4733 kg/ha) at the end of third season (Table 5). This increase may be attributed to the crop rotation effect of the legume and also due to turning in of about 2.4 tonnes of haulms having narrow C: N ratio after harvest. The highest rice yield (5866 kg/ha) was observed when sunnhemp was rotated with rice involving recycled FYM and was followed by rice –brinjal rotation involving paddy straw and mushroom spent substrate (5761 kg/ha). The addition of sunnhemp biomass to the soil (14.89 t/ha) as green manure might have favourably influenced the soil environment through increased activity of soil microorganisms through addition of organic matter.

Similarly, brinjal rotation added 6.25 t/ha of potential usable residue to the soil that resulted in an increased organic matter content of soil, inturn favourably influencing the subsequent rice yield. Soil carbon gains are directly correlated to the amount of crop residue carbon returned to the soil. Improved soil aggregation was also associated with increase in carbon content of the aggregates. Cropping intensification also provides positive feedback to soil productivity via the increased amount of crop residue being turned to the soil.

Among the manurial resources, recycling of paddy straw with mushroom spent substrate recorded consistently better performance with a mean yield increase of 365 kg/ha over no recycling of manure. It was followed by recycling of FYM. Addition of organic matter coupled with nutritionally rich mushroom spent substrate provided favorable environment for growth and yield of rice as was reflected through decreased chaffyness (8.4% in M_3 over 9.2 % in control) while the effect of FYM was visible in terms of productive tillers (11.8/hill), panicle length (19.4 cm) and filled grains(68.2/panicle) in the third season crop (2002 *kharif).*

Sustainability of rice yield

Among the rice based cropping systems studied, rice-groundnut system was found to be more stable in terms of its yield potential as reflected by higher Sustainability Yield Index (0.78) and was followed by rice–brinjal system (Table 6). Leguminous nature of groundnut crop with substantial leaf shedding, biological nitrogen fixation through root nodules and turning of its biomass might have contributed for its stable performance in rice-groundnut system while in rice-brinjal system, the locally adopted high yielding brinjal have contributed for its stability.

Table 6. Sustainability of rice grain yield as affected by different cropping systems over three years.

Cropping system	Sustainability Yield Index				Mean
	M_0	M_1	M_2	M_3	
Rice – Fallow	0.71	0.67	0.69	0.82	0.72
Rice – Groundnut	0.62	0.79	0.85	0.84	0.78
Rice – Cowpea	0.77	0.57	0.82	0.63	0.70
Rice – Brinjal	0.82	0.65	0.68	0.85	0.75
Rice – Sunnhemp	0.55	0.85	0.55	0.61	0.64
Mean	0.69	0.71	0.72	0.75	

Among the recycled manures, paddy straw with mushroom spent substrate recorded the highest SYI (0.75) as compared to others indicating that the practice is more sustainable in its yield influence. Further, easy availability of recyclable waste/decomposed paddy straw within the system also facilitates for its sustainable usage.

Effect on physico-chemical properties

In situ incorporation of crop residues (rice straw, groundnut and cowpea haulms, brinjal and sun hemp stalks or addition of poultry manure or farm yard manure), was advantageous as reflected in improvement in physico-chemical properties of soil over the period.

Soil pH, in general was neither influenced by manures nor by cropping systems (Table 7). Out of the recycled manures, recycling of paddy straw along with mushroom spent substrate has marginally lowered the soil reaction (from 5.99 to 5.60) after two years. Among the cropping systems, growing cowpea or groundnut was found to reduce the soil reaction marginally (5.44 and 5.47 pH, respectively from 5.99 pH) compared to brinjal (5.82 pH),

Table 7. Soil reaction at the end of third year as influenced by different recycled manures and cropping systems.

Cropping system	Soil reaction (pH)*				Mean
	M_0	M_1	M_2	M_3	
Rice – Fallow	5.58	5.74	5.73	5.51	5.64
Rice – Groundnut	5.42	5.41	5.48	5.44	5.44
Rice – Cowpea	5.51	5.53	5.38	5.46	5.47
Rice – Brinjal	5.66	5.93	5.88	5.82	5.82
Rice – Sunnhemp	5.68	5.53	5.64	5.66	5.63
Mean	5.77	5.63	5.62	5.60	

* Initial pH : 5.99.

sunnhemp (5.63 pH) or keeping the land fallow (5.64 pH).

Incorporation of paddy straw *in situ* along with mushroom spent substrate over two years had beneficial cumulative effect on soil fertility as observed in post-harvest samples after second year (Table 8). The pooled data showed that on an average, these plots had 0.05 % more organic carbon over no recycled manure treatment. During initial period of paddy straw decomposition, although there is a temporary locking of nutrients due to immobilization, the microbial degradation with time releases the nutrients.

Table 8. Organic carbon status of soil during third year as influenced by different recycled manures and cropping systems.

Cropping system	Organic Carbon (%)				
	M_0	M_1	M_2	M_3	Mean
Rice – Fallow	1.32	1.37	1.44	1.32	1.36
Rice – Groundnut	1.32	1.49	1.38	1.41	1.40
Rice – Cowpea	1.24	1.33	1.32	1.38	1.32
Rice – Brinjal	1.26	1.32	1.32	1.29	1.30
Rice – Sunnhemp	1.19	1.26	1.29	1.27	1.25
Mean	1.27	1.35	1.35	1.33	

*Soil had a initial organic carbon content of 0.90 %.

Although the effect of cropping systems on soil organic carbon was not appreciable, rice-groundnut system was observed to increase the soil organic carbon marginally (1.40%). Fallowing of rice fields also served as a rotation in maintaining soil carbon status (1.36%).

Among the recycled manures, FYM and poultry manure influenced the soil marginally to improve its fertility after successive rotation of different cropping systems (1.35%) as compared to no manure recycling. Recycling of paddy straw with mushroom spent substrate had an impact in retaining carbon status of soil (1.33%)

Thus, it may be concluded that rice-groundnut sequential cropping system may be followed for stabilized production keeping the resource base soil with better productivity.

Coconut based integrated farming systems for midlands and valleys

Field investigations were carried out during 1998-2001 to identify a suitable forage grass with legume combination for intercropping in coconut. Further, dairy integration with the forage produced from coconut garden and recycling of wastes from coconut and dairy for betterment of soil was attempted.

Productivity of the system

The productivity levels of individual components of the farming system revealed that the base crop coconut yielded 4,700 nuts/ha/year in the system. The intercropped forage grass-legume mixture with hybrid napier (PBN-16) and *Centrosema* yielded 82.6 t/ year/ha of coconut garden. Further, the milk yield from the integrated dairy unit was 1,648 litres/year. The productivity levels of coconut were relatively less as the coconut garden was in the transition stage towards improved management. Although, the milk yield from the integrated unit was not substantial, an additional productivity was obtained with minimum requirement of land. Further, the incidental by-products of coconut (5.74 t/ha), litter (3.2 t/ha) and cowdung (8.69 t/ha) from the dairy were additional inputs available for recycling in the system. An attempt to compost these recyclable manurial resources yielded about 4.70 t of coconut compost, which was available for recycling of nutrients within the system.

The mean cost of cultivation for the coconut was worked out to be Rs.12,150/ha during the experimental period (Table 9). Similarly, for intercropping forage and legume an additional cost of Rs.16,850/ha was incurred making the total to Rs.28,995/ha for coconut + forage intercropping. Further, the cost of maintenance of two milch cows under normal situations was worked out to Rs.33,540 during the period. Thus, in total to maintain coconut based integrated farming unit in a ha of garden, a total cost of Rs. 62,535 was incurred. The higher cost with dairy integration was due to the establishment costs including feed and labour.

Growing 'Benaulim' coconut alone resulted in a net return of Rs 6,225/ha. However, the net returns from a high yielding forage grass (PBN-16) with legume (*Centrosema)* intercropped in coconut was Rs.19,350/ha, totaling the net returns to Rs.25,575/ha for coconut intercropping with forage grass. The mean net returns from two milch cows was worked out to Rs.17,710/year. Thus, the overall net returns of the integrated system was Rs.32,335/year. High yielding nature of hybrid napiers used for intercropping coupled with on-farm generation of inputs in terms of feed for cattle and manure for the crop resulted in higher net returns.

The benefit : cost ratio was found higher for intercropping of forage crops (1.15) compared to all the others as the hybrid napiers used were multi-cut (perennial) high yielding ones with least maintenance costs. Christopher Lourduraj *et al.* (1992) also noted lesser cost of cultivation with hybrid napiers due to lesser cost of seed and fertilizers and no involvement of inter cultural operations like weeding or plant protection.

It was observed that monocropping of coconut in-

Table 9. Economics (x10^3 Rs/ha) of a coconut based farming system of garden for a year.

Component	Cost of maintenance			Net returns			B : C ratio	Labour requirement (Mandays)		
	99-00	00-01	Mean	99-01	00-01	Mean		Men	Women	Total
Coconut alone	11.85	12.44	12.150	5.45	7.00	6.23	0.51	72	5	77
Grass inter crop alone	19.15	14.55	16.850	17.25	21.45	19.35	1.15	157	62	219
Coconut + grass intercrop	31.00	26.99	28.995	22.70	28.45	25.58	0.88	91	46	137
Coconut + grass* + dairy	63.72	61.35	62.535	28.33	36.34	32.34	0.52	248	108	356

*With the presumption that extra grass yield is sold @ Rs. 500/t.

volved an employment potential of 77 man days, the majority of the works being men oriented (93.5%). Further, intercropping of forage grasses in coconut depicted a potential of 142 mandays of employment, 60 per cent being men oriented works. In total, forage intercropping in coconut provided an employment potential of 219 mandays. Compared to a monocropped situation, intercropping added an additional 142 mandays of employment. Further, if family labour (Labour wages calculated @ Rs. 100/day for men labour and Rs.60 for women labour) could be employed for this additional activity, an estimated Rs.11,920/- could be the additional revenue in terms of wages for the farm family.

Employment potential of a coconut based farming system in a hectare of garden per year.

Maintenance of two milch cows right through the year required an additional 137 mandays. Thus, in the overall integrated system, nearly 356 mandays of employment was involved showing the potential for employment of a person right through the year. In contrast to monocropping of coconut (77 mandays), the integrated system thus involved an additional 279 mandays of employment, which when engaged by the family labour, could lead to an additional income of Rs.23,780/ha. Further, integrated dairy provided intermittent returns and regular employment throughout the year for maintenance of cows and forage production. Thus, integrated system presents a higher degree of resource use efficiency, productivity and sustainability. The results of a seven year study on farming system by Singh *et al.* (1997) also confirmed that the income and employment generation was consistent throughout the period of seven years.

Arecanut based integrated farming systems for valleys

Arecanut as a sole crop does not utilize fully the natural resources i.e. soil, space and light. Orientation and structure of arecanut canopy permits 40 % of incident radiation to penetrate down. Studies on rooting pattern revealed that arecanut palms planted at 2.7 × 2.7 m could use effectively only 30 % of land area. Arecanut plantations are more ideal for inter/mixed cropping and multi storeyed cropping than coconut plantations. The compact nature of arecanut crown raised well above the ground (10 to 15 m), allows more sunlight to pass down to ground and maintain high humidity which in turn favours excellent growth of shade loving shrubs/trees (banana and cocoa) and vines (betel leaf and pepper) and variety of short statured biennials and annuals (pineapple, ginger, turmeric, yams and other tuber crops). Cardamom has been one of the time tested most remunerative spice crop in arecanut gardens. Returns as high as Rs. 1,61,840/ha could be obtained by mixed cropping of arecanut and cardamom as against Rs. 1,03,625/ ha (mean of 8 years) in case of sole arecanut. In recent years, Vanilla as mixed crop with arecanut has become the most profitable spice

System approach in other plantations and spices

Careful exploitation of agro-biodiversity involving plantation crops and spices requires proper identification of crops/varieties and other management practices including processing and value addition to fully harness the potential. These crop combinations have better microclimatic and physiological parameters.

Vesicular-arbuscular mycorrhizae and phosphate solublizers in *robusta* coffee and cardamom mixed copping systems had a favourable effect on plant growth and performance. Organic recycling of farm waste particularly coffee pulp in the mixed cropping of coffee and cardamom had a better impact in enhancing the fertility status. Integrated input management in these crop combinations had a clear impact on efficient utilization of various cash inputs. Some of the combined cultural operations followed in the crop combinations also could bring down the total cost of cultivation. Mixed cropping of cardamom and pepper with coffee generated additional gainful employment. The economic analysis of mixed cropping of coffee is quite encouraging.

Cashew based integrated farming systems:

Cashew is the major horticultural crop covering an area of 55,612 ha with a total annual production estimated at 21,942 tonnes. The productivity (395 kg/ha) is far below the national average of about 900 kg/ha.

Majority of cashew plantations in Goa are located on hill slopes. These plantations are in general comprised of un-orderly planted or self-sown seedlings progenies of diverse genetic origin. Invariably such plantations are also observed to possess other tree species like teak, jackfruit, mango, jamun, etc. Here management practices are hardly attended. Density of trees varied from very high (400 trees/ha in different age groups) to too sparse (40-50 trees/ha with other tree species). In fact, the very nature of cashew tree to thrive well under least care makes it very apt for such difficult terrains. However, in order to make such plantations more productive, orderly planting of more than two high yielding varieties ad-mixtured with other compatible trees species has to be meticulously planned to achieve suitable agroforestry system.

In the initial period of establishment of intensive cashew garden with graft of improved varieties, it is recommended for taking up inter crops for the first few years depending upon the location. It is possible to grow intercrops such as pineapple, papaya, annual drumstick, cucurbits, groundnut, etc in Goa region. This is the most important practice to tide over the gestation period of the garden. Here careful selection of intercrop to achieve appropriate temporal and spatial sequence has to be ensured to avoid the crop competition over a period of time. Many commercial gardens are established based on this approach in Goa. Intercrop like finger millet, groundnut, cowpea, chillies, brinjal, amaranthus, marigold, etc are taken up with protective irrigation in the *rabi* season. The practicing farmers believe that the cultivation of these crops is not only profitable but also helps the cashew trees to perform better due to protective irrigation provided to intercrops. Livestock is a common component in such farming and farmyard manure is invariably recycled into the fields. Further, cashew trees, like in other states, also find place in homestead agroforestry in Goa with other trees like coconut, mango, Jackfruit, breadfruit, etc (Desai and Adsule, 2002).

Stability though IFS

IFS involving diversified components such as field crop production, horticulture, forestry and animal husbandry have been proved to be economically viable, technically feasible, environmentally sustainable and socially acceptable. In a study conducted at ICAR Research Complex, Goa, it was revealed that rice-brinjal crop rotation is the best in terms of productivity and profitability owing to higher yield of the brinjal. The system yielded a total productivity of 11.22 t/ha rice grain equivalent yield with a net return of Rs.46, 440/ha. Further, with the integration of mushroom and poultry production (based on the resources availability within the system) the system productivity was increased to 21, 487 kg/ha especially with rice-brinjal rotation leading to an additional returns of Rs 30,865/ha with integration. In addition, the system approach was found to sustainable as reflected from the changes in soil organic carbon and indicated by sustainability yield index.

Integrated farming system (IFS) models

Development of ecologically stable and environmentally sound IFS model to replace or to improve the traditional farming systems would maximize the productivity of the farming systems.

In a trial on duck-fish integrated farming system for Goa, about 70 to 100 m^2 area was needed as night shelter to accommodate 200 to 250 birds which would cater the need of one ha pond. With 200 to 250 birds about 10-12 t droppings were recycled/year which was sufficient to meet the manure requirement for one ha pond. Further, for poultry-fish integrated system in Goa, four varieties of fish namely catla, rohu, mrigal and common carp were stocked in the ratio of 2:2:1:1 at the stocking density of 6000/ha. Poultry shelter of the size of 100-200 m^2 area was required to accommodate 400-500 birds which were sufficient to fertilize a pond of one ha size. A fish production rate of 1,250 kg/ha/8 months was achieved with an average individual growth of one kg when stocked with advanced carp fingerlings at 1500-2000/ha stocking density and without supplementary feeding and pond fertilization (Anon., 1997)

The integrated systems provide scope not only to augment income of the farmers but also bring improvement in soil health through recycling of organic wastes and thereby increase the overall productivity of the crops. The energy obtained from an IFS in various forms is much higher than energy input, as the by- products/wastes of these allied enterprises provide all the raw material and energy required for the food chain in another system. This complimentarity when carefully chosen, keeping in view the soil and environmental conditions, ushers in greater dividends.

It is concluded that there is a need to study the sustainability of the identified systems under different agro-climatic situations in the long run including high value crops. There is an urgent need to study the nutrient dynamics of soil with continuous cropping and recycling of manurial resources with different systems over time. Modeling of the identified farming system options to suit a given agro-climatic and socio-economic situation, needs to be attempted. In addition, there is a need to identify the constraints in adoption of identified farming systems by the farmers for further refinement. Farmer participatory approach is the need of the hour in identifying and adopting specific farming systems based on the needs, aspirations of both the producers and consumers and marketability of various crops and commodities.

Thus, integrated intensive farming systems (IIFS) are the need of the day in India to help our small and marginal farmers to make a living out of their avocation. The green revolution followed by white revolution could be sustained only through IIFS on a micro as well as macro level.

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