Sustainable integrated management of crop with allied enterprises

Ensuring livelihood security of small and marginal farmers

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This paper presents insights into integrated farming systems of crops with allied enterprises, implemented both in on-station and on-farm situations. Research studies have demonstrated the technical feasibility and economic viability of integrated farming systems. Besides facilitating cash income, integrated farming system generates additional employment for family labour and minimizes the risk associated with conventional cropping system. It also sustains soil productivity through the recycling of organic nutrient sources from the enterprises involved. The advantage of using low-cost or no-cost material at farm level for recycling is reduced production costs, with improved farm income.

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Introduction

At the dawn of the new millennium, agriculture in India is facing the challenge to achieve sustainable food security with shrinking land resources by producing an additional 50 million tonnes of food to meet the requirement of the prognosticated population of 1,000 million in the country. Because of declining per capita availability of land in India, there is hardly any scope for horizontal expansion of land for food production. Only vertical expansion is possible by integrating appropriate farming components that require lesser space and time to ensure periodic income to the farmer. Further, modest increments in land productivity are no longer sufficient for the resource-poor farmers. Hence, intelligent management of available resources, including optimum allocation of resources, is important to alleviate the risk related to land sustainability. Moreover, proper understanding of interactions and linkages between the components would improve food security, employment generation as well as nutritional security.

This approach can be transformed into a farming system that integrates crops with enterprises such as – agroforestry; horticulture; cow, sheep and goat rearing; fishery; poultry and pigeon rearing; mushroom production; sericulture; and biogas production – to increase the income and improve the standard of living of small and marginal farmers. The challenge of such an integrated farming system (IFS) is to upgrade technological and social disciplines on a continuous basis and integrate these disciplines to suit the region and the farm families in a manner that will ensure increased production with stability, ecological sustainability and equitability.

Research studies carried out in low land, irrigated upland and dry land at the Tamil Nadu Agricultural University (TNAU) in Coimbatore have demonstrated the technical feasibility and economic viability of the integrated farming systems. Besides facilitating cash income, these farming system models generated additional employment for family labour and minimized the risk associated with conventional cropping system. However, the possibilities of exploring the linkage of components in the farming system were not explored in the farm field. Therefore, a study was conducted in farmers' field – also as participatory research – to evaluate the efficiency of integrated component technologies in terms of productivity, income increase and employment generation, and to quantify the nutrient flow efficiency of linked components to soil. This paper presents some insights on an IFS of crop and allied enterprises, implemented both in on-station and on-farm situations.

On-station

Lowland farming system

Field experiments were conducted at TNAU in lowland involving cropping, and enterprises involding rearing of poultry (chicken, duck), pigs, goats, pigeons and fish and mushroom cultivation, in different combinations in which the residue and by-products of one component would be recycled by another. The recycling process would reduce the cost of production per unit of grain, meat, milk, egg, mushroom, biogas, etc., and thereby widen the gap between the production cost and net return. In a 1 ha farm, 0.90 ha was used for cropping rice. The remaining area (0.10 ha) assigned to a fishpond populated with 1,000 polyculture fingerlings. Either 50 layers from the "Bapkok" variety or hundred productive pairs of pigeon could be linked to supplement the feed requirement of the fingerlings. Mushroom production at an average of 5 kg/day was found to be a balanced activity.

Crop + Pigeon + Fish + Mushroom integration was found to be superior in obtaining the highest net return to the tune of Rs 90,252/ha (US$1 = Rs 50), with higher per day return of Rs 247/ha and benefit cost ratio of 2.44 (Jayanthi, 1997).

The required resources – feed for poultry, fish and pigeon; substrate for mushroom production; and organic manure for field crops – can be secured at minimal cost through proper integration in the farming system. Stability of egg production in the poultry unit can be achieved with 74 per cent productivity by ensuring an average annual production of 270 eggs/layer, by procuring 13 weeks-old bird after completing all required precautionary measures instead of opting for a day-old chick. The reduction in production cost through recycling, which is up to 58 per cent over a commercial poultry farm, would help improve the net profit of the poultry unit. Cost of production of fish meat was Rs 13.60/kg in artificial feeding as against the Rs 6.55/kg and Rs 6.68/kg, respectively, in poultry and pigeon-linked systems.

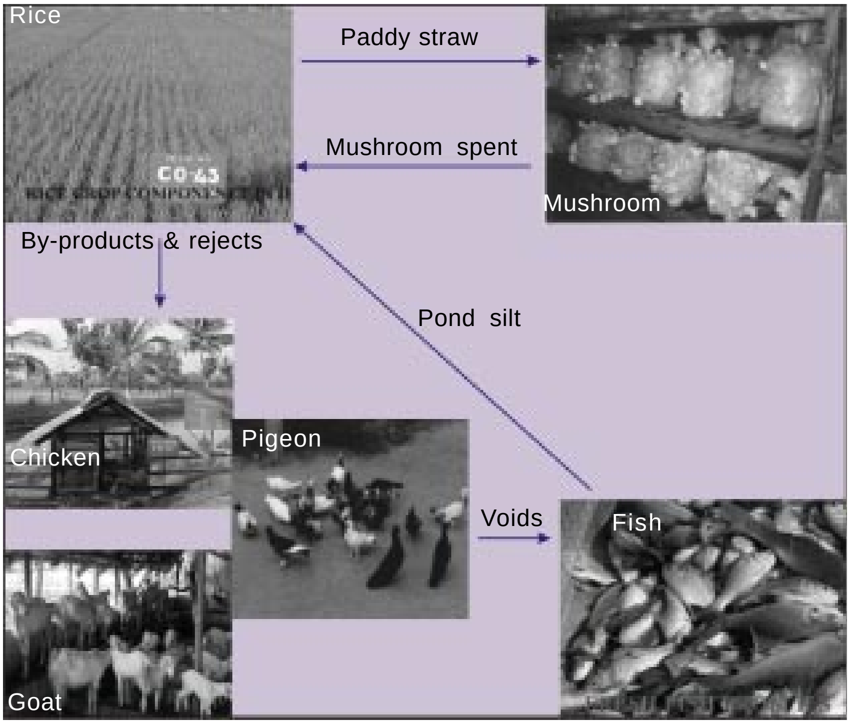
Fish growth obtained was similar when droppings of either 50 layers (Figure 1) or 100 pairs of pigeon were used as fish feed. As the feed cost involved for pigeon rearing was less owing to open grazing, the net profit under pigeon-linked system was higher than in poultry-linked system. Each productive pair on an average gave nine pairs of squabs in a year; that is, 900 pairs of squabs weighing about 810 kg of meat can be obtained from 100 pairs. An annual income of Rs 40,500 could be realized from 1,800 one-month-old squabs. An additional net income of Rs 9,000 per year could be obtained from rearing pigeon over the poultry unit.

Crop + Piggery + Fish + Mushroom linkage was also found to enhance the net return. Annual cash return from this system was Rs 80,500/ha, with a per day productivity of Rs 221/ha.

Crop + Goat + Fish integration was tried by allocating 0.32 ha, 0.04 ha and 0.04 ha for crop, fodder and fishpond, respectively (Figure 2). Inclusion of one unit of goat (20 females + 1 male) could enhance the net income by Rs 36,000 per year and productivity of Rs 98 per day. The goat unit would provide 11 tonnes of valuable manure apart from supplementing the feed requirement of fish (400 fingerlings). It also helped in generating employment op-

Figure 1: Poultry and fish integration under lowland system, using droppings of layers as fish feed

Figure 2: Component integration and resource recycling in lowland ecosystem



portunity to the family labour to the tune of 182.5 workdays per year, distributed uniformly over the year (Jayanthi, 2002).

About 10 kg of rice straw or crop wastes could be effectively utilized as substrate for producing 5 kg of edible mushroom per day. Cost of production per kg of mushroom in IFS was Rs 12 as compared with a commercial venture where the production cost is Rs 20. Thus, at an annual production of 1,460 kg of edible mushroom, IFS offers an additional net income of Rs 11,680. It also helps in supplementing the crop activity with high-value organic manure (mushroom spent compost) of up to 3 tonnes. Employment opportunity was enhanced at the rate of 1/2 workday per day, or 182 workdays per year, to the family labour. Recycling no-cost/low-cost material of one enterprise as input to another enterprise helps reduce the unit cost of production of output.

Vermicomposting is an effective process of using earthworms to recycle farm residues – such as wheat and rice straw, sugarcane bagasse, groundnut husk, banana sheath, cotton stalks, turmeric leaves, coir pith, vegetable wastes, tree litter, and problematic weeds like parthenium and water hyacinth – into rich manure that increases humus content of the soil. It is boon for sustainable agriculture.

Earthworms are able to convert 1,000 tonnes of moist organic waste into 300 tonnes of rich dry vermicompost. It can consume almost all kinds of organic matter, including bone and eggshell, equivalent to their body weight everyday. In 45-60 days, 1 kg of earthworm (approximately 1,000-1,250 worms) would produce roughly 10 kg of vermicast, the nutrient-rich excreta of the worm. Vermicompost (mix of vermicast and other compost) contains 5, 7, 11, 2 and 2 times more nitrogen, phosphorous, potassium, calcium and magnesium, respectively, than crop waste or animal manure. Matured vermicompost is applied at the rate of 5 t/ha.

Integration of allied enterprises with cropping increased nutritive value of products in low land system. Carbohydrate yield was higher in cropping combined with poultry + fish + mushroom. Cropping with pigeon + fish + mushroom was found to have the highest protein of 1,963 kg. Integration of cropping with fish + mushroom + pigeon/poultry resulted in 31-52 per cent higher protein yield than cropping alone. Highest fat yield of 1,355 kg was recorded by the integration of cropping with poultry + fish + mushroom, which was 139 per cent more than that of cropping alone.

Irrigated upland farming system

A study was taken up by integrating crop, dairy, biogas production, spawn and mushroom production, silk worm rearing, mulberry cultivation, apiary and homestead garden under irrigated upland conditions in one hectare farm area. The dairy unit consists of 3 milch animals. They were maintained in such a way that two cows were in milk throughout the year. By keeping three animals, a net income of Rs 29 225/year could be achieved. The dung collected from 3 cows was sufficient to generate 2 m^3 of biogas everyday. This could meet the fuel requirement of farm family apart from the preparation of gruel to the dairy unit, lighting two lamps in the farm house, and for the boiling and cooking activities of mushroom and spawn production.

The economic produces and their by-products of crop activity (maize grain, sorghum grain, cotton seed secured through ginning of cotton, cake obtained after extraction of oil from sunflower and groundnut seed, and soybean) will be utilized for the preparation of concentrate for dairy animals. Thus, the cost of concentrate could be reduced to the level of 35 per cent of the value of commercial products available in the market. Similarly, sorghum stalk, maize sheath and straw from the crop activity and biogas from the biogas unit could be utilized for the production of spawn and to cultivate edible mushroom at cheaper rate.

The sericulture activity can also be linked together with other enterprises contemplated for irrigated upland. The mulberry bits left after feeding silkworm, along with feacal matter of the worms, could be an excellent supplement for the biogas unit. The leftover after reeling the silk yarn is rich in protein and this could be a good supplement for poultry, pigeon and fish feed. It can also be mixed with dairy concentrate. The sericulture activity with 100 disease-free layings, could improve the income to the tune of Rs 20,000 per annum. Moreover, this will also help in generating additional employment by 3 workdays every day and nearly 1,100 workdays extra in a year.

Rabbit rearing is also one of the good enterprises highly suitable for integration into irrigated upland situation. One unit with 10 females and one male could yield around 200 kindles together weighing around 1,000 kg of meat per annum. The disposal value of the kindles per annum would be Rs 30,000. The net income after deducting the cost of production will be Rs 12,000 to Rs 15,000. Effective recycling will bring in an additional income of 35 per cent over a similar commercial unit. The droppings can be utilized as input for generation of biogas.

Planting of coconut saplings on the boundary of the farm land, along irrigation channels, will help boost income. At 4 m spacing, 1 ha of land will accommodate 52 trees, which will yield around 5,200 nuts per annum. Raising sunhemp between the trees and trampling around the tree at appropriate intervals would help achieve nutrient enrichment. Vermicompost prepared from crop wastes can be a rich organic source, which would help the farm to be maintained without any inorganic supplement. The annual net income from the planting of coconut would be Rs 7,800.

Homestead garden with an area of 200 m^2 near farmhouse involving vegetables, fruit trees (guava, papaya and banana) and greens would supplement the family food requirement. The surplus produce can be sold, and this could provide income to meet out the seed cost and plant protection expenses. The nutrient requirement for the garden can fully be met using vermicompost.

One or two honeybee hives can also be housed in the homestead garden. This will facilitate collection of honey from the flowering crops. Natural honey can be tapped through these units for 5½ to 6 months and in the remaining period, through artificial feeding.

Dry land farming system

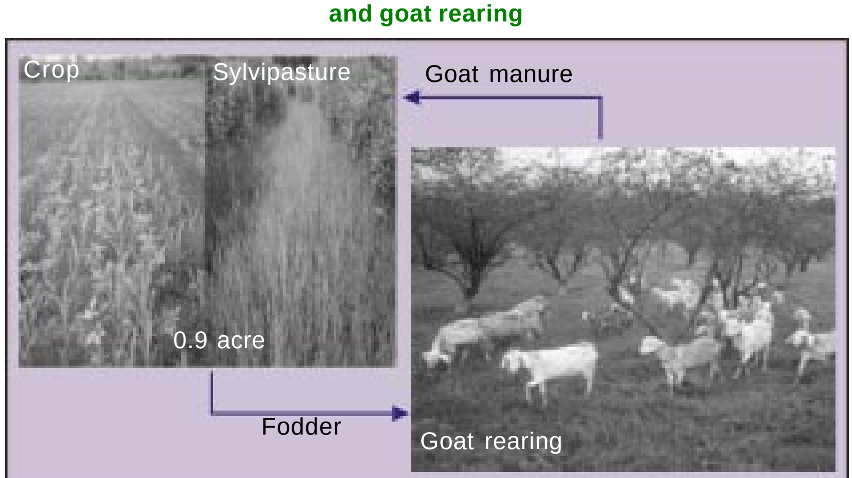
The meteorological data of different agro climatic regions of Tamil Nadu have clearly indicated that the seasonal rainfall in rainfed areas is very low and the distribution is also highly erratic. It is evident that if the required moisture and nutrients at the critical growth phase of the short-duration field crops are not satisfied, the yield of the crop will be affected drastically. The farmer often experiences complete failure of crop because of non-availability of moisture at the critical stage. This is why conventional rainfed agriculture is said to be an out and out gamble. Integrating different enterprises and utilizing the biomass built up have been identified as dependable paths to ensure regular income from rainfed farming. The outcome of these enterprises will be an alternative source for carbohydrate, protein, fat, minerals, vitamins and energy. Drought-tolerant and perennial timber trees can also be raised utilizing the rainfall, as a good source for valuable fuel wood or timber after some years. Similarly, drought-tolerant, perennial horticultural fruit crops can also be raised to improve the income from rainfed farms.

Rainfed soils are not only thirsty but also hungry. The linkage of other enterprises – such as goat, buffalo, pigeon and rabbit – will also provide good amount of organic nutrients to the soil to enhance the yield substantially. In view of all these factors, some IFS models involving varied enterprises have been developed for the benefit of farmers.

An IFS study involving grain crop, fodder crop, fodder trees, perennial grasses and goat rearing in an area of 1 ha of rainfed land was formulated. The results revealed that through short-duration field crops and perennial crops, the feed requirement for one productive unit, consisting of 20 does and one buck, can be satisfied for all the 365 days. After 5 years, the perennial fodder trees could provide sufficient quantity of loppings to supplement – along with millets, legumes and perennial grass linked in the system – the fodder requirement of 21 adult goats.

Tellicherry goat is a good breed to build up body weight for every unit of feed secured through different sources under rainfed condition. It is a dual-purpose animal: it gives 80 to 100 ml of milk every day after satisfying the full requirement of dependent kids. Twenty productive females could give 45 kids per annum. Each kid at the time of weaning will weigh around 12 kg and thus could give a salable live weight of 540 kg per year and could give an income of Rs 43,200. After deducting all the expenses involved, the net income would be Rs 35,000. In addition, the unit of 21 goats with kids at different ages would give 11.2 tonnes of valuable manure under deep litter system (Figure 3). This not only provides primary, secondary and micro

Figure 3: Resource recycling in rainfed land through crop, sylvipasture and goat rearing



nutrients for the crops but also absorbs more moisture, retains it in the soil and releases it to the crop appropriately for better yield.

Buffalo can also be linked to rainfed agriculture, as it will yield good amount of milk even with low-quality fodder. Three productive buffaloes can be maintained solely with the fodder/ feed raised on 1 ha rainfed land from different crops such as cereals, legumes and perennial grass. Of the three animals, two will be in milk round the year and could give an average milk yield of 9 litres per day, or 3,285 litres per year. Including the income from the calves sold off, the gross income from this enterprise would be around Rs 27,000. The net income, excluding the costs of production and maintenance, would be Rs 18,240 per year, with a per day productivity of Rs 49.97. Moreover, this will provide nearly 12 tonnes of good organic manure to the rainfed land. If the farmer is residing in the farm, he can integrate 2 m^3 biogas unit, also making use of the dung secured from the animal.

Farm Pond is yet other, important enterprise for rainfed agriculture. In the cultivated land, 1/25th the area is fixed at the outlet point of the land to harvest entire water run-off. For 1 ha model, the farm pond should be 40 m ×10 m ×1.5 m. It can hold 600 m^3 of rain water when full. Water in the farm pond will last for 30-40 days after the last rain and can be used for watering the perennial trees by employing family labour. This pond will not only hold the run-off water but also act as silt settling pool and thus retain 4-6 tonnes of eroded, nutrient-rich top soil of the land every year. The settled silt in the pond can be removed after drying and applied to the perennial fruit/ timber trees as a source of organic nutrients. If the seasonal rainfall is widespread and if the water in the pond is going to hold for more than 3½ to 4 months, tilapia fish can be reared in the pond. This would yield 30 to 40 kg of fish at the time of drying of the pond, the sale of which would bring an extra income of Rs 750 to Rs 1,000.

The ability of IFS to improve consumer's nutritional status in upland system was observed with enterprise combination of crops fed with composted buffalo manure and pigeon, goat, buffalo, agro-forestry and farm pond in terms of carbohydrate, protein and fat. The highest carbohydrate, protein and fat yields were obtained in farming system involving crops {maize (F) + cowpea (F)-chickpea + coriander (0.25 ha); sorghum (F) + cowpea (F)-chickpea + coriander (0.25 ha); sorghum (G) + cowpea (0.02 ha) and sunflower + coriander (0.10 ha) fed with composted buffalo manure}, buffalo (2 milking + 1 calf), goat (5:1), pigeon (10 pairs), agroforestry and farm pond. Buffalo milk yield of 3,163 litres/year provided 1,878 kg of carbohydrate, 1,614 kg of protein and 2,440 kg of fat to the system combination. Thus, the nutritional security offered by IFS makes an effective strategy for small and marginal farmers in upland systems, besides efficient bio-resource utilization, residue recycling and employment generation.

On-farm

Research was conducted on three farm fields at Chinnamathampalayam (Location I), Arasur (Location II) and Vaiyampalayam (Location III) in the western zone of Tamil Nadu. The farms are situated at 11º N latitude, 77º E longitudes and at an altitude of 426.7 m above mean sea level. The mean annual rainfall of western zone is 657 mm (mean of 83 years) distributed over 47 rainy days. The mean maximum and minimum temperatures are 30.0ºC and 21.4ºC, respectively. The soil of the experimental field at Location I is sandy loam in texture, while Location II and Location III are clayey loam in texture. The soil of three locations was classified as low, high and high, respectively, for available nitrogen, phosphorus and potassium.

Components in farming system

Cropping

The crop activity in IFS consists of field crop (60 per cent), vegetable crop (10 per cent) and fodder crops (20 per cent) that are suitable for irrigated upland conditions. The cropping system in field crop is sunflower-maize + cowpea-green gram (0.60 acre); in vegetable crop, okra-chillies (0.10 acre); and in fodder crop, pearl millet Napier hybrid grass (CO 3) + desmanthus (0.20 acre). Crop activities in farming system were taken in 0.90 acre. For comparison, one acre of land of the same farmer where traditional practices were followed for the past five years was taken. The traditional practices were: sorghum/ tomato-brinjal (aubergine)/ floriculture + 2 milch cows + vermicompost in Location I; maize-sorghum/tomato-Chillies + 3 milch cows in Location II; and cotton-fodder maize + 2 milch cows in Location III.

Livestock

Livestock components, vermicompost and biocompost were taken in 0.10 acre.

Milch cows

Two cross breed milch cows + one calf were taken for the study in each location.

Goats

Tellicherry goats comprising ten does and one buck were maintained under deep litter system in each location with slated floor built above the ground at a height of 2-3 feet, designed for the convenience of manure collection without wastage, to ensure proper ventilation and to maintain clean and dry environment to avoid soiling and incidence of diseases. The buck was housed separately in the same stall to prevent indiscriminate mating with pregnant does and to avoid fighting with other goats.

Guinea fowl

Twenty Guinea fowls (15 female + 5 male), purchased from a local breeder, were reared in each location. The Guinea fowl was introduced in the project because of its hardy and gregarious nature. The fowls were kept in a cage built above the vermicompost pit in all the three locations for collecting the manure and to maintain hygiene standards. During the initial stages the keets were reared totally under an intensive system to provide adequate protection for them from predators and harsh environmental conditions.

Vermicompost and biocompost

Compost pits were made in each location for composting crop residues and farm wastes. The manure obtained from milch cows and field and fodder crop residues were used for making biocompost. Vermicompost was prepared utilizing goat and guinea fowl droppings and vegetable waste. The quantity of available manure was calculated based on dry weight basis. The total quantity of solid waste on wet and dry basis and their nutrient potential before and after composting were observed.

The farming system experiments were taken in 1 acre land area and each location was considered as one replication. Farming system treatments were compared by quantifying physical indicators of sustainability based on system productivity, profitability and employment generation. The productivity of the components integrated in each system was finally converted as maize grain equivalent on the basis of prevailing unit cost of the produce of each component. The productivity of cross-bred milch cows was assessed using the milk yield and from the sale of manure obtained from them. The productivity of Tellicherry goat was ascertained by the sale of kids and manure, and that of Guinea fowl on the basis of egg production, sale of chicks and manure. Labour requirement for various activities were recorded and given as workdays per year. A man or woman working for 8 hours a day was considered as one workday. The labour utilized in the different enterprises in a system were added to get workdays per farmlet per acre per year. The economics of each enterprise was calculated based on the economic produce of that enterprise.

Productivity

Integration of cropping with components like milch cows, Guinea fowl and vermicompost resulted in higher productivity in both years in all three locations. The mean maize grain equivalent yield was about 9,417 kg/acre/year under traditional cropping system whereas under IFS, the maize grain equivalent yield was about 22,754 kg/acre/year. Inclusion of high-yielding varieties and allied components would have helped in increasing the productivity and as a result the maize grain equivalent yield increased. This corroborates the findings of Rangasamy and others (1995).

Profitability

Compared with traditional cropping system, IFS brought increased revenue, which might be due to resource recycling. The net return from inclusion of allied enterprises in IFS is about Rs 60,141, and the increase in income over traditional cropping system was about 43.6 per cent. Resource recycling by way of utilization of fodder cultivated in the field – which accounts for a major part of the cost of maintenance of cows and goats – would have reduced the cost of production. The purchase of fertilizers for the crops is also reduced by way of recycling the manures from animal components, vermicompost and biocompost as organic fertilizers. The resource and residue recycling had reduced the cost of production of an unit of economic produce viz., meat, milk and egg from goat, milch cows and Guinea fowl, than when produced with total dependence on external inputs (Jayanthi, 2007). This agrees with the findings of Radhamani (2001), and Esther and others (2005).

Employment

IFS treatments generated more workdays of employment compared with the traditional system involving cropping and dairy. Cropping in traditional system generates 25 workdays per acre per year, while the various cropping systems under IFS generated 49 workdays of employment. A maximum of 183 workdays per acre per year was generated from animal components in IFS, whereas in traditional cropping system it is only about 80 workdays. Additionally, 3 workdays per acre per year was generated from vermicomposting and biocomposting.

Employment generation in cropping is limited to the key operations of sowing, intercultural operations and harvest, and labour is not required during the rest of the year. Contrary to this, employment generation in a multi-enterprise farming system is spread uniformly throughout the year. The results corroborate this, and the finding is supported also by Devendra (1999), as well as Jayanthi and others (2002).

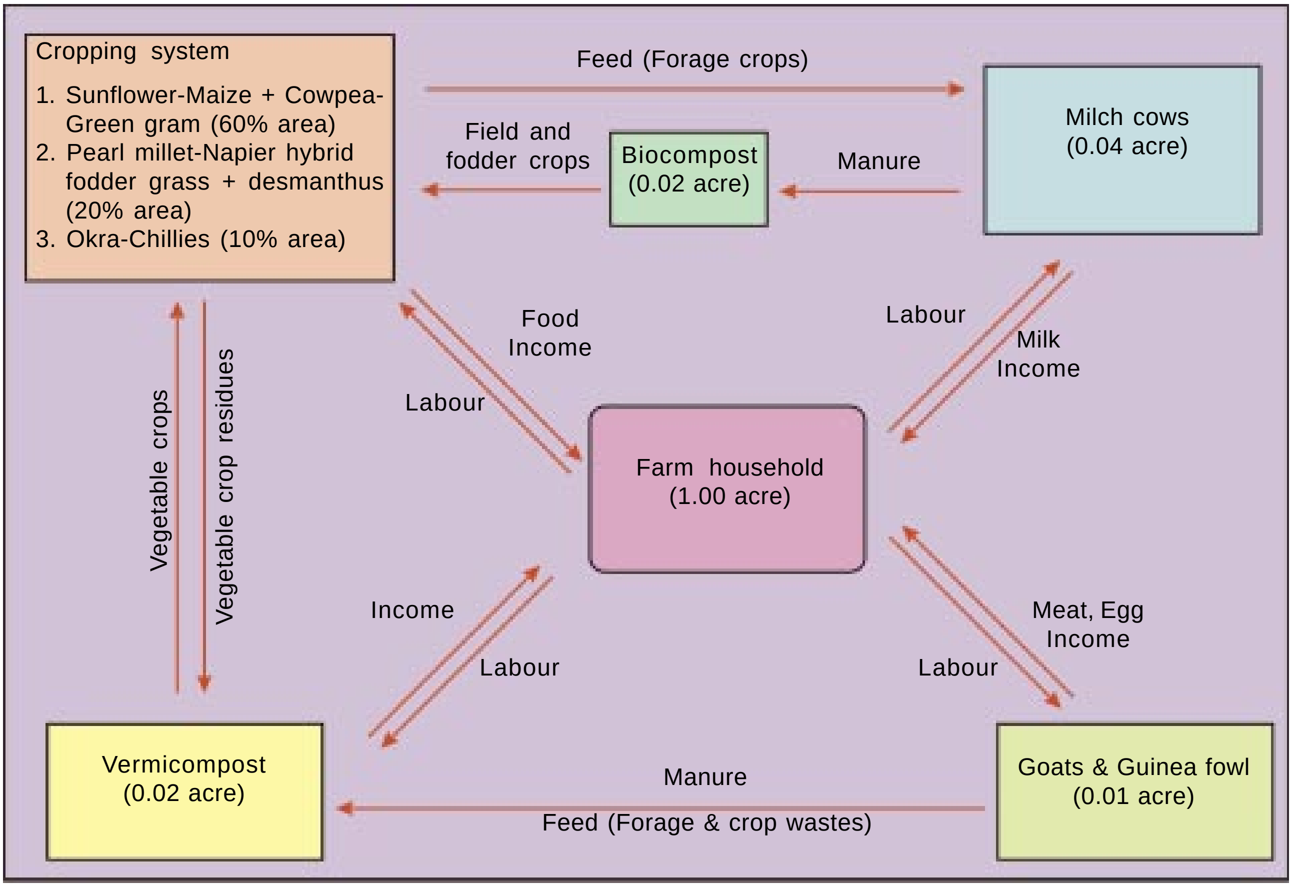
Residue recycling

The total quantity of biocompost obtained from IFS was approximately 3.5 tonnes. Of this, 2.6 tonnes were applied to annual crop, which was raised in 0.6 acre and the remaining 0.9 tonne was diverted to fodder crops raised in 0.2 acre of land area. About 1.5 tonnes of vermicompost were obtained by way of recycling vegetable crop waste, and the manure from the goat and the Guinea fowl. Of this, around 0.5 tonne of vermicompost was diverted to vegetable crop raised in 0.10 acre. The remaining 1 tonne was sold to add to the farm revenue. In the traditional cropping system, the residue generated is less as compared with IFS.

The nutrient contents in biocompost and vermicompost were, respectively: nitrogen – 0.7 per cent and 2.3 per cent; phosphorus (P_2O_5) – 0.6 per cent and 0.7 per cent; and potassium (K_2O) 0.7 per cent and 1.2 per cent. As can be seen, the nutrient content was slightly higher in vermicompost than the biocompost owing to the higher nutrient content in goat and Guinea fowl manures. The manures obtained were both recycled as nutrient input to the crops after composting. The system of crop + milch cows + goat + Guinea fowl + biocompost and vermicompost could provide better bio-resource utilization and recycling. Synergistic interaction of the farming system in terms of labour, resources and residue recycled is depicted in Figure 4. The decrease in dependence on external inputs for all the systems during the second year indicates that over long periods of time, IFS will become more self-sufficient and thus sustainable. This is in line with the findings of Jayanthi and others (1997).

Based on the farmer participatory research, it was concluded that IFS approach is better than traditional system in its contribution to productivity, profitability, economics and employment generation for small and marginal farmers of Tamil Nadu.

Figure 4: Resource flow model of integrated farming system for irrigated upland (1.00 acre)



It is clear from the above results that IFS for different situations enhances productivity, profitability and nutrition security of the farmer and sustains soil productivity through recycling of organic source of nutrients from the enterprises involved. The most notable advantage of utilizing low-cost/ no-cost material at the farm level for recycling is that it will certainly reduce the production cost and ultimately improve the farm income considerably. IFS approach has started gaining momentum with farmers of all types, and is expected to reach its peak of acceptance around 2020. IFS would help in enhancing the productivity to satisfy the ever-increasing population of the country, and create confidence among farmers through higher profitability.

References

1. Devendra, C. (1999). Goats: Challenges for increased productivity and improved livelihoods. *Outlook on Agriculture,* 28:215-226.
2. Esther Shekinah, D., Jayanthi, C. and Sankaran, N. (2005). Physical indicators of sustainability - A farming systems approach for the small farmer in rainfed vertisols of the Western zone of Tamil Nadu. *Journal of Sustainable Agriculture,* 25(3):43-65.
3. Jayanthi, C. (2002). Sustainable farming system and lowland farming of Tamil Nadu. IFS Adhoc Scheme. Completion Report.
4. Jayanthi, C., Rangasamy, A. and Chinnusamy, C. (1997). Integrated nutrient management in rice based cropping systems linked with lowland integrated farming system. *Fertilizer News,* 42(3):25-30.
5. Jayanthi, C., Vennila, C., Nalini, K. and Vivek, G. (2007). Physical indicators on farm farming system for irrigated uplands of Western zone of Tamil Nadu. *Journal of Farming Systems Research and Development,* 13(1):17-25.
6. Mahapatra, I. C. and Bapat, S.R. (1992). Farming systems research: Challenges and opportunities. Resource management for sustained crop production. In Proceedings of the XII National Symposium of Indian Society of Agronomists. 25-28 February 1992, Bikaner, India. pp 382-390.
7. Radhamani, S. (2001). Sustainable integrated farming system for dryland vertisol areas of Western Zone of Tamil Nadu. Ph.D. dissertation, submitted to Tamil Nadu Agricultural University, Coimbatore, India.
8. Rangasamy, A., Venkitasamy, R., Jayanthi, C., Purshothaman, S., and Palaniappan, S.P. (1995). Rice-based farming system: A viable approach. *Indian Farming,* 44(11):27-29.❐