

MODERN CONCEPTS OF AGRICULTURE

Farming Systems

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Introduction

To meet the multiple objectives of poverty reduction, food security, competitiveness and sustainability, several researchers have recommended the farming systems approach to research and development. A farming system is the result of complex interactions among a number of inter-dependent components, where an individual farmer allocates certain quantities and qualities of four factors of production, namely land, labour, capital and management to which he has access (Mahapatra, 1994). Farming systems research is considered a powerful tool for natural and human resource management in developing countries such as India. This is a multidisciplinary whole-farm approach and very effective in solving the problems of small and marginal farmers. The approach aims at increasing income and employment from small-holdings by integrating various farm enterprises and recycling crop residues and by-products within the farm itself (Behera and Mahapatra, 1999; Singh *et al.*, 2006).

The Indian economy is predominantly rural and agricultural, and the declining trend in size of land holding poses a serious challenge to the sustainability and profitability of farming. In view of the decline in per capita availability of land from 0.5 ha in 1950-51 to 0.15 ha by the turn of the century and a projected further decline to less than 0.1 ha by 2020, it is imperative to develop strategies and agricultural technologies that enable adequate employment and income generation, especially for small and marginal farmers who constitute more than 80% of the farming community. The crop and cropping system based perspective of research needs to make way for farming systems based research conducted in a holistic manner for the sound management of available resources by small farmers (Jha, 2003). Under the gradual shrinking of land holding, it is necessary to integrate land based enterprises like fishery, poultry, duckery, apiary, field and horticultural crops, etc. within the bio-physical and socio-economic environment of the farmers to make farming more profitable and dependable (Behera *et al.*, 2004). No single farm enterprise is likely to be able to sustain the small and marginal farmers without resorting to integrated farming systems (IFS) for the generation of adequate income and gainful employment year round (Mahapatra, 1992; 1994). Farming systems approach, therefore, is a valuable approach to addressing the problems of sustainable economic growth for farming communities in India.

The basic aim of IFS is to derive a set of resource development and utilization practices, which lead to substantial and sustained increase in agricultural production (Kumar and Jain, 2005). There exists a chain of interactions among the components within the farming systems and it becomes difficult to deal with such inter-linking complex systems. This is one of the reasons for slow and inadequate progress in the field of farming systems research in the country. This problem can be overcome by construction and application of suitable whole farm models (Dent, 1990). However, it should be mentioned that inadequacy of available data from the whole farm perspective currently constrains the development of whole farm models.

Integrated farming systems are often less risky, if managed efficiently, they benefit from synergisms among enterprises, diversity in produce, and environmental soundness (Lightfoot, 1990). On this basis, IFS models have been suggested by several workers for the development of small and marginal farms across the country (Rangaswamy *et al.*, 1996; Behera and Mahapatra, 1999; Singh *et al.*, 2006).

Conceptual Definition

“Farming System is a complex inter-related matrix of soil, plants, animals, implements, power, labour, capital and other inputs controlled in parts by farming families and influenced to varying degrees by political, economic, institutional and social forces that operate at many levels” (Mahapatra, 1992). The term "farming system" refers to a particular arrangement of farming enterprises that are managed in response to physical, biological and socio-economic environment and in accordance with farmer's goals, preferences and resources (Shaner *et. al* 1982). “The household, its resources and the resource flows and interactions at the individual farm levels are together referred to as a farm system” (FAO, 2001)

“Systems” could be defined as an organised unitary whole composed of two or more inter dependant and interacting parts, components or subsystems delineated by identifiable boundary or its environmental super system (Singh, 2001). It is a set of interrelated elements each of which is associated directly or indirectly with other elements and no subset is under-related to any other subsets. In system approach, the whole farms rather than the individual crops/enterprises is considered before any decision relation to the choice of enterprise and or technology is made.

The farming systems can be described and understood as by its structure and functioning. The structure in its wider sense includes among others, the land use pattern, production relations, land tenures, size of holding and their distribution, irrigation, marketing including transport and storage, credit institutions and financial markets and research and education. Thus, the “farming system” is the result of a complex interaction among a number of interdependent components. To achieve it, the individual farmer allocates certain quantities and qualities of four factors of production: land, labour, capital and management, which has access the processes, like crop, livestock and off farm enterprises in a manner, which within the knowledge he possess will maximize the attainment of goal he is striving for.

The Farming System, as a concept, takes into account the components of soil, water, crops, livestock, labour, capital, energy and other resources with the farm family at the centre managing agricultural and related activities. The farm family functions within the limitations of its capability and resources, the socio-cultural setting, and the interaction of these components with the physical, biological and economic factors.

Farming system focuses on:

- The interdependencies between components under the control of household and,
- How these components interact with the physical, biological and socio-economic factors, which is not under the control of household.
- Farm household is the basic unit of farming system and interdependent farming enterprises carried out on the farm.
- Farmers are subjected to many socio-economic, bio-physical, institutional, administrative and technological constraints.
- The operator of the farming system is farmer or the farming family.

The primary inter-relationships at the farming system level are illustrated in Figure 1. This highly simplified model puts the farmer the decision maker, at the center. Decisions are influenced by the priorities of the household, farmer's knowledge and experiences, and resource at his command. External factors - natural, economic and sociocultural, also plays significant roles.

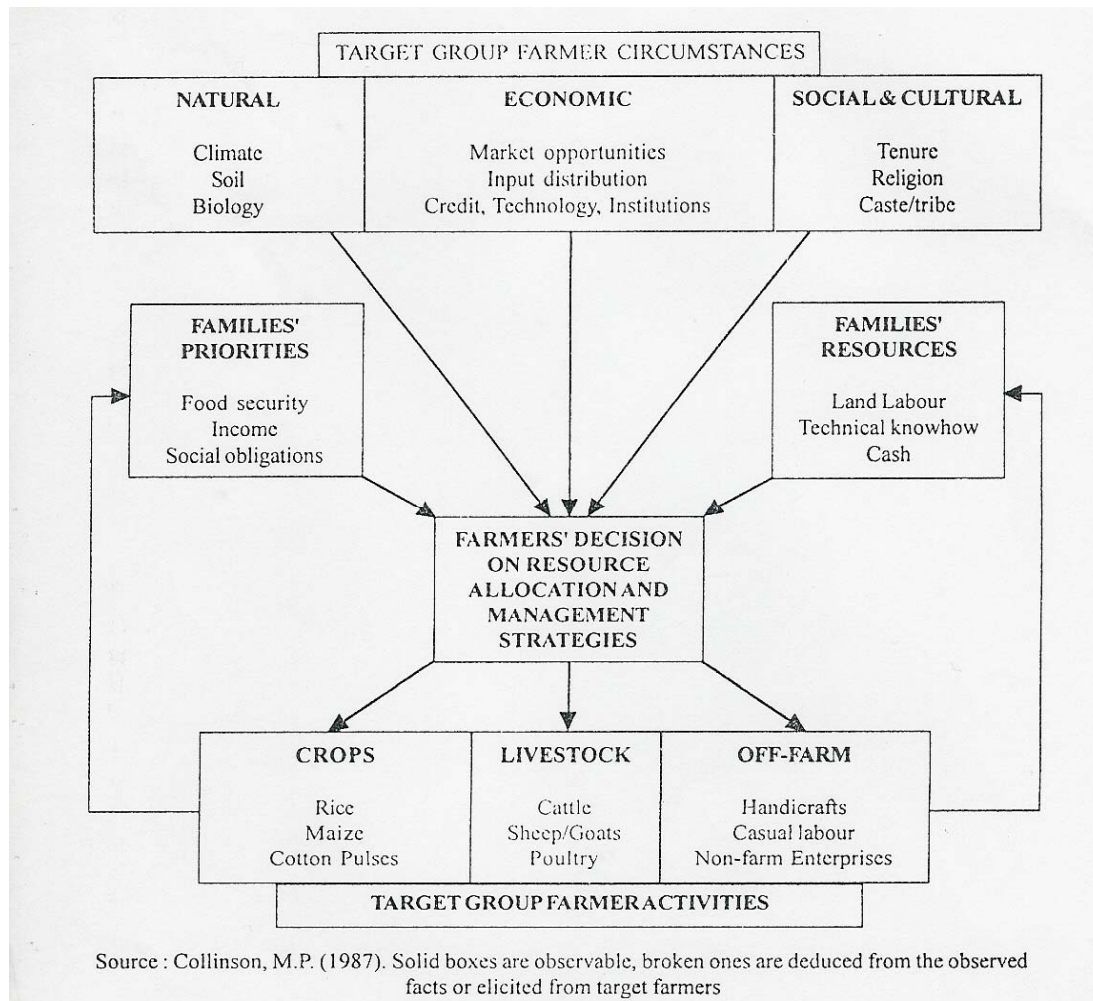


Fig.1: Farming System Model showing interrelationships at the farming system level

Determinants of Farming Systems

The key categories of determinants influencing farming system are as follows:

(i) Natural Resources and Climate: The interaction of natural resources, climate and population determines the physical basis for farming systems. The increased variability of climate, and thus agricultural productivity, substantially increases the risk faced by farmers, with the concomitant reduction in investment and input use. Certain soil and water regimes are suitable only for given type of crops. Similarly, some of the physical and geographical features e.g. drainage characteristics, elevations and slopes as well as climatic factors e.g. total rainfall and its distribution, minimum and maximum temperature, humidity and intensity of sun light etc.

are other factors which have to be taken in to considerations while making decision with respect to selection of enterprise for a farming systems.

(ii) Science and Technology: Investment in agricultural science and technology has expanded rapidly during the last four decades. During this period, major technical and institutional reforms occurred, which shaped the pattern of technology development and dissemination.

The research driven growth in developing countries has been green revolution, where it achieved considerable achievement in the field of food grain production and for this the policy and other aspects supported the farming system for such achievement. Research has been focused principally upon intensifying crop and livestock production. There has been less research on integrated technologies for diversifying the livelihoods of small farmers in developing countries and increasing the sustainability of land use.

Despite these weaknesses, the natural and global research agenda is gradually moving from a focus on individual crop performance to a growing acceptance of the importance of increased system productivity. There has been emphasis in recent agriculture of targeting technologies towards women farmers and poorer households.

(iii) Trade Liberalization and Market Development: Markets have a critical role to play in agricultural development as they form the linkages between farm, rural and urban economics upon which the development processes depend. As a result of the reduction of impediments to international trade and investment, the process of trade liberalization is already generating changes in the structure of production at all levels-including small holder-farming systems in many developing countries. Not only the market development is accelerating, but patterns of production and natural resources usage are also changing profoundly in response to market forces.

The availability of new production, post harvest and transport technologies will also change demand patterns due to delivery of new products or established products in new forms to markets, where they have been previously unattainable.

(iv) Policies, Institutions and Public goods: The development of dynamic farming systems requires a conducive policy environment. Moreover, the establishment of the farm-rural-urban linkages requires effective demand. Policy makers have increasingly shifted their attention to the potential to increase the efficiency of service delivery through the restructuring of institutions. The production incentives have dramatic effect on farming systems. Policies on land ownership, water management and taxation reform etc have a great bearing on types of farming system in a region or area.

(v) Information and Human Capital: The evolution of farming systems based upon increasing specialization (e.g. large scale broiler units) or integrated intensification (e.g. rice-fish-ducks) has required extra knowledge on the part of farm operators. The need for better information and enhanced human capital has also increased, as production systems have become more integrated with regional, national and international market systems.

Lack of education, information and training is frequently a key limiting factor to smallholder development. Many observers anticipated an information revolution i.e. bridge gap of knowledge between scientists and farmers will be very key factor for agricultural growth of these small farmers. Whilst in the past many development efforts failed women-because planners had a poor understanding of the role women play in farming and household food security-greater efforts are being made to take account of their actual situations. It is increasingly recognized and acknowledged by development workers that the empowerment of women is the key to raising levels of child and family nutrition, improving the production and distribution of food and agricultural products, and enhancing the living conditions of rural populations. It has been concluded that, if women in Africa received the same amount of education as men, farm yield would rise by between seven and 22 percent (FAO, 1990).

Similarly, better access to credit, land and extension services would enable women to make an even greater contribution to eliminating rural hunger and poverty. As gender bias is progressively eliminated during coming years - often in the face of severe cultural and religious barriers productivity within many farming systems will be transformed.

(vi) Indigenous Technological Knowledge: Indigenous technical knowledge is the knowledge that people in a given community has developed over times, and continues to develop. It is based on experience, often tested over long period of use, adapted to local culture and environment, dynamic and changing, and lays emphasis on minimizing risks rather than maximizing profits. The ITK covers a wide spectrum – soil water and nutrient management; pasture and fodder management; crop cultivation; plant protection; farm equipment, farm power, post-harvest preservation and management; agro-forestry; bio-diversity conservation and also exploitation; animal rearing and health care; animal products preservation and management; fisheries and fish preservation; and ethnic foods and homestead management. Thus, the ITK of a farmer has a great influence in managing the farm and farming system.

Components of Farming Systems

The potential enterprises which are important in farming system in the way of making a significant impact of farm by generating adequate income and employment and providing livelihood security are as follows:

1. Crop Production

Crop production is an important farming practice adopted invariably by every farmer. It is an integral part of farm activities in the country. Cropping systems based on climate, soil and water availability have to be evolved for realizing the potential production levels through efficient use of available resources. The cropping system should provide enough food for the family, fodder to the cattle and generate sufficient cash income for domestic and cultivation expenses. These objectives could be achieved by adopting intensive cropping. Methods of intensive cropping include multiple cropping and intercropping. Intensive cropping may pose some practical difficulties such as shorter turn-around time lapse for land preparation before the succeeding crop and labour shortage at peak periods of agricultural activities. These practical handicaps can easily be overcome by making modifications in the cropping techniques. Alteration of crop geometry may help to accommodate intercrops without losing the base crop population.

(I) Sequential Cropping Systems: In sequential cropping, the preceding crop has considerable influence on the succeeding crop. This includes the complementary effects such as release of N from the residues of the previous crop, particularly legume, to the following crops and carries over effects of fertilizer applied to preceding crops. The adverse effects include allelopathy, temporary immobilization of N due to wide C/N ratio of the residues and carry over effect of pest and diseases.

In India, food crop is predominantly grown in most suitable seasons and thus particular food crop is basic to the cropping system followed by the farmers. Accordingly the cropping systems are usually referred to as:

- (i) Rice-based cropping system
- (ii) Sorghum-based cropping system
- (iii) Pearl millet-based cropping system
- (iv) Wheat and gram-based cropping system

Some of the cropping systems based on commercial crops are (i) cotton-based, (ii) groundnut-based, (iii) sugarcane-based, (iv) plantation crop-based and (v) vegetable-based cropping system.

The grain production potential in different regions of the country under intensive cropping ranges from 11-18 t/ha. In maize-potato or toria-wheat-moong system followed at IARI, New Delhi, it was possible to produce 14-15 tonnes of food per ha per annum without impairing the soil health. The results of multiple cropping demonstrations under irrigated conditions showed that production potential can be as high as 19.8 t/ha in cereal-based cropping system of rice-rice-rice. The yield potential of multiple cropping varies from region to region depending upon the physical and socio-economic conditions.

(II) Multi-tier Cropping: The practice of growing different crops of varying height, rooting pattern and duration is called 'multi-tier cropping' or multi-storied cropping. Multi-storied cropping is mostly prevalent in plantation crops like coconut and areca nut. There is scope for intercropping in coconut garden up to the age of 8 years and after 25 years. During this period there is adequate light transmission to the ground, which permits cultivation of intercrops. The objective of this system of cropping is to utilize the vertical space more effectively. In this system, the leaf canopies of intercrop components occupy different vertical layers. The tallest components have foliage tolerant of strong light and high evaporative demand and the shorter component(s) with foliage requiring shade and on relatively high humidity e.g. coconut + black pepper + cocoa + pineapple.

In this system, coconut is planted with a spacing of 7.5 m. Rooted cuttings of black pepper are planted on either side of coconut about 75 cm away from the base. On the coconut trunk at a height of about one meter from the ground level, the vines of pepper are trailed. A single row of cacao is planted at the center of space between coconut rows. Pineapple is planted in the inter-space.

Coconut growing to a height of more than 10 m occupies the top floor. Black pepper growing to about 6-8 m height forms the second floor. Cacao with its pruned canopy of about 2.5 m height and pine apple growing to about 1 m height form the first and ground floors, respectively.

In another multi-tier system in coconut, ginger or turmeric and partial shade loving vegetables form the first tier, banana in second tier, pepper in third tier and coconut or areca nut in the final tier.

In the areca nut plantation, tuber crops are predominantly intercropped. Elephant yam, tapioca, greater yam and sweet potato are common intercrops in humid tropics. Banana and pine apple are also cultivated as intercrops in areca nut gardens.

In coffee based multi-tier cropping system, first tier is with pine apple, second tier with coffee, third tier with cacao/mandarin and final tier with fast growing shade trees necessary for coffee plantation (e.g., dadaps and silver oak).

(III) Evaluation of Cropping Systems: Various types of cropping systems are practiced in a farm/region. They are to be properly evaluated to find out their stability and relative advantage. Such a comparison may be made with reference to land use efficiency, biological potential, economic viability, etc. Some of the important indices to evaluate the cropping systems are discussed here.

(i) Land Use Efficiency

(a) Multiple Cropping Index or Multiple Cropping Intensity (MCI): It was proposed by Dalrymple (1971). It is the ratio of total area cropped in a year to the total land area available for cultivation and expressed in percentage.

$$MCI = \frac{\sum_{i=1}^n a_i}{A} \times 100$$

Where, i = 1,2,3..... n, n = total number of crops, ai = area occupied by ith crop and

A = total land area available for cultivation.

(b) Cultivated Land Utilization Index (CLUI): Cultivated land utilization index (Chuang, 1973) is calculated by summing the products of land area planted to each crop, multiplied by the actual duration of that crop divided by the total cultivated land area, times 365 days.

$$CLUI = \frac{\sum_{i=1}^n a_i d_i}{A \times 365} \times 100$$

Where, i = 1,2,3.....n, n = total number of crops, a₁ = area occupied by the ith crop, di = days that the ith crop occupies ; and A = total cultivated land area available for 365 days.

CLUI can be expressed as a fraction or percentage. This gives an idea about how the land area has been put into use. If the index is 1 (100%), it shows that the land has not been left fallow and more than 1, speaks about the specification of intercropping and relay cropping. Limitation of CLUI is its inability to consider the land temporarily available to the farmer for cultivation.

(c) Crop Intensity Index (CII): Crop intensity index assesses farmer's actual land use in area and time relationship for each crop or group of crops compared to the total available land area

and time, including land that is temporarily available for cultivation. It is cultivated by summing the product of area and duration of each crop divided by the product of farmer's total available cultivated land area and time period plus the sum of the temporarily available land area with the time of these land areas actually put into use (Menegay *et al.*, 1978). The basic concept of CLUI and CII are similar. However, the latter offers more flexibility when combined with appropriate sampling procedures for determining and evaluating vegetable production and cropping pattern data.

$$CII = \frac{\sum_{i=1}^{Nc} a_i t_i}{AoT + \sum_{j=1}^M A_j T_j}$$

Where, $i = 1, 2, 3, \dots, Nc$, Nc = total number of crops grown by a farmer during the time period, T , a_i = area occupied by i^{th} crop, t_i = duration of i^{th} crop (months that the crop i occupied an area a_i), T = time period under study (usually one year), Ao = Total cultivated land area available with the farmer for use during the entire time period, T , M = total number of fields temporarily available to the farmer for cropping during time period, T , $j = 1, 2, 3, \dots, M$, A_j = land area of j^{th} field and T_j = time period A_j is available. $CII = 1$ means that area or land resources have been fully utilized and less than 1 indicates under utilization of resources.

(ii) Biological potential

Production Efficiency (PE):

(a) Crop Equivalent Yield (CEY): Many types of crops/cultivars are included in a multiple cropping sequence. It is very difficult to compare the economic produce of one crop to another. To cite an example, yield of rice cannot be compared with potato yield. Similarly the yield of crops grown for fodder purposes cannot be compared with the yield of grain cereals or pulse crops and so on. In such situations, comparisons can be made based on economic returns (gross and net returns). The yields of protein and carbohydrate equivalents can also be calculated for valid comparison. Efforts have also been made to convert the yields of different crops into equivalent yield of any one crop such as wheat equivalent yield (Singh, 1997). The equation for calculating wheat equivalent yield (WEY) is as follows:

$$WEY = \sum_{i=1}^n (Y_i e_i)$$

Where, Y_i = the economic yield of i^{th} crop, e_i = the wheat equivalent factor of i^{th} crop,

$e_i = \frac{P_i}{P_w}$, P_i = the price of unit weight of i^{th} crop, and P_w = the price of a unit weight of wheat.

This type of comparison is valid when considering the gross returns. However, it does not indicate the net gain obtained from a cropping system. This will not give any explanation about the land use pattern of the cropping system.

Some of the common indices have been developed to measure and compare farm land use and production potential in multiple cropping. Land Equivalent Ratio is the most important one.

(b) Land Equivalent Ratio (LER): This is the most frequently used efficiency indicator. LER can be defined as the relative area of sole crop that would be required to produce the equivalent yield achieved by intercropping.

$$LER = \sum_{i=1}^n \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}$$

Where, Y_{ab} = yield of crop a in intercropping, Y_{ba} = yield of crop b in intercropping, Y_{aa} = yield of crop a in pure stand and Y_{bb} = yield of crop b in pure stand.

LER of more than 1 indicates yield advantage, equal to 1 indicates no gain or no loss and less than 1 indicates yield loss. It can be used both for replacement and additive series of intercropping.

(iii) Economic viability

(a) Gross returns or Gross profit: The total monetary returns of the economic produce such as grain, tuber, bulb fruit, etc. and bye-products viz., straw, fodder, fuel, etc. obtained from the crops included in the system are calculated based on the local market prices. The total return is expressed in terms of unit area, usually one hectare.

The main draw back in this calculation is that the market price of the produce is higher than that actually obtained by the farmer. Generally gross returns calculated is somewhat inflated compared to the actual receipt obtained by the farmer.

(b) Net returns or net profit: This is worked out by subtracting the total cost of cultivation from the gross returns. This value gives the actual profit obtained by the farmer. In this type of calculating only the variable costs are considered. Fixed costs such as rent for the land, land revenue, interest on capital, etc. are not included. For a realistic estimate, however, fixed costs should also be included.

(c) Rupees per rupee invested: This is also called profit-cost ratio or input- output ratio.

$$\text{Return per rupee invested} = \frac{\text{Gross returns}}{\text{Cost of cultivation}}$$

(d) Per day return: This is called as income per day and can be obtained by dividing the net returns by number of cropping period (days).

$$\text{Per day return} = \frac{\text{Net returns}}{\text{Cropping period (days)}}$$

This gives the efficiency of the cropping system in terms of monetary value. If the system is stretched over one year, the denominator can be replaced by 365 days and per day return for the whole year can be calculated.

2. Dairy Farming

Dairy farming is an important source of income to farmers. Besides producing milk and/or draft power, the dairy animals are also good source of farm yard manure, which is good source of organic matter for improving soil fertility. The farm byproducts in turn are gainfully utilized for feeding the animals. Though the total milk production in the country as per current estimates have crossed 90 million tones/annum marks, the per capita availability of milk is still about 220g/day against the minimum requirement of 250g/day as recommended by Indian Council of Medical Research.

The dairy sector in India is characterized by very large number of and very low productivity. Around 70% of Indian cows and 60% of buffaloes have very low productivity. This sector is highly livelihood intensive and provides supplementary incomes to over 70% of all rural and quite a few urban households. The sector is highly gender sensitive and over 90% of the households dairy enterprise is managed by family's women folk.

(a) Cattle Rearing: Cattle rearing in India are carried out under a variety of adverse climatic and environmental conditions. The cattle are broadly classified into three groups.

- (i) Draft breeds:** The bullocks of these breeds are good draft animals, but the cows are poor milkers, e.g. Nagore, Hallikar, Kangeyam, Mali.
- (ii) Dairy breeds:** The cows are high milk yielders, but the bullocks are of poor draft quality, e.g., Sahiwal, Sindhi, Gir.
- (iii) Dual purpose:** The cows are fairly good milkers and the bullocks are with good draft work capacity, e.g., Haryana, Ongole and Kankrej.

Exotic breeds: The exotic breeds are high milk yielder e.g., Jersey, Holstein-Friesian, Ayrshire, Brown Swiss and Guernsey.

(b) Buffaloes: Important dairy breeds of buffalo are Murrah, Nili Ravi (which has its home tract in Pakistan), Mehsana, Suti, Zafarabadi, Godavari and Bhadawari. Of these Godavari has been evolved through crossing local buffaloes in coastal regions of Andhra Pradesh with Murrah.

(i) Housing: Each cow requires 12 to 18 sq.m. space and the buffaloes need 12 to 15 sq.m. It is important to provide good ventilation and an open shed of housing is always preferable. Dairy building should be located at an elevated place to facilitate easy drainage. The floor should be rough and have gradient of 2.5 cm for every 25 cm length.

(ii) Breeding and Maintenance: The cows remain in milk for 9-10 months, the average calving interval being 16-18 months. A cow does not require more than 6-8 weeks of dry period. From the economic point of view, cow should ordinarily be bred during the second and third months after calving. In weak animals and heavy milkers, breeding may be delayed by 1 or 2 months. Cattle come to heat in more or less regular cycles of about 21 days which lasts for about a day. The best time to serve a cow is during the last stage of heat. If artificially inseminated, it is better

to inseminate for 3 days continuously to have better probability to conceive. The gestation period varies with individual cows and breeds and normally it is about 280 days.

In the case of buffaloes, the lactation period last for 7-9 months. She buffalo comes to heat every 21-23 days. The gestation period is 310 days. Calf rearing is very important in the case of buffalo maintenance. Since they require abundant water, wallowing is required. Regular de-worming is needed for buffalo maintenance.

Under Indian conditions, cattle commonly mature at the age of about three years. This period can, however, be reduced by six months under well-managed herd.

(iii) Feeding: Cattle feed generally contains fibrous, coarse, low nutrient straw material called roughage and concentrates as well as green fodder round the calendar year to harvest potential yield.

Roughages: Dairy cattle are efficient user of the roughages and convert large quantities of relatively inexpensive roughage into milk. Roughages are basic for cattle ration and include legumes, non-legume hays, straw and silage of legume and grasses.

Concentrates: Grains and byproducts of grains and oilseeds constitute the concentrates. They are extensively used in dairy cattle ration. These include cereals (maize, sorghum, oats, barley), cotton seeds, industrial wastes (bran or wheat, rice, gram husk) and cakes of oilseeds (groundnut, sesame, rapeseed, soybean, linseed).

Vitamins and mineral mixtures: It is advisable to feed a supplement containing vitamins A and D. Mineral mixtures containing salt, Ca, Mg and P should also be provided in the ration.

The ration per animal per day includes concentrate @ 1 kg for 2 litres of milk yield, green fodder (20-30 kg), straw (5-7 kg) and water (32 litres).

3. Goat and Sheep Rearing

The system of sheep and goat rearing in India is different from that adopted in the developed countries. In general, smaller units are mostly maintained as against large scale in fenced areas in the developed countries.

(i) Goat Rearing: In India, activity of goat rearing is sustained in different kinds of environments, including dry, hot, wet and cold, high mountains or low lying plains. The activity is also associated with different systems such as crop or animal-based, pastoral or sedentary, single animal or mixed herd, small or large scale. Goat is mainly reared for meat, milk, hide and skin. Goat meat is the preferred meat in the country. A goat on hoof (live goat) fetches a better price than a sheep on hoof.

Housing: Goats can be maintained under stall-fed conditions. Successful goat rearing depends on the selection of site. Goats do not thrive on marshy or swampy ground. Goats are to be provided with a dry, comfortable, safe and secure place, free from worms and affording protection from excessive heat and inclement weather. The kids are kept under large inverted baskets until they are old enough to run along with their mothers. Males and females are generally kept together. The space requirement for a goat is 4.5 to 5.4 sq.m.

Breeding and Maintenance: Goat matures in about 6-7 months. Breeding is allowed for buck at one year and doe after 10 months of age. Gestation period is 145-155 days. It gives birth to 1-3

kitts per time. Number of evings is three per 2 years. The kitts can be weaned after 30-45 days. Mother can be allowed for mating 45-60 days after evings. Once in five years, the buck can be changed to avoid deterioration due to inbreeding. When the young ones attain a body weight of about 25-30 kg in about nine months, they can be sold.

Feeding: The requirement of nutrients per head in respect of goats is relatively low. Hence, they are suitable for resource poor small farmers with marginal grazing lands. They are essentially browsers and eat plants, which any other animals won't touch. Goats eat 4-5 times that of their body weight. Since the profit depends on weight addition, adequate proteins and calorie should be given to goats. They eat more of tree fodder and hence 40-50% of green fodder should contain tree leaf fodder and the rest with other grass species. Goats should be fed with concentrates of maize, wheat, horsegram, groundnut cake, fish meal and wheat bran. Common salt and vitamin mixtures should also be added. Abundant clean fresh water should be made available to goats. Water should be changed every morning and evening. Fresh water is required for digestion, blood circulation and removal of waste from the body. Water is also required for regulation of the body temperature.

(ii) Sheep Rearing: Sheep are well adapted to many areas. They are excellent gleaners and make use of much of the waste feed. They consume large quantities of roughage, converting a relatively cheap food into a good cash product. Housing need not be elaborate or expensive. However, to protect the flock from predatory animals, the height of the fencing should be raised to two meters.

Breeds of Indian Sheep: There are three types of sheep in India based on the geographical division of the country.

- (i) The temperate Himalayan region:** Gurez, Karanah, Bhakarwal, Gaddi, Rampur-Bushiar.
- (ii) Dry western Region:** Lohi, Bikaneri, Marwari, Kutchi, Kathiawari
- (iii) Southern Region:** Deccani, Nellore, Bellary, Mandya, Bandur

Breeding and Maintenance: One ram can be maintained for 40-50 ewes. Rams are liable to fight when two or more of them are put in a pen. Unlike other farm animals, ewes in general do not come in heat at regular intervals throughout the year but are seasonal in this respect. The duration of the heat period will range from 1-3 days and 75% of the ewes remain in heat for 21-39 hours. The optimum time of service is towards the end of heat period. Average heat interval is 18 days during the breeding season. The gestation period will vary from 142-152 days with an average of 147 days. A normal ram is in full vigour for breeding from the age of 2½-5 years. Sheep grow fully at two years of age when the ewe is ready for breeding. Under average range conditions, ewes may be expected to produce about five crops of lambs.

Feeding: A sheep requires about 1-2 kg of leguminous hay per day depending on the age of sheep and its body weight. Proteins may be supplied through concentrates such as groundnut cake, sesame cake or safflower cake when the pastures are poor in legumes or when scarcity conditions prevail. Normally 110-225 g of cake is sufficient to maintain an average sheep in good condition. Feeding a mixture of common salt, ground limestone and sterilized bone meal in equal parts is required to alleviate deficiency of minerals in the feed.

4. Piggery

Pigs are maintained for the production of pork. They are fed with inedible feeds, forages, certain grain byproducts obtained from mills, meat byproducts damaged feeds and garbage. Most of these feeds are either not edible or not very palatable to human beings. The pig grows fast and is a prolific breeder, farrowing 10 to 12 piglets at a time. It is capable of producing two litters per year under good management conditions. The carcass return is high at 65-70% of the live weight.

Breeds: Imported breeds of Large White Yorkshire and Landrace are being used widely. Yorkshire is the most extensively used exotic breed in India. It is a prolific breed having good carcass quality, growth rate and feed conversion ability. For a small breeding farm or unit, the selection of a herd boar is extremely important. A good boar weighs 90 kg in about 5-6 months and is strong on feet and legs. The mother of the pig to be selected should have large litters of eight piglets or more.

Housing: Housing should provide maximum comfort to pigs so that their growth is optimum. There should not be dampness, draft and over heating. Locally available materials can be used for housing. One pig requires about 2.7 sq.m. with a wall of 1.2 m height. Eight boars can be kept in 2.7-4.5 sq.m. area with 2.4-6.0 sq.m. open space.

Feeding: Feed plays an important role in successful pig production. Pigs are the most rapidly growing livestock and suffer more from nutritional deficiencies than the ruminants. Protein, carbohydrates, fats, minerals, vitamins and ample good water form a complete diet for pig. Pigs have a simple stomach; therefore, they must be fed with maximum of concentrates and minimum of roughage. The main ingredients of swine ration are cereals and millets and their byproducts. The fibre content in swine ration should be very low (around 5-6%) for better feed utilization efficiency. Mixed ration should also contain 0.5% of added salt. Swine requires comparatively higher percentage of Ca and P than do cattle or sheep. When pigs are maintained with agricultural/kitchen waste or fish and slaughterhouse waste, the cost of production remains low. On an average, the consumption of feed is 3.5% of total weight. Feed allowance is calculated as 2.5-3.0 kg/100 kg body weight + @ 0.25 kg feed per piglet with the lactating mothers.

Management: As a general rule, well-developed gilts weighing about 100 kg, when 12-14 months old, may be used for breeding. The body weight is more important than age at breeding. Sows with low body weight show higher rate of fetal and pre-weaning mortality and have been proved as mothers with poor nursing ability. The gestation period is on an average 114 days. Litter size at birth may be 1-16 numbers with the body weight of 1-25 kg. Normal period between birth of piglets is 10-20 minutes. Time taken for the whole process of farrowing ranges from 1.5 to 4.0 hours. Sows are weaned after 40 days. It is advantageous to cull the sow after fifth or sixth litter in a commercial herd. Weaned sows come into heat in 3-10 days after weaning and may be allowed to breed. The boar-sow ratio should be 1:15. It is profitable to raise two litters from each sow each year.

Mortality in piglets is an important cause of heavy economic loss leading to failure of pig industry. In general, one fourth of piglets farrowed die before they are weaned. Another one tenth is also categorized into stunt or unprofitable group due to disease or parasite infection. Thus about 60-65% of the piglets farrowed perform as healthy piglets at slaughter age. Death rate is high during farrowing and the first week after farrowing. The farrowing season also determines mortality rate. Mortality in newborn piglets is maximum when farrowing takes place in acute cold or hot climate. Therefore, mating should be planned in such a way that farrowing could be avoided in such seasons.

5. Poultry

Poultry is one of the fastest growing food industries in the world. Poultry meat accounts for about 27% of the total meat consumed worldwide and its consumption is growing at an average of 5% annually. Poultry industry in India is relatively a new agricultural industry. Till 1950, it was considered a back yard profession in India. In the sixties, the growth rate of egg production was about 10% and it increased to 25% in the seventies. The growth rate came down to 7-8% by 1990 due to price-rise in poultry feed. By 2000, the total egg production may reach up to 5000 crores. Broiler production is increasing at the rate of 15% per year. It was 31 million in 1981 and increased up to 300 million in 1995 (Singh, 1997). Nearly 330 thousand tonnes of broiler meat are currently produced. The average global consumption is 120 eggs per person per year and in India, it is only 32-33 eggs per capita year. As per the nutritional recommendation, the per capita consumption is estimated at 180 eggs/year and 9 kg meat/year.

Breeds: Specific poultry stocks for egg and broiler production are available. A majority of the stocks used for egg production are crosses involving the strains or inbred lines of white Leghorn. To a limited extent, other breeds like Rhode Island Red, California Grey and Australop are used. Heavy breeds such as white Plymouth Rock, White Cornish and New Hampshire are used for crossbred broiler chickens. Hence, it is essential to consider the strain within the breed at the time of purchase. Several commercial poultry breeders are selling day old chicks in India. It is best to start with the day old chicks.

Housing: Adequate space should be provided for the birds. Floor area of about 0.2 m² per adult bird is adequate for light breeds such as white Leghorn. About 0.3-0.4 m² per bird is required for heavy breeds. The house should have good ventilation and reasonably cool in summer and warm during winter. It should be located on well-drained ground, safe from flood waters.

Feed: The feed conversion efficiency of the bird is far superior to other animals. About 60-70% of the total expenditure on poultry farming is spent on the poultry feed. Hence, use of cheap and efficient ration will give maximum profit. Ration should be balanced containing carbohydrates, fats, minerals and vitamins. Some of the common feed stuffs used for making poultry ration in India are:

Cereals: Maize, barley, oats, wheat, pearl millet, sorghum, rice-broken.

Cakes/meal: Oil cakes, maize-gluten-meal, fish meal, meat meal, blood meal.

Minerals/salt: Limestone, Oyster shell, salt, manganese

From the day old to 4 weeks of age, birds are fed on starter ration and thereafter finisher ration, which contains more energy and 18-20% protein. Feed may be given 2-3 times in a day. In addition to the foodstuffs, antibiotics and drugs may also be added to the poultry ration. Laying hens are provided with oyster shell or ground limestone. Riboflavin is particularly needed.

Maintenance: The chicks must be vaccinated against Ranikhet diseases with F₁ Strain vaccine within the first 6-7 days of age. One drop of vaccine may be administered in the eye and nostril. When chicks get the optimum body weight of 1.0-1.5 kg around six weeks, they can be marketed for broiler. Hens may be retained for one year for production i.e., upto the age of about 1½ years since egg production would get reduced. One hen is capable of laying 180-230 eggs in a year starting from the six month. In addition, a laying hen produces about 230 g of fresh droppings (75% moisture) daily.

6. Duck Rearing

Ducks account for about 7% of the poultry population in India. They are popular in states like West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Tripura and Jammu and Kashmir. Ducks are predominantly of indigenous type and reared for egg production on natural foraging. They have a production potential of about 130-140 eggs/bird/year. Ducks are quite hardy, more easily brooded and resistant to common avian diseases. In places like marshy riverside, wetland and barren moors where chicken or any other type of stock do not flourish, duck rearing can be better alternative.

Breeds: The important Indian breeds are Sylhet Mete and Nageswari, which are mostly found in the Eastern region of the country. Their annual production of 150 eggs/bird/year. Improved breeds for egg and meat production are available. Khaki Campbell and Indian Runner are the most popular breeds for egg laying. Khaki Campbell has a production of 300 eggs/bird/year. Indian Runner is the second best producer. White Pekin, Muscovy and Aylesbury are known for meat production. White Pekin is the most popular duck in the world. It is fast growing and has low feed consumption with fine quality of meat. It attains about 3 kg of body weight in 40 days. Indigenous types, however, still continue to dominate in duck farming. Desi ducks are robust, well adapted to local conditions and free of diseases.

Housing: Ducks prefer to stay outside day and night even during winter or rains. In mild climate, it is possible to raise ducks without artificial shelter. A light fence of at least 1.2 m high enclosing the yard is enough to stop any predators. One nest of size 0.3 x 0.3 x 0.45 m to every 3 ducks is sufficient. In case of laying birds, a mating ratio of 1 drake: 6-7 ducks and in meat type 1:4-5 is allowed. The duck house should be well ventilated, dry, leaf and rat proof. The roof may be of thatched or asbestos sheeted. A water channel of 0.5 m wide and 0.20 m deep is constructed at the far end on both sides parallel to the night shelter in the rearing or layer house.

Feeding: Ducks normally require lesser attention. They supplement their feed by foraging, eating fallen grains in harvested paddy fields, small fishes and other aquatic materials in lakes and ponds. However, for intensive rearing, pellet feeding may be given. Ducks prefer wet mash due to difficulties in swallowing the dry mash. Hence, ducks should never have access to feed without water. During the first 8 weeks, birds should always have an access to feed. Later on they must be fed twice a day in the morning and late afternoon.

Maintenance: The general management of ducks is similar to that of the chickens. The incubation period is 28 days. A broody duck or hen may be used for small scale hatching and incubator for large scale hatching. During the early part of the life, newly hatched ducklings require warm temperature under the natural or village conditions. A duck or broody hen can take care of 10-15 ducklings. Artificial brooding may be resorted for large number of ducklings. High egg-laying strains of duck come into production at 16-18 weeks of age. Ducks are resistant to common avian diseases. Some of the common diseases in duck are duck plague, duck virus hepatitis, duck cholera and aflatoxicosis.

7. Apiculture

Apiculture is the science and culture of honeybees and their management. Apiculture is a subsidiary occupation and it is a additional source of income for farm families. It requires low investments and so can be taken up by small, marginal and landless farmers and educated unemployed youth.

Species: There are two bee species, which are most commonly grown in India. They are *Apis cerana indica* and *A. mellifera*, are complementary to each other but have different adaptations. *A. cerana* is known as Indian bees, while *A. mellifera* is known as European/western bee.

Apis cerana: serves commercial bee keeping in most parts of the country and is reared mostly in ISI- A Type bee-hyve. *Apis cerana* has instinctive behaviour of swarming and absconding. Its honey yield varies from 12 to 15Kg/ hive/ annum with foraging range between 0.8 and 1.0 km.

Apis mellifera: This species has achieved a great success in northwestern states of India. Its worker cell is 5.3mm in width and drone cell is 1-3 times larger. Average honey production from this species is between 30 and 40 kg/ hive/annum with foraging range extending up to 2-3 km.

Management: The beekeeper should be familiar with the source of nectar and pollen within his locality. Bee flora species are specific to different areas and have micro regional habitats. Under subtropical climates of India, nectar and pollen sources are available for most part of the year, but continuous succession throughout the year is lacking in some localities. Flowers of large number of plants species are visited by honeybees for nectar and pollen. The most important sources of nectar and pollen are maize, mustard, sunflower and palm, litchi, pongamia, coconut, sesamum etc. The beginner should start with 2 and not more than 5 colonies. A minimum of 2 colonies is recommended because in the event of some mishap, such as the loss of the queen occurring in one, advantage may be taken with the other.

The hive consists of bottom-board, brood chamber, brood chamber frames, super chamber, super chamber frames, top cover, inner cover, and entrance rod. These parts can easily be separated. The hive may be double walled or single walled. The single walled hive is light and cheap. The most suitable time for commencing bee keeping in a locality is the arrival of the swarming season. Swarming is a natural tendency of bees to divide their colonies under conditions that are generally favourable for the survival of both parent colony and the swarm. This occurs during the late spring or early summer.

Honey collection: Honey is a sweet viscous fluid produced by honeybees mainly from the nectar of the flowers. Honey should have good quality to meet the national and international standards. Qualities such as aroma, colour, consistency and floral sources are important. Proper honey straining and processing are needed to improve the quality of the produce. Honey varies in the proportion of its constituents owing to the differences in the nectar produced by different plants. The nectar collected by bees is processed and placed in comb cells for ripening. During the ripening, sucrose is converted into glucose and fructose by an enzyme called invertase, which is added to it by the bees. Honey is an excellent energy food with an average of about 3500 calories per kg. It is directly absorbed into the human blood stream, requiring no digestion.

8. Fishery

Ponds serve various useful purposes, viz., domestic requirement of water, supplementary irrigation source to adjoining crop fields and pisciculture. With the traditional management, farmers obtain hardly 300-400 kg of wild and culture fish per ha annually. However, composite-fish culture with the stocking density of 5000-7500 fingerlings/ ha and supplementary feeding can boost the total biomass production.

Pond: The depth of the pond should be 1.5-2.0 m. This depth will help for effective photosynthesis and temperature maintenance for the growth of zoo and phytoplankton. Clay soils have higher water retention capacity and hence are best suited for fish rearing. Pond water should

have appropriate proportion of nutrients, phosphate (0.2-0.4 ppm), nitrate (0.06-0.1 ppm) and dissolved oxygen (5.0-7.0 ppm). Water should be slightly alkaline (pH 7.5-8.5). If the pH is less than 6.5, it can be adjusted with the addition of lime at regular interval of 2-3 days. Higher pH (>8.5) can be reduced with the addition of gypsum. Application of fresh dung may also reduce high pH in the water.

Soil of the pond should be tested for N and P content. If the nutrient content is less, nitrogenous fertilizers like ammonium sulphate and urea and phosphatic fertilizer like super phosphate can be added. Organic manures such as FYM and poultry droppings may also be applied to promote the growth of phyto and zooplanktons.

Species of fish:

- (i) Among the Indian major carps, Catla (*Catla catla*) is the fast growing fish. It consumes a lot of vegetation and decomposing higher plants. It is mainly a surface and column feeder.
- (ii) Rohu (*Labeo rohita*) is a column feeder and feeds on growing fish. It consumes a lot of vegetation and decomposing higher plants. It is mainly a column and surface feeder.
- (iii) Calbasu (*Labeo calbasu*) is a bottom feeder on detritus. Mrigal (*Cirrhinus mrigala*) is also a bottom feeder, taking detritus to large extent, diatoms, filamentous and other algae and higher plants. Common carp (*Cyprinus carpio*) is a bottom feeder and omnivorous.
- (iv) Silver carp (*Hypophthalmichthys molitrix*) is mainly a surface and phytoplankton-feeder and also feeds on micro-plants.
- (v) Grass carp (*Ctenopharyngodon idella*) is a specialized feeder on aquatic plants, cut-grass and other vegetable matter. It is also a fast growing exotic fish.

Composite Fish Culture: The phytophagous fish (Catla, Rohu and Mrigal) can be combined with omnivorous (Common carp), plankton-feed (Silver carp) and mud-eaters (Mrigal and Calbasu) in a composite fish culture system.

Management: For higher productivity fish are to be provided with supplementary feeding with rice bran and oilseed cakes. This will enable faster growth and better yield. Each variety of carps could be stocked to 500 fingerlings with the total 5000-8000 per ha. This stocking density will enable to get a maximum yield of 2000 to 5000 kg/ha of fish annually under good management practices.

9. Sericulture

Sericulture is defined as a practice of combining mulberry cultivation, silkworm rearing and silk reeling. Sericulture is a recognized practice in India. India occupies second position among silk producing countries in the world, next to China. The total area under mulberry is 188 thousand ha in the country. It plays an important role in socio-economic development of rural poor in some areas. In India more than 98% of mulberry-silk is produced from five traditional sericultural states, viz., Karnataka, Andhra Pradesh, West Bengal, Tamil Nadu, and Jammu and Kashmir.

The climatic conditions in India are favourable for luxuriant growth of mulberry and rearing and silkworms throughout the year. The temperature in Karnataka state, major silk producing state in India, ranges from 21.2 to 30°C. Climatic conditions in Kashmir are favourable to silk worm from May to October.

Moriculture: Cultivation of mulberry plants is called as 'moriculture'. There are about 20 species of mulberry, of which four are commonly cultivated. They are *Morus alba*, *M. indica*, *M. serrata* and *M. latifolia*. The crop can yield well for 12 years, after which they are pulled out and fresh planting is done. Yield of mulberry leaves is 30-40 t/ha/year.

Silk worm rearing: There are four types of silk worm viz. (i) Mulberry silk worm – *Bombyx mori* (ii) Eri silk worm – *Philosamia ricini* (iii) Tassar silk worm – *Antheraea mylitta* (iv) Muga silk worm – *Antheraea assami*

Rearing and Maintenance: The fertilized moth is covered with an inverted funnel or cellule and eggs are allowed to be laid over a cardboard. Parasites may be removed by brushing the egg masses with a fine brush. This will also enable to obtain a uniform hatch. In a bamboo tray rice husk is spread. Tender chopper mulberry leaves are added to the tray. The hatched out larvae are transferred to the leaves. It is important to change the leaves every 2-3 hours during the first 2-3 days.

The cocoon is constructed with a single reelable thread of silk. If the moths are allowed to emerge from the cocoons, the silk thread is cut into pieces. Hence the pupa are killed 2-3 days before the emergence of moth and processed. The cocoons required for further rearing are kept separately and moths are allowed to emerge from them.

10. Mushroom Cultivation

Mushroom is an edible fungus with great diversity in shape, size and colour. Essentially mushroom is a vegetable that is cultivated in protected farms in a highly sanitized atmosphere. Just like other vegetables, mushroom contains 90% moisture with high in quality protein. Mushrooms are fairly good source of vitamin C and B complex. The protein have 60-70% digestibility and contain all essential amino acids. It is also rich source of minerals like Ca, P, K and Cu. They contain less fat and CHO and are considered good for diabetic and blood pressure patients.

Species: There are three types of mushrooms popularly cultivated in India. They are (i) Oyster mushroom – *Pleurotus spp.* (ii) Paddy straw mushroom – *Volvariella volvacea* (iii) White bottom mushroom – *Agaricus bisporus*

Method of production

Oyster Mushroom: Take fresh paddy straw and cut into small pieces of 3-5 cm length. Soak them in water for 4-6 hours and then boil for half an hour. Drain the water and dry the straw in shade till it is neither too dry nor wet. Take polythene bags of 60 x 30 cm size and make two holes of one cm diameter in the center of the bag such that they face opposite sides. Tie the bottom of the bag with a thread to make a flat bottom. Fill the bag with paddy straw to 10 cm height. Then inoculate with the spawn. Likewise prepare 4-5 layers of straw and spawn alternatively. The last layer ends up in straw of 10 cm height. Keep this in a spawn running room maintained at a temperature of about 22-28°C and with RH 85-90%. After 15-20 days when the

spawn running is completed, cut open the polythene bag and take it to cropping room and allow it to grow for 7 days and harvest the mushroom. Mushroom yield is around 0.5-1.0 kg/bag.

Paddy straw Mushroom: Cut the straw into long pieces of 60-90 cm and soak in water for 12 hours and sterilize 15 minutes. Arrange the straw in bundles. Lay the moistened straw bundles on the slightly raised concrete floor or on wooden platform in layers of four bundles width. Spawn or seed the beds simultaneously in each layer either by broadcasting or placing the grain spawn at different spots. Sprinkle grain dhal over each layer on the spawn. Don't spawn below the topmost layer. Maintain it at 30-35°C. Harvesting is ready after 25-30 days. Yield is around 1-1.5 kg/bed.

Button Mushroom: It requires a complex method of preparing compost, which is used as a substrate for mushroom production. Spawning is done by three methods, viz., surface spawning, layer spawning and trough spawning. Fill the trays with compost and do spawning. After spawning, compost is pressed hard to make it compact. The trays are arranged in the cropping room in tiers and cover with newspaper sheet sprayed with 2% formalin. The temperature of 20-25°C and RH of 90-95% should be maintained. After spawn running is completed in 15-20 days and do casing. Pin heads appear within 10-15 days after casing. Cropping continues for 60-75 days. Mushrooms can be harvested at button stage. Yield ranges from 6-7 kg/m².

11. Agroforestry

Agroforestry is a collective name for land use systems and technologies, in which woody perennials (trees, shrubs, palms, bamboos etc) are deliberately combined on the same land-management unit as agricultural crops and/or animals, either in some form of spatial arrangement or in a temporal sequence.

In agroforestry systems, there are ecological and economical interactions among different components. That implies that: (i) agroforestry normally involves two or more species of plants (or plants and animals) at least one of which is woody perennials; (ii) an agroforestry system always has two or more outputs; (iii) the cycle of an agroforestry system is always more than one year; and (iv) even the simplest agroforestry system is structurally, functionally, and socio-economically more complex than a monocropping system. Agroforestry is important for meeting fodder, fuel wood and small timber of farmers, conserving soil and water, maintenance of soil fertility, controlling salinity and water logging, positive environment impact and alternate land use for marginal and degraded lands. Selection of proper land use systems conserve biophysical resources of non-arable land besides providing day-to-day needs of farmer and livestock within the farming system.

The different commonly followed agro-forestry systems in India are: (1) Agri-silviculture (crops + trees), which is popularly known as farm forestry (2) Agri-horticulture (crops + fruit trees); (3) Silvi-pasture (Trees + pasture + animals); (4) Agri-horti-silviculture (crops + fruit trees + MPTS + pasture); (5) Horti-silvi-pasture (fruit trees + MPTS+ Pasture); (6) Agri-silvi-pasture (crops + trees + Pasture); (7) Homestead agroforestry (multiple combination of various components); (8) Silvi-apiculture (trees + honey bees); (9) Agri-pisci-silviculture (crops + fish + MPTS); (10) Pisci-silviculture (Fish + MPTS) etc.

Agri-silvicultural Systems: This system emphasizes raising of trees and cultivation of field crops and/or fodder crops in the available space between the trees. In arid and semi-arid regions hardy trees like *Prosopis cineraria* (Khejri), *Eucalyptus* sp., *Acacia tortilis*, *Hardwickia binata* (Anjan), *Azadirachta indica* (Neem), *Ailanthes excelsa*, *Ziziphus jujuba* etc. could be grown along with dry land crops such as pulses (pigeonpea, blackgram), millets (finger millet, sorghum) etc. This is practiced mostly on arable lands, wherein multipurpose trees used for fuel and fodder can be grown with crops in the fields as alley farming. The hedges follow contour and compromise trees and shrubs like *Leucaena* or pigeonpea. Leguminous perennials are more suitable due to fixation of nitrogen.

Agri-horti-silviculture: In this system fruit trees are grown along with crops and multipurpose trees (MPTs). Under rainfed situation hardy fruit trees like ber, aonla, pomegranate, guava could be grown along with dryland crops like pigeonpea, til, mothbean, mustard etc. Grafted ber (Var., Gola, Seb, Mundiya, Banarasi Kasak) may be planted at 6 x 6 m with 2 plants of subabul in between.

Under partial irrigation, Guava, pomegranate, Lemon, Kinnow have been successfully grown at 6 x 5 m along with crop like wheat, groundnut and subabul (200 pl/ha) for quick leaf fodder and fuel wood production. For further protecting fruit crops from desiccating hot summer and cold winter planting of subabul/sesbania at every 2 m apart as wind breaks. Alternate plants of subabul/sesbania could be harvested for quick fodder and fuel wood production every 3rd year. Relative grain yield was 70-85% even in 3rd and 4th year.

Silvi-Pastoral system: In the silvi-pastoral system, improved pasture species are introduced with tree species. In this system grasses or grass legume mixture is grown along with the woody perennial simultaneously on the same unit of land. In the marginal, sub-marginal and other degraded lands silvipastoral system has been found to be most economic agroforestry system especially in arid and semi-arid regions. It involves lopping trees and grazing understorey grasses and bushes in forests or plantations. It helps in reduction of the cost of concentrated feed to animal during lean period. A number of fodder trees like *Leucaena latisiliqua*, *Bauhinia variegata*, *Albizia labbek*, *Albizia amara*, *Moringa olerifera*, *Sesbania sesban*, *S. grandiflora*, *Hardwickia binata* are identified for different regions of the country for silvi pastoral systems. Trees provide fuel and timber in the extreme dry season and lean periods, animal graze on pastures and feed on the leaves of nutritious trees and shrubs. Multilayered vegetation covers are very effective in controlling run-off and soil loss from erosion prone areas.

Horti-Pastoral system: It involves integration of fruit trees with pasture. In the degraded arid and semi arid rangeland regimes number of over grazed plants of *Ziziphus nummularis* are found which could be successfully budded with improved variety of ber (viz., Gola, Seb, Umran, Banaras, Kaska) besides planting MPTs like anjan, Subabul, Khejri along grasses and legumes like *Cenchrus*, *Lasiurus*, *Chrysopogon*, *Stylosanthes*, *Sirato* etc.

Agri-silvi-pasture: It is a combination of agri-silviculture and silvi-pastoral system. In arid degraded lands of Rajasthan, Gujarat and Haryana often dryland crops viz. bajra, moth, urad, til etc. are grown in strips along with grass strips to avoid shifting sand reaching cropped area. MPTs could be introduced both in the pasture strips as well as in the crop strips, which besides protecting the crops from desiccating hot and cold wind would also provide leaf fodder, timber etc. besides pasture when there is a crop failure. Woody plants could be *Acacia senegal*, ber, anjan, neem etc. Grasses like *Cenchrus*, *Lasiurus* and legume *Stylo* spp.

Pastoral silvicultural system: Integrated crop farming is practiced to meet the requirements of grasses and fodder for livestock. The pastoral silvicultural system is the practice in which grazing is the main component with scattered trees grown in the area. This practice is adopted in semi-arid regions of the country comprising the states of Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and Madhya Pradesh.

The cultivators leave the fields fallow with existing trees and protect the same. *Dichanthium annulatum* is an important grass under this system. The important planted trees in the system are *Eucalyptus* hybrid, *Casuarina equisetifolia*, *Borassus flabellifera* and *Phoenix sylvestris*. Generally trees are lopped for fuel and fodder. Custard apple, mango, Zizyphus and tamarind fruits are used for domestic consumption.

12. Biogas

A biogas unit is an asset to a farming family. It produces good manure and clean fuel and improves sanitation. Biogas is a clean, unpolluted and cheap source of energy, which can be obtained by a simple mechanism and little investment. The gas is generated from the cow dung during anaerobic decomposition. Biogas generation is a complex biochemical process. The cellulosic material is broken down to methane and carbon dioxide by different groups of microorganisms. It can be used for cooking purpose, burning lamps, running pumps etc.

Selection of a model: The two main designs of biogas plants are the floating gas holder and fixed-dome types. The merits and demerits of each design need to be considered while selecting a model.

- (i) **Float dome type:** Different models are available in this category e.g., KVIC vertical and horizontal, Pragati model, Ganesh model.
- (ii) **Fixed dome type:** The gas plant is dome shaped under ground construction. The masonry gas holder is an integral part of the digester called dome. The gas produced in the digester is collected in dome at vertical pressure by displacement of slurry in inlet and outlet. The entire construction is made of bricks and cement. The models available in this category are Janata and Deen-Bandhu.

The selection of a particular type depends on technical, climatological, geographical and economic factors prevailing in a given area.

Selection of Size: The size of the biogas plant is decided by the number of family members and the availability of dung. One cubic metre capacity plant will need two to three animals and 25 kg of dung. The gas produced will meet the requirement of a family of 4-6 members. It would suffice to have a 2 cubic metre plant to cater to the needs of a family of 6-10 members.

Site selection and management: The site should be close to the kitchen or the place of use. It will reduce the cost of gas distribution system. It should also be nearer to the cattle shed to reduce the cost of transport of cattle dung. Land should be leveled and slightly above the ground level to avoid inflow or run-off of water. Plant should get clear sunshine during most part of the day. Generation of dung has a direct bearing on the quantity of gas generated. The amount of gas production is considerably higher in summer followed by rainy and winter seasons. Gas production would be maximum at a temperature between 30 to 35°C. If the ambient temperature falls below 10°C gas production is reduced drastically.

Biogas slurry: Slurry is obtained after the production of bio-gas. It is enriched manure. Another positive aspect of this manure is that even after weeks of exposure to the atmosphere, the slurry does not attract fleas and worms.

Interactions

Integrated Farming System (IFS), a component of farming systems introduces a change in the farming techniques for maximum production in the cropping pattern and takes care of optimal resource utilization. The farm wastes are better recycled for productive purposes in the integrated farming system. The inter-related, interdependent and interlinking nature of IFS, involves the utilization of primary produce and secondary produce of one system as basic input of the other system, thus, making them mutually integrated as one whole unit. This incidentally helps to reduce the dependence on procurement of inputs from open market, making thereby the IFS a self-supporting entity and sustainable system over time.

Unlike the specialized farming system (SFS), integrated farming systems activity is focused round a few selected, interdependent, interrelated and often interlinking production systems based on a few crops, animals and related subsidiary professions. The exploitation of possible complementarities or synergy among the various components or subsystems needs to be explored for improving resource use efficiency within the farming systems.

The on-station study involving enterprises such as crop, fishery, poultry, duckery, apiary and mushroom production revealed that there is chain of interactions among these enterprises. The byproduct of one enterprise may effectively utilize for the other enterprise, thus ensuring higher and efficient resource use efficiency.

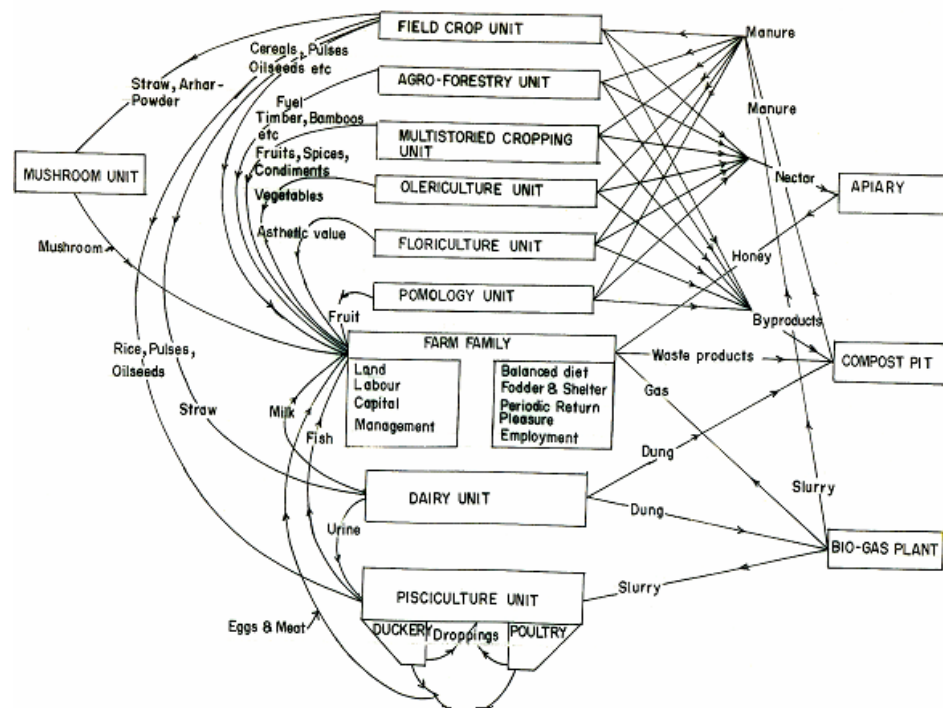


Figure 2: Interactions among different components of Farming Systems

A close examination of resource recycling (Fig.2) indicates the interdependence of the different components of the total farming system to make the farmer self sufficient in terms of ensuring the family members a balanced diet for leading healthy life and also making farm self sufficient through recycling of by products. The by-products of dairy i.e. cow dung forms a major raw materials for biogas plants. Digested slurry of bio-gas plant forms a major part of feed of pisciculture for increasing plankton growth as well as supplying valuable manure to raise the productivity of field crops/enrich the soil. The by products of field crops like paddy straw forms a major by-product of mushroom cultivation. Straw after use in mushroom production is utilized as cattle-feed and compost preparation. Similarly, the poultry droppings form an important ingredient of pisciculture for increasing the plankton growth as well as increasing the fertility of land. Even apiary played a role of improvement in pollination, apart from giving a wholesome product like honey to farmers. Therefore, it is dangerous to deal separately in such linked agricultural system.

The entire philosophy of integrated farming system revolves round better utilization of time, money, resources and family labour of farm families. The farm family gets scope for gainful employment round the year, thereby ensuring good income and higher standard of living.

Farming System Approach to Research and Development

Farming system research has emerged as a major theme in international agricultural research and rural development. The farming system approach to research and rural development has two interrelated thrusts. One is to develop an understanding of the farm household, the environment in which it operates, and the constraints it faces, together with identifying and testing potential solutions to those constraints. The second thrusts involve the dissemination of the most promising solutions to other farm households facing similar problems. The central issue of the approach is that the analysis of farming systems within which the rural poor live and work can provide powerful insights in to strategic priorities for the reduction of the poverty and hunger now affecting so many of their lives.

Farming System Research (FSR)

Concept: The FSR concept was developed in 1970s in response to the observation that groups of small-scale farm families operating in harsh environment were not benefiting from the conventional agricultural research and extension strategies.

The farming system, as a concept, takes into account the components of soil, water, crops, livestock, labour, capital, energy and other resources with the farm family at the center managing agricultural and related activities. The farm family functions within the limitations of its capability and resources, socio-cultural setting and interaction of these components with physical, biological and economic factors. The term FSR in its broadest sense is any research that views the farm in a holistic manner and considers interactions (between components and of components with environment) in the system.

This type of research is most appropriately carried out by interdisciplinary teams of scientists, who, continuously interact with farmers in the identification of problems and in advising ways of solving them. It aims at generating and transferring technologies to increase the resource productivity for an identified group of farmers.

Objectives and Principles: The FSR advocates that: (i) development of relevant and viable technology for small farmers having the full knowledge of the existing farming system and (ii) that technology should be evaluated not solely in terms of its technical performance but in terms of its conformity to the goals, need and socio- economic circumstances of the targeted small farm system with special reference to profitability and employment generation.

FSR is based on the following basic principles:

- (a) Make the farm household self-sufficient and make the farm free being vulnerable from external forces.
- (b) Enterprise diversification to increase income, employment, risk minimization, improvement in natural resources, environment and diet of farm families.
- (c) The interactions between the components and the components with the environments

Core Characteristics: Many of the core activities of FSR/E can be operationalized in different ways. The approach is open to multiple interpretations. In spite of the variations in their perceptions about FSR/E among the practitioners, the approach has certain distinctive core characters. These are:

- i) **It is problem solving:** As an applied problem solving approach, it emphasizes on developing and transferring appropriate technologies to overcome production constraints through diagnosis of biophysical, socio-economic and institutional constraints that influence technological solutions.
- ii) **It is holistic:** The whole farm is viewed as a system encompassing interacting sub-systems, and no potential enterprise is considered in isolation.
- iii) **It acknowledges the location specificity of technological solutions:** Recognizing the location specific nature of agricultural production problems, it emphasizes on testing and adaptation of technological solutions based on agro-ecological and socio-economic specificities.
- iv) **It defines specific client groups:** Emphasis is made on the identification of specific and relatively homogeneous groups of farmers with similar problems and circumstances for whom technology is to be developed as the specific client groups. On the basis of common environmental parameters, production patterns and management practices, relatively homogeneous recommendation domains need to be identified.
- v) **It is farmer participatory:** It revolves round the basic principle that successful agricultural research and development efforts should start and end with the farmers (Rhoades and Booth, 1982). Farmer participation is ensured at different stages of technology generation and transfer processes such as system description, problem diagnosis, design and implementation of on- farm trials, and providing feedback through monitoring and evaluation.
- vi) **It gives weightage to ITK system:** The Indigenous Technical Knowledge (ITK), which is time tested at the farmer's level for sustainability through a dynamic process of integrating new innovations into the system as they arise, has to be properly understood by the scientists and utilised in their research activities.
- vii) **It is concerned with 'Bottom-up' research strategy:** It begins with an understanding of existing farming system and the identification of key production constraints.

vii) **It is interdisciplinary:** It lays greater emphasis on interdisciplinary cooperation among the scientists from different areas of specialisation to solve agricultural problems that are of concern to farmers.

ix) **It emphasizes extensive on-farm activities:** It involves problem analysis through diagnostic surveys, on-farm testing of the developed technologies, and providing feedback through evaluation to influence the research agenda of the experiment stations. It provides a structural framework for the farmers to express their preferences and apply their evaluation criteria for selecting technologies suiting to their circumstances.

x) **It is gender sensitive:** While explicitly acknowledging the gender-differentiated roles of farm family in agriculture, it emphasizes the critical review of farming systems in terms of activities analysis, access and control over resources and benefits and implication's in developing relevant research agenda.

xi) **It is iterative:** Instead of trying to know everything about a system at a time, it requires step-by-step analysis of only key functional relationships.

xii) **It is dynamic:** It involves recurrent analysis of the farming systems, permitting continuous learning and adaptations.

xiii) **It recognizes interdependencies among multiple clients:** The generation, dissemination and adoption of relevant technologies to improve the productivity and sustainability of agriculture require productive and interactive linkages among the policy planners, scientists, developmental agencies and farmers. The approach attaches more importance for this critical factor.

xiv) **It focuses on actual adoption:** It is to be judged by the extent to which it influences the production of socially desirable technologies that diffuse quickly amongst specified groups of farmer clients.

xv) **It focuses on sustainability:** It seeks to harness the strengths of the existing farming practices, and to ensure that productivity gains are environmentally acceptable. Towards preserving the natural resource base and strengthening the agricultural production base, it attempts to develop technologies that are environment friendly and economically viable.

xvi) **It complements experiment station research:** It only complements but does not substitute on station research. It has to draw upon the scientific knowledge and technologies generated at research stations. It has to be kept in mind that the approach is not being promoted as panacea for all maladies of local agricultural production systems.

Procedures and Methodologies: Generally farming system research is conducted by the following three possible ways:

(a) FSR: On-farm Adaptive Research (OFAR)

(b) FSR: On-station studies

(c) FSR: Study of farming system by modeling, using suitable computer soft ware.

(a)On-farm research: On-farm research refers to the research which is conducted at farmers' field in relatively large plots compared to conventional on-station research with active participation of the farmers with the hope that technology generated through the combined

efforts of researchers and farmers will be realistic to the socio-economic environment of the resource poor group and the problematic situations that the farmers practically face during the process of farming.

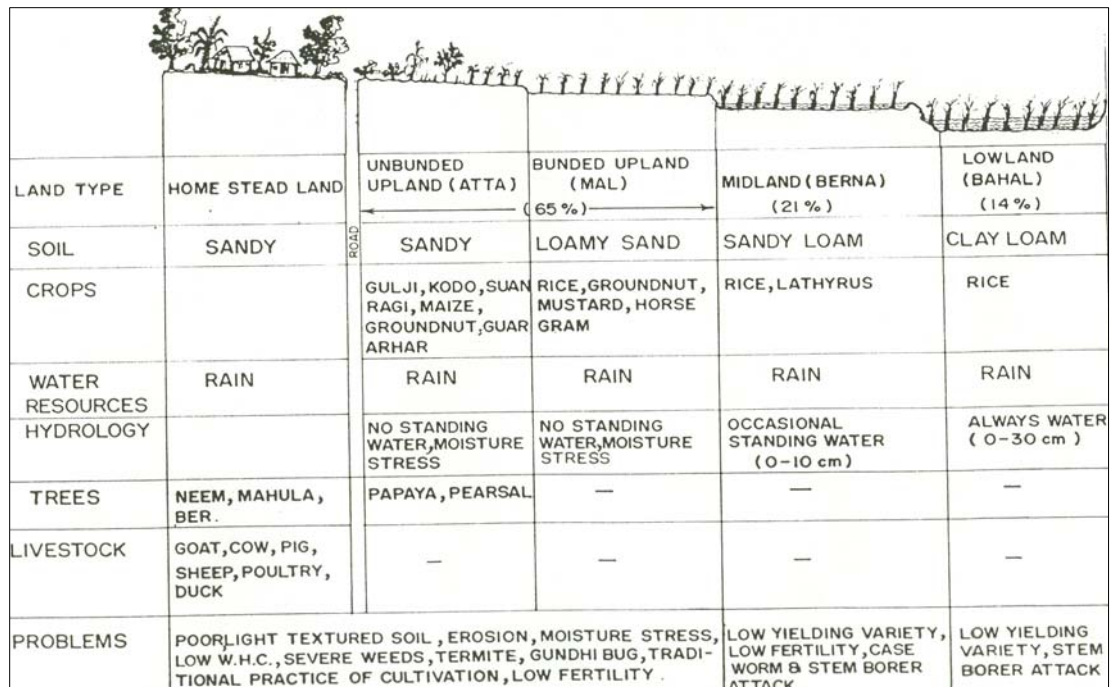
While conducting on-farm research in farming system perspective the following principles need to be considered.

- (i) The whole farm viewed as a system - the research is conducted with recognition and emphasis on choice of priorities that reflect the whole farm.
- (ii) Avoid complex procedures that require scarce and highly qualified individuals to collect and analyse data.
- (iii) Maximise the returns by making results more widely applicable. This means defining target groups of farmers (recommendation domains) in broad terms. The extent to which improved systems can be transferred or extrapolated to other areas directly affects their efficiency.
- (iv) Be open to using second best solutions or the best of those readily available. Therefore, the emphasis in FSR has been on developing improved technologies that are better than most but not necessarily best for each environment.

On-farm research processes: After identification of target area and research area, the following 4 important operational stages in on-farm research process need to be followed (Zandstra *et al.*, 1981):

- (i) **Descriptive or diagnostic stage:** In this stage, target area is picked, the frame of farming families are divided into target groups or recommendation domains. Then efforts are made to determine the constraints farmers face in increasing the farm productivity, the circumstances in which farmers work, the weakness, strength, the opportunities and the threats with the farmers. The main aim is to understand the farming system; to prepare an inventory of farm resources, production constraints and support services. Talking to knowledgeable people, examining relevant secondary sources of information, surveys and technical monitoring are the chief strategies of this stage. In general, however, the methods used should be based on criterion of the lowest possible cost commensurate with the degree of understanding that is necessary. Extra accuracy takes resources and time. This information through diagnostic survey help in improving experimental (trial) planning in: bounding treatment levels; verifying evaluation criteria; identifying special locational characteristics to be observed in setting experiments and assessing current productivity levels. Other aspects important in this diagnostic or descriptive stage are: Participatory rural appraisal (PRA), agro-ecosystem analysis, establishing recommendation domains. Some of the information generated based on agroecosystem analysis and PRA are presented in figure 3.
- (ii) **Design or Planning stage:** The priority for research is identified/recognized from the descriptive/diagnostic stage. Planning or design stage is recognized as crucial to the success of FSR in technology generation. On the whole, farmer's problems are readily identified. Range of strategies is identified that are thought to be relevant in dealing with constraints. The factors taken in to considerations are: technical feasibility, economic viability, social acceptability. In this stage suitable action plan for the selected farmers is formulated. The main variables included in designing and planning are: (i) potential for poverty reduction /

income / employment generation; (ii) Potential for agricultural growth and (iii) Demographic or ecological or economic importance etc.



LAND TYPE	HOME STEAD LAND	UNBUNDED UPLAND (ATTA)	BUNDED UPLAND (MAL)	MIDLAND (BERNA)	LOWLAND (BAHAL)
		(65 %)		(21 %)	(14 %)
SOIL	SANDY	SANDY	LOAMY SAND	SANDY LOAM	CLAY LOAM
CROPS		GULJI, KODO, SUAN, RAGI, MAIZE, GROUNDNUT, GUAR, ARHAR	RICE, GROUNDNUT, MUSTARD, HORSE GRAM	RICE, LATHYRUS	RICE
WATER RESOURCES	RAIN	RAIN	RAIN	RAIN	RAIN
HYDROLOGY		NO STANDING WATER, MOISTURE STRESS	NO STANDING WATER, MOISTURE STRESS	OCCASIONAL STANDING WATER (0-10 cm)	ALWAYS WATER (0-30 cm)
TREES	NEEM, MAHULA, BER.	PAPAYA, PEARSAL	—	—	—
LIVESTOCK	GOAT, COW, PIG, SHEEP, POULTRY, DUCK	—	—	—	—
PROBLEMS	POOR LIGHT TEXTURED SOIL, EROSION, MOISTURE STRESS, LOW W.H.C., SEVERE WEEDS, TERMITE, GUNDHI BUG, TRADITIONAL PRACTICE OF CULTIVATION, LOW FERTILITY.			LOW YIELDING VARIETY, LOW FERTILITY, CASE WORM & STEM BORER ATTACK	LOW YIELDING VARIETY, STEM BORER ATTACK

Figure 3: Agro-ecosystem transect of village Palsipani (district Kalahandi) of Orissa based on participatory rural appraisal

(iii) Testing stage: The objective of this stage is to evaluate the improved practices flowing from the design or planning stage to the farm. The evaluation criteria should be those found important to farmers in the descriptive/diagnostic stage. Usually the performance of the improved technology drops when it moves from the artificial conditions of the experimental station to the farm and drops even further when farmers manage and implement the final trials. In this stage most promising strategies identified at the design stage are evaluated under local farmers' conditions.

At the testing stage compromises have to be made in the experimental design, farm trials need to be less complex than those undertaken on experiment stations because of costs, worries about too much land being asked from farmers and the desirability of interaction between farmers and research workers. Researcher – farmer interaction is less likely when experiment become too complex. We place a lot of more emphasis on replication across farmers' fields rather than within farmers' fields at this stage of testing. The problem of experimental work is exposed to many additional sources of variation, including differences in management and non-treatment of variables by host farmers and often inability to explain differences between plots. During testing stage generally three types of trials are conducted with the participation of farmers, viz. Researcher designed and researcher managed trial (RDRM), Researcher designed and farmers managed trial (RDFM), Farmers designed and farmers managed trials (FDFM)

(iv) Recommendation and Dissemination stage: The acceptable new technology is promoted in collaboration with the line department of the state Govt. and NGO. Thus the technology is promoted. Once the technology or product is ready for extension, necessary supplies and support services must be ensured by the policy makers and planners and other involved such as extension workers and researchers.

After the technology has been demonstrated and promoted to all the farmers in the target group, it is important that their experiences with it are monitored. The improvement suggested may not always suit the farmers' situation, especially as circumstances may change over time. There may need to be a number of options rather than single recommendation. Feedback of the farmers' reaction to the technology will determine if technology is suitable and also when changes are needed. This review phase is vital since it emphasizes the continuous nature of needed improvements.

(b) On-station FSR: FSR is considered as highly farmers' participatory and conducted at the farmers' field by the interdisciplinary group of scientists. Farmer participation is ensured at different stages of technology generation and transfer processes such as system description, problem diagnosis, design and implementation of on-farm trials, and providing feedback through monitoring and evaluation (Rhoades and Booth, 1982). On-station experiments on farming system perspectives are also conducted at the research station by taking into consideration the farmers problems, resource availability with farmers such as land, labour, capital etc. and farm constraints (physical and bio-physical) into consideration (Rangaswamy *et al.*, 1996; Behera and Mahapatra, 1999).

Number of on-station studies on integration of different enterprises: lowland rice cum pisciculture farming system, rice-poultry-fish-mushroom integrated farming systems for low land, alternate system of land use through diversification of farming system etc. have been conducted in different parts of the country just by simulating the small and marginal farms situations (Rangasamy *et al.*, 1996; Rangaswamy *et al.* 1992; Mahapatra, 1994, Rath, 1989, Rautaray, 2004).

(c) F.S.R. through System Modeling: A model is a simplified abstraction of the real world. It simulates the behaviour of a real system. Modelling begins with the analysis of the systems, its circumstances and purposes. Defining the model gives insight into the working of the system. So far, the farming systems research has been rather inadequate or slow, particularly in less developed countries. Perhaps the only way by which improvement can be achieved is by the construction and application of suitable whole farm models (Dent, 1990). Recent computer software development may provide the basis for a start in modelling of whole farm systems even with incomplete conceptual understanding and data sets.

(i) Utility of FSR models: Farming system models are useful in the following ways:

(a) To improve the understanding of farming systems, thereby helping in prioritisation of enterprises, better planning and designing of FS experiments, and farm management and policy development.

(b) To analyse and explain behaviour of a complex system and to determine the relative importance of different components/enterprises of the systems.

- (c) To examine the different scenarios resulting due to integration or mixing of different components or modifying different components in the systems.
- (d) To identify the areas where the knowledge of the system is fundamentally lacking.
- (e) Improvising the system for its wider application in varying situations i.e. under varying resource availability and resource constraints situations.
- (f) Models are cheaper than real life farming systems experiments. Experimentation in real world is expensive, time consuming and there are severe problems in controlling variables exogenous to the experiment. Thus, model saves energy, time and resources. The FSR studies are very complicated and time consuming and involve huge expenditure. With the help of suitable software, the results can be simulated for important decision- making. With the due perfection of the technique, a series of options can be chalked out and a few most important ones can be tested under actual field conditions.
- (g) Development of science. The FSR models help in integration of knowledge of various disciplines, better understanding of the process and their linkages with others and in identifying gaps in knowledge. This will help in re-orienting the research priorities of commodity and discipline based research institutes.

(ii) Enterprise mix by using Linear Programming (LP) Models: The purpose of constructing a LP farming system model is to identify which one of the new technologies are profitable at the farm level and on which type of farm they are likely to yield the best financial results. This model assesses the economic and production consequences of adoption of new technology at the farm levels (Yates, 2000). The linear programming models help in taking decisions for efficient allocation of the limited resources to optimize well-defined objective under a set of constraints. For example, a small farmer wishes to allocate his farm resources such as labour, land, capital and other resources between various potential agricultural enterprises in order to maximize gross margins.

Linear programming modelling is a mathematical technique and has been developed to overcome various shortcomings of planning techniques. Since its application started over a half century ago, it has been regarded as an established method for investigating resource allocation and enterprise combination problems (Dantzig, 1982). The application of linear programming to a certain problem involves different steps as: problem definition, matrix building, model solutions, results interpretations, model verification and validation, results stabilizing tests and action on results.

(iii) Concept of Linear Programming: The linear programming (LP) technique has been developed to handle complex situations and its practical use has been made possible only with the development of relevant computer software (LINDO, MPEXPRESS, MS EXCELL). Linear programming is a technique that is used to arrive at optimal combination of farm enterprises to maximise profit at the end of a specific time period such that all farm constraints are taken into account.

In general, the linear programming model can be written as follows:

$$\text{Max } Z = \sum_{j=1}^n C_j X_j \dots\dots\dots 1.0$$

$$j=1$$

Subject to

$$\sum_{j=1}^n a_{ij} X_j \leq b_i \quad i = 1 \text{ to } m \quad 1.1$$

And

$$X_j \geq 0 \quad j = 1 \text{ to } n \quad 1.2$$

Where,

Z = total gross margin

X_j = the level of the j^{th} activity

C_j = the gross margin of the j^{th} activity

a_{ij} = the quantity of the i^{th} resource required to produce a unit of j^{th} activity.

b_i = the amount of the i^{th} resource available.

In general LP model, there are 'n' activities represented by the 'X' vector whose values are to be determined. The 'C' vector is known as the cost (return) vector and represents the cost (or margins) associated with each activity. The 'A' matrix represents the resources required for each activity unit, whilst the 'B' vector represents some predetermined limit of the available resources. The LP problems are usually solved using the simplex method developed by Dantzig (1982), although other algorithms are now also available (Karmakar, 1984).

Types of Farming Systems

Integrated Farming

Integrated farming is defined as biologically integrated system, which integrates natural resources in a regulation mechanisms into farming activities to achieve maximum replacement of off-farm inputs, secures sustainable production of high quality food and other products through ecologically preferred technologies, sustain farm income, eliminates or reduces sources of present environment pollutions generated by agriculture and sustains the multiple function of agriculture (IOBC, 1993). It emphasizes a holistic approach. Such an approach is essential because agriculture has a vital role to play that is much wider than the production of crops, including providing diverse, attractive landscapes and encouraging bio-diversity and conserving wild life. Sustainable development in agriculture must include integrated farming system with efficient soil, water crop and pest management practices, which are environmentally friendly and cost effective.

The future agricultural system should be reoriented from the single commodity system to food diversification approach for sustaining food production and income. Integrated farming systems,

therefore, assume greater importance for sound management of farm resources to enhance farm productivity, which will reduce environment degradation and improve the quality of life of resource poor farmers and to maintain agricultural sustainability. The aims of the integrated farming system can be achieved by:

- Efficient recycling of farm and animal wastes
- Minimizing the nutrient losses and maximizing the nutrient use efficiency
- Following efficient cropping systems and crop rotations and
- Complementary combination of farm enterprises

The various enterprises that could be included in the farming system are crops, dairy, poultry, goat rearing, fishery, sericulture, agro-forestry, horticulture, mushroom cultivation etc. Thus it deals with whole farm approach to minimize risk and increase the production and profit with better utilization of wastes and residues. It may be possible to reach the same level of yield with proportionately less input in the integrated farming and the yield would be more sustainable because the waste of one enterprise becomes the output of another, leaving almost no waste to pollute the environment or to degrade the resource base. To put this concept into practice efficiently, it is necessary to study linkages and complementarities of different enterprises in various farming system. The knowledge of linkages and complementarities will help to develop farming system (integrated farming) in which the waste of one enterprise is more efficiently used as an input in another within the system.

Goals of Integrated Farming System: The four primary goals of IFS are:

- Maximization of yield of all component enterprises to provide steady and stable income at higher levels
- Rejuvenation/amelioration of system's productivity and achieve agro-ecological equilibrium.
- Control the build up of insect-pests, diseases and weed population through natural cropping system management and keep them at low level of intensity.
- Reducing the use of chemical fertilizers and other harmful agro-chemicals and pesticides to provide pollution free, healthy produce and environment to the society at large.

Farming systems in Rainfed areas: Agriculture in the rainfed areas and fragile ecosystems is inevitable for meeting the food, fibre and energy needs of the local inhabitants. The conservation of natural resources employing the modern concepts of integrated farming systems is essential for sustainable agricultural development and ensuring greater livelihood securities to the poor people of ecologically handicapped areas. Hence, integrated and holistic development of rainfed/fragile areas including hill, drylands and coastal areas need to be promoted by resource conservation techniques on watershed basis for improving productivity, profitability and thereby removing hunger and poverty. Integrated farming systems have emerged as a well-accepted, single window and sound strategy for harmonizing simultaneously joint management of land, water, vegetation, livestock and human resources. A number of such illustrations can be given emphasizing the greater advantage of integrated farming system in generating technologies aimed at combating land degradation (Solanki and Newaj, 1999). It is this approach that can lead to a quantum jump in the productivity on a sustainable basis and ensure better livelihood securities to the people in fragile ecosystems. Diversified cropping strategies such as mixed/intercropping, strip cropping, alley cropping and agri-horticultural systems are developed

to retain maximum amount of rainfall *in situ* and ensure higher production and protection against erosion. Integrated farming systems have been developed for these areas, which reduce the risk of soil degradation, preserve the soil's productive potential, decrease the level of inputs required and sustain crop productivity.

Indigenous Farming Systems

(i) Shifting Cultivation: It refers to farming system in north-eastern areas in which land under natural vegetation (usually forests) is cleared by slash and burn method, cropped with common arable crops for a few years, and then left unattended when natural vegetation regenerates. Traditionally the fallow period is 10-20 years but in recent times it is reduced to 2-5 years in many areas. Due to the increasing population pressure, the fallow period is drastically reduced and system has degenerated causing serious soil erosion depleting soil fertility resulting to low productivity. In north-eastern India many annual and perennial crops with diverse growth habits are being grown.

(ii) Taungya Cultivation: The *Taungya* system is like an organized and scientifically managed shifting cultivation. The word is reported to have originated in Myanmar (Burma) and *tauang* means hill, *ya* means cultivation i.e. hill cultivation. It involves cultivation of crops in forests or forest trees in crop-fields and was introduced to Chittagong and Bengal areas in colonial India in 1890. Later it had spread throughout Asia, Africa and Latin America. Essentially, the system consists of growing annual arable crops along with the forestry species during early years of establishment of the forest plantation. The land belongs to forest department or their large scale leases, who allow the subsistence farmers to raise their crops and in turn protect tree saplings. It is not merely temporary use of a piece of land and a poverty level wage, but is a chance to participate equitably in a diversified and sustainable agroforestry economy.

(iii) Zabo Cultivation: Zabo is an indigenous farming system practiced in north eastern hill regions particularly in Nagaland. This system refers to combination of forest, agriculture, livestock and fisheries with well-founded soil and water conservation base. The rain water is collected from the catchment of protected hill tops of above 100% slopes in a pond with seepage control. Silt retention tanks are constructed at several points before the runoff water enters in the pond. The cultivation fully depends on the amount of water stored in the pond. The land is primarily utilized for rice. This system is generally practiced in high altitude hill areas, where it is not possible to construct terraces and or irrigation channels across the slope. This is a unique farming system for food production to make livelihood. Zabo means impounding of water. The place of origin of zabofarming system is thought to be the Kikruma village in Phek district of Nagaland.

Conclusion

Per capita availability of land in India has declined from 0.5 ha in the year 1950-51 to 0.15 ha in the year 2000-01. Due to conversion of valuable irrigated agricultural lands for non-agricultural purposes viz. residential houses, industrial and business establishments and subdivision and fragmentation of holdings, the per capita availability of land is declining day by day. Therefore, no single farm enterprise is able to meet the growing demands of food and other necessities of the small and marginal farmers.

Agriculture is in the hands of 125 million farm families of which 75% are the marginal farmers (<1 ha holding). World prices of wheat and rice have declined substantially. The odds are pitted against small and marginal farmers. Burden on marginal farmers are becoming unbearable. Hence, there is necessity of adoption of “Farming Systems approach” by these vulnerable sections of farming community.

Table 1: Economics of Rice based farming systems for a marginal farmer (0.4 ha) under low land ecosystem in Tamil Nadu (mean of five years).

Component	Expenditure (Rs)	Gross return (Rs)	Net return (Rs)
Integrated Farming System (IFS)			
Crop	11,398	19,076	7,678
Poultry	1,944	2,861	917
Fishery	1,486	3,568	2,082
Mushroom	5,078	6,156	1,078
Total	19,906	31,661	11,755
Conventional Cropping System(CCS)	7,202	13,536	6,334
Additional income in IFS over CCS			5,421

Source: Indian Journal of Agronomy (1996)

Table 2: A suggested model of enterprise diversification on 1.25 ha farmland at Bhubneshwar and its economics

Components	Employment generation (man days)	Total expenditure (Rs)	Net return (Rs)	Return/rupee invested (Rs)
Field crops	98.2	3315	5638	2.70
Multistoried cropping	87.0	3831	9089	3.37
Pomology	18.4	900	1466	2.63
Olericulture	96.4	3812	8302	3.18
Floriculture	4.0	125	100	1.80
Pisciculture	31.0	3722	16603	5.46
Poultry	23.0	9240	981	1.11
Duckery	23.0	5387	713	1.13
Mushroom cultivation	180.0	18184	12856	1.70
Apiary	1.0	170	1180	7.94
Biogas	11.0	600	1431	3.38
Total	573.0	49,286	58,360	2.18

Source: Indian Journal of Agronomy(1999)

“Farming Systems” represent the integration of farm enterprises such as cropping systems, horticulture, animal husbandry, fishery, agro-forestry, apiary etc. for optimal utilization of farm resources bringing prosperity to the farmers. A judicious mix of cropping systems with associated enterprises like fruits, vegetables, flowers, dairy, poultry, duckery, piggery, goatary, fishery sericulture etc. suited to the given agro-climatic conditions and socio-economic status of the farmers shall be able to generate additional employment and income for the small and marginal farmers both under rainfed and irrigated conditions.

Improved agricultural technologies even when considered technically sound for individual component of the farming system are of limited value if they are not adopted by the farming community. The farming system, as a concept, takes into account the components of climate, soil, water, crops, farm wastes livestock, land, labour, capital, energy and other resources with the farm family at the centre managing agriculture and related activities.

The FSR views the farm in a holistic manner and considers interactions (between components and of the components with the environment) in the system. This type of research is most appropriately carried out by the interdisciplinary team of scientists who in association with the Extension Officers continuously interact with the farmers in the identification of the problems and finding their solutions.

Farming system approach to agricultural research and development efforts would accelerate agricultural growth of the country and thereby providing leverage for transforming poverty prone rural India to a prosperous India by strengthening rural economy. Certainly this will play a key role in agricultural revolution in the 21st Century, which is very much important to make India a developed nation.

References

1. Behera, U.K. and Mahapatra, I.C. 1999. Income and employment generation of small and marginal farmers through integrated farming systems. *Indian Journal of Agronomy*. **44**(3): 431-439.
2. Behera, U.K., Jha, K.P. and Mahapatra, I.C. 2004. Integrated management of available resources of the small and marginal farmers for generation of income and employment in eastern India. *Crop Research* **27**(1): 83-89
3. Chuang, F.T. 1973. An Analysis of Change of Taiwan's cultivated land utilisation for recent years. Rural Economic Division JCRR Rep. 21, Taipei, Taiwan.
4. Collinson, M.P. 1987. *Experimental Agricultural*, **23**:385-386.
5. Dalrymple, D.F. 1971. *Survey of Multiple Cropping in Less Developed Nations*. USDFA, Washington, D.C. FEDS. p.108.
6. Dantzig, G.B. 1982. Reminiscences about the origin of linear programming. *Operations Research Letters*, **1**:43-48.
7. Dent, J.B. 1990. *Systems theory applied to agriculture and the food chain*. Elsevier, Amsterdam.
8. FAO, 2001. *Farming Systems and Poverty: Improving Farmers' livelihoods in a changing World*. Food and Agriculture organization of the United Nations, Rome pp 412.
9. FAO. 1990. *Women in Agricultural Development: Gender Issues in Rural Food Security in Developing countries*. FAO, Rome, Italy.
10. IOBC. 1983. International organization for biological and integrated control. Technical bulletin 16 (1).
11. Jha, D. 2003. An overview of farming systems research in India. *Annals of Agricultural Research* **24**(4):695-706.
12. Karmakar, N. 1984. A new polynomial time algorithm for linear programming. *Combinatorica*, **4**: 373- 395.

13. Kumar, S. and Jain, D.K. 2005. Are linkages between crops and livestock important for the sustainability of the farming system? *Asian Economic Review* **47**(1):90-101.
14. Lightfoot, C. 1990. Integration of aquaculture and agriculture: a route to sustainable farming systems. Naga, The ICLARM Quarterly **13**(1):9-12.
15. Mahapatra, I.C. 1992. Farming systems research challenges and opportunities. *Eastern Indian Farming System Research & Extension, Newsletter* **6**(4):3-10.
16. Mahapatra, I.C. 1994. Farming system research – A key to sustainable agriculture. *Fertilizer News*, **39**(11) :13-25.
17. Mahapatra, I.C. and Behera, U.K. 2004. Methodologies of farming systems research. Panda, D., Sasmal, S., Nayak, S.K., Singh, D.P. and Saha, S.(Eds), *Recent Advances in Rice-based Farming Systems*, 17-19 November 2004, Cuttack, Orissa, Central Rice Research Institute, pp79-113.
18. Menegay, M.R., Hubbel, J.N. and William, R.D. 1978. Crop intensity index : a research method of measuring land use in multiple cropping. *Horticultural Science* **13**: 8-11
19. Rangaswamy, A, Venkataswamy, R., Premsekhar, M. and Palaniappan, S.P., 1992. Sustainable agriculture for rice (*Oryza sativa*) based ecosystem, *Indian Journal of Agronomy* **37** (2): 215-219.
20. Rangaswamy, A. Venkataswamy R. Purushothaman and Palaniappan, Sp.1996. Rice-Poultry – Fish – Mushroom integrated farming systems for lowlands of Tamil Nadu – *Indian Journal of Agronomy*, **41**(3): 344-348.
21. Rath, R.K. 1989. Integrated fish farming system in China: An analytical Review. *Fishing Chimes* (Sept. issue):20-27.
22. Rautaray, S.K., Das, P.C., Sinhababu, D.P., Sinhababu, D.P and Singh, B.N. 2004. Increasing farm income through rice-fish based integrated farming system in rainfed lowlands of Assam. *Indian Journal of Agricultural Sciences* (Communicated).
23. Rhoades, R.E. and Booth, R.H. 1982. Farmer-back to back farmers: a model for generating acceptable agricultural technology. *Agricultural Administration* **11**: 127-137.
24. Shaner, W.W., Philipp, P.F. and Schmehl, W.R. 1982. *Farming Systems Research and Development: Guide for Developing Countries*. West View Press, Colorado, USA.
25. Sharma, A.R. and Behera, U.K. 2004. Fertiliser use and option for diversification in rice-wheat cropping systems in India. *Fertiliser News* **49**(12):115-131.
26. Singh, A.K. 2001. Farming system and its sustainability with reference to ground water resource use in Uttar Pradesh (unpublished paper)
27. Singh, Kalyan, Bohra, J.S., Singh, Y. and Singh, J.P. 2006. Development of farming system models for the north-eastern plain zone of Uttar Pradesh. *Indian Farming* **56** (2): 5-11.
28. Singh, S.S. 1997. Crop Management under irrigated and rainfed conditions. Kalyani Publishers, Ludhiana, India.
29. Yates, C.M. 2000. Modelling consequences of new reproductive technologies in the bovine sector of U.K. Agriculture. Ph.D. Thesis, The University of Reading, Reading, U.K.
30. Yates, C.M. 2000. Modelling consequences of new reproductive technologies in the bovine sector of U.K. Agriculture. Ph.D. Thesis, The University of Reading, Reading, U.K.
31. Zandstra, H.G.*et.al.* 1981. A methodology for on-farm cropping systems research, IRRI, Los Banos, Philippines.
32. Zandstra, H.G. 1978. Cropping systems Research for the Asian Rice farmers'. *Agricultural Systems*. **4**: 135-153.

Suggested Readings:

1. Balguru, T and Manikandan, P.2001. Implementation of farming systems research in India- case study. National Academy of agricultural research Management, Rajendranagar, Hyderabad-500030
2. Birthal, Pratap S., Kumar, Anjani, Tiwari, Laxmi. 2002. Livestock in different Farming Systems in India. Advanced Publishing Concept, New Delhi
3. Dent, J.B.1990. Systems theory applied to agriculture and the food chain. Elsevier, Amsterdam.

4. Mahapatra, I.C. and Behera, U.K. 2004. Methodologies of farming systems research. Panda, D., Sasmal, S., Nayak, S.K., Singh, D.P. and Saha, S., editors 2004. "*Recent advances in Rice-based Farming systems*", 17-19 November, 2004, Cuttack, Orissa, Central Rice Research Institute.pp79-113.
5. Mahapatra, I.C., Mahapatra, P.K. and Batra, P.K. 2002. Field Manual for On-farm Adaptive Research. Agroecosystem Directorate (Rainfed farming). National Agricultural Technology Project. Central Research Institute for Dryland Agriculture, Hyderabad.
6. Malcolm Hall.2001. Farming Systems and Poverty: Improving farmers lively hood in changing World. FAO and World Bank, Rome and Washington, D.C.
7. Raman, K.V. and Balguru, T.1992. Farming Systems research in India : strategies for implementation. Proceedings of the National Workshop, November 25-28, 1991, NAARM, Hyderabad, India
8. Rangaswamy, A, Annadurai, K, Subbain, P and Jayanti, C.2002.Farming Systems in The Tropics, Kalyani Publishers.
9. Romeo, C. and Rehman, T. 1989. Multiple criteria analysis for Agricultural Decisions. Elsevier, Amsterdam.
10. Singh, A.K., Sharma, S.K., Batra, P.K. and Sharma, N.K. 2003. Instruction manual for on-farm research (cropping systems). Project Directorate for cropping Systems Research, Modipuram, Meerut-250110 (India).